16 WCSI XIII PHKCC

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RUSSIAN ASSOCIATION FOR EARTHQUAKE ENGINEERING AND PROTECTION FROM NATURAL AND MANMADE HAZARDS (RAEE)

16 WCSI 16th World Conference on Seismic Isolation, Energy Dissipation and Active Vibration Control of Structures

ABSTRACTS

WELCOME MESSAGE
DR. GIANMARIO BENZONI

It is a great honor and pleasure to wish you All a warm welcome to the 16th World Conference on Seismic Isolation, Energy Dissipation and Active Vibration Control of Structures on behalf of event of the Anti-Seismic Systems International Society (ASSISi). This biennial conference, initiated in the City of Assisi, Italy in year 2001, is organized this year in parallel with the XIII Russian National Conference on Earthquake Engineering and Seismic Zoning. It represent the major event of the ASSISI's activity and is focused on fostering development and acceptance of seismic protection solutions and techniques. The 16th edition aims to positively compete with the previous editions, the most recent in Wellington New Zealand in 2017, bringing to the magnificent city of St. Petersburg prestigious speakers from all over the World for days of
exciting lectures on various aspect of the current seismic protection technologies, addressing the most important advances of our discipline. The traditional format of our Conferences also includes presentations of the State of the Art of the development and the implementation of the technology in major countries around the World.

The unique opportunity to spend the entire week interacting with the active members of the Russian Association for Earthquake Engineering and Protection from Natural and Manmade Hazards (RAEE) will make this event furthermore invaluable and will allow a constructive sharing of ideas, opportunities and knowledge to contribute to build disaster resilient societies and to create new directions of research and technology implementation.

I am sure everybody will join me, at the starting of this Conference, in addressing the hard work of the Local Organizing Committee and the support of all the sponsors, to provide us with the opportunity to enrich our professional life while enjoying a delightful and stimulating week.

ORGANIZERS

The Anti-Seismic Systems International Society (ASSISi) was founded on October 5, 2001 in Assisi (Italy), during the Closing Panel of the 7th International Seminar on Seismic Isolation, Passive Energy Dissipation and Active Control of Seismic Vibrations of Structures. Having ASSISi as the acronym for the Society reaffirms the founders' willingness to take a clear symbolic position to build a better and safer world through international cooperation and collaboration.
ASSISi brings together academicians, design engineers, manufacturers, agencies' representatives and students involved, or simply interested, in the seismic isolation and energy dissipation technology. The association's goal is to disseminate the results of research programs, application examples and basic training material to foster further development and acceptance of seismic protection solutions and techniques.

The Russian Association for earthquake engineering and protection from natural and manmade hazards (RAEE) was established in 1995. Currently, more than 400 leading experts from almost 200 scientific, design and survey, industrial and educational organizations of the regions of Russia and CIS countries are united by RAEE events.
The activity of RAEE is aimed at:
- development of preventive measures to protect the population and territories from natural and manmade impacts, analysis and elimination of their consequences;
- development and implementation of legal and economic norms and standards to ensure the protection of the population and territories from natural and manmade impacts;
- introduction of new technologies in construction to ensure seismic safety of buildings and structures;

ORGANIZERS

- participation in the preparation and implementation of measures to improve the skills of specialists related to the safety and reliability of buildings and structures in seismic regions;
- protecting the property and copyright of the members of the Association;
- organization of information support (conferences, seminars);
- publication of scientific and methodical literature and scientific and technical journal "Earthquake Engineering. Constructions safety".

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CONFERENCE PROGRAM

ATTENTION TO PARTICIPANTS! THIS PROGRAM COULD BE CORRECTED BY THE CONFERENCE ORGANIZING COMMITTEE IF NECESSARY DEPENDING OF SPECIFIC CIRCUMSTANCES

Sunday, June, 30/ 30 июня, воскресенье			
Time/ Время	**Event/ Мероприятие**	**Venue/Место проведения**	**Conference/Конференция**
09:00-18:00	1. Installation of Exhibition Pavilions and Poster Presentations. Монтаж выставочных павильонов и постерных презентаций	Foyer of the Congress Hall Фойе Конгресс-холла	16WCSI& 13PHKCC (13RNCEE)
14:00-18:00	2. Registration of Conference Participants Регистрация участников конференции		
Monday, July, 01/ 01 июля, понедельник			
08:00	Registration of Conference participants Регистрация участников конференции	Foyer of the Congress Hall Фойе Конгресс-холла	16WCSI& 13PHKCC (13RNCEE)
09:00	Official Opening and Welcome Официальное открытие конференций и приветствия: Benzoni Gianmario (ASSISi) Vedyakov Ivan (RAEE) Gusev Boris (IEA & REA) Begaliev Ulugbek (IAEEE) Kappos Andreas (EAEE) Khakimov Shamil (JSC «Toshuyjoy LITI») Kostarev Viktor (CVS) Kul'baev Begman (KazNIISA) Kuzmin Alexander (RAACS) Zvezdov Andrei (JSC RCC) Bubis Alexander (RAEE)	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 PHKCC)

CONFERENCE PROGRAM

PLENARY 1 / ПЛЕНАРНОЕ ЗАСЕДАНИЕ 1 **Orals 30 min.** **Chairmen: Benzoni Gianmario, Bubis Alexander**			
10:00- 11:30	Гусев Борис Gusev Boris Новые подходы к решению проблемы материалов для сейсмоизоляции New Approaches to Solving the Problem of Materials for Seismic Insulation	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Ведяков Иван Vedyakov Ivan Успешные практики применения металлических конструкций в России Successful Practices of Application of Steel Building Structures in Russia	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Whittaker David Recent Developments in New Zealand in Seismic Isolation, Energy Dissipation and Vibration Control of Structures (2019)	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
11:30-12:00 Coffee Break/Кофе-брейк **Foyer of the Congress Hall/Фойе Конгресс-Холла**			
PLENARY 1, continuation / ПЛЕНАРНОЕ ЗАСЕДАНИЕ 1, продолжение **Orals 30 min.** **Chairmen: Whittaker David, Gusev Boris**			

CONFERENCE PROGRAM

12:00- 14:00	Medeot Renzo Development and Revision of the European Standard EN 15129 on Anti-Seismic Devices	Concert Hall Концертный зал	16WCSI& 13 RNCEE (13 РНКСС)
	Ansal Atilla, TonukGokce, Kurtulus Aslı Uncertainties in Site Specific Response Analysis	Concert Hall Концертный зал	16WCSI& 13 RNCEE (13 РНКСС)
	Martelli Alessandro, Clemente Paolo Recent Applications of Seismic Isolation in Italy	Concert Hall Концертный зал	16WCSI& 13 RNCEE (13 РНКСС)
	Бубис Александр Bubis Alexander New Applications of Base Isolation and Energy Dissipation in Russia	Concert Hall Концертный зал	16WCSI& 13 RNCEE (13 РНКСС)
	Chien–Chih Chen Shanghai Center Building Introduction of Pendulum Eddy Current Tuned Mass Damper	Concert Hall Концертный зал	16WCSI& 13 RNCEE (13 РНКСС)

CONFERENCE PROGRAM

	Хакимов Шамиль Khakimov Shamil' Новые конструктивные системы жилищно-гражданских зданий и проблемы актуализации сейсмических норм New Structural Systems of Housing and Civil Buildings and Problems of Actualization of Seismic Norms	Concert Hall Концертный зал	16WCSI& 13 RNCEE (13 РНКСС)
14:00-15:00 Lunch (Restaurant «Bering») Обед (Ресторан «Беринг»)			
PLENARY 1, continuation / ПЛЕНАРНОЕ ЗАСЕДАНИЕ 1, продолжение Orals 30 min. Chairmen: Vedyakov Ivan, Medeot Renzo			
15:00-18:00	Белаш Татьяна, Костарев В., Рутман Ю., Уздин А. BelashTatiana, Kostarev V., RutmanYu., UzdinA. Развитие сейсмоизоляции в России Development of Seismoisolation in Russia	Concert Hall Концертный зал	16WCSI& 13 RNCEE (13 РНКСС)
	Demin Feng, Takafumi Miyama, Wenguang Liu Certification System of Seismic Isolation Devices in Japan	Concert Hall Концертный зал	16WCSI& 13 RNCEE (13 РНКСС)

		Concert Hall Концертный зал	16WCSI& 13 RNCEE (13 PHKCC)
	Kuo-Chun Chang, Jenn-Shin Hwang, Shiang-Jung Wang, Chung-Han Yu , Wang-Chuen Lin , Cho-Yen Yang Recent Progress and Experience in Taiwan on Passive Control Technology and Applications	Concert Hall Концертный зал	16WCSI& 13 RNCEE (13 PHKCC)

CONFERENCE PROGRAM

	Тихонов Игорь, Галишникова В.В., Окольникова Г.Е., Тихонов Г.И., Кузьменко Н.Ю. Tikhonov Igor, Galishnikova V.V., Okol'nikova G. E., Tikhonov G.I., Kuzmenko N.V. Эффективный арматурный прокат с четырехрядным винтовым профилем для сейсмостойкого строительства (производство, исследование, проектирование, применение) Effective Reinforcing Bars with Four-row Screw Profile for Earthquake-resistant Construction (Production, Research, Design, Application)	Concert Hall Концертный зал	16WCSI& 13 RNCEE (13 РНКСС)
	Erdik Mustafa State of the Art on Application, R&D and Design Rules for Seismic Isolation and Energy Dissipation in Turkey	Concert Hall Концертный зал	16WCSI& 13 RNCEE (13 РНКСС)

CONFERENCE PROGRAM

	Кривцов Юрий Krivtsov Yu. Обеспечение пожарной безопасности объектов капитального строительства в сейсмоопасных районах Fire Safety of Capital Construction Projects in Earthquake-prone Areas	Concert Hall Концертный зал	16WCSI& 13 RNCEE (13 РНКСС)
	Technical inform		
19:00- 23:00 Welcome Reception for 16WCSI & 13 RNCEE Participants Restaurant «Bering»			
Tuesday, July, 2 / 2 июля, вторник PLENARY II / ПЛЕНАРНОЕ ЗАСЕДАНИЕ II Orals 20 min. Chairmen: Taiki Saito, Belash Tatiana, Tyapin Alexander			
09:00- 11:30	Заалишвили Владислав, Бурдзиева О. Zaalishvily Vladislav, Burdzieva O. Сейсмический риск современного города SeismicRiskofModernCity	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)

CONFERENCE PROGRAM

	Аптикаев Ф.Ф., Эртелева Ольга Aptikaev Felix, Erteleva Olga О строительных нормах нового поколения On the Construction Standards of New Generation	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Takayama Mineo, Morita Keiko Finite Element Analysis of Laminated Rubber Bearing Compressed by Steel Column with Smaller Cross Section Area than Rubber Bearing	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Жарницкий В., Кабанцев Олег, Алипур Мансурхани Али Zharnitskiy Valerii, Kabantsev Oleg, Alipur Mansurhani Ali Деформационные критерии предельных состояний каменных и железобетонных конструкций сейсмостойких зданий Deformation Criteria of Limit States of Stone and Reinforced Concrete Structures of Earthquake-resistant Buildings	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)

CONFERENCE PROGRAM

	Алешин Александр Aleshin Alexander «Трудные вопросы» развития сейсмического микрорайонирования “Difficult Issues” of Seismic Microzoning Development	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Taiki Saito, Kazuhiro Hayashi, Ryuto Doi Shaking Table Test to Verify a New Seismic Response Control System Using Blok& Tackle	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Тяпин Александр Tyapin Alexander Концепция опасного направления сейсмического воздействия: плюсы и минусы The Concept of the Dangerous Direction of Seismic Impact: Pros and Cons	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
11:30-12:00 Coffee Break/Кофе-брейк Foyer of the Congress Hall/ ФойеКонгресс-Холл			
KEYNOTE LECTURES			

CONFERENCE PROGRAM

12:00-14:00	Benzoni Gianmario, Lomiento G., Montuori R. Progress on Seismic Isolation and Energy Dissipation	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Lagos Rene Seismic Resilience in Concrete High-rise Building Design: the Chilean Perspective	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Wada Akira Recent Earthquakes and New Concepts for Earthquake-resistant Design	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Kappos Andreas Performance-based Design of Seismically Isolated Bridges	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
14:00-15:00 **Lunch (Restaurant «Bering») Обед (Ресторан «Беринг»)**			
PLENARYII, continuation / ПЛЕНАРНОЕ ЗАСЕДАНИЕ II, продолжение **Orals 20min.** **Chairmen: Shiang-Jung Wang, Begaliev Ulugbek**			

CONFERENCE PROGRAM

15:00-18:00	Кульбаев Бегман, Шокбаров Ералы, Ицков Игорь Kul'baev Begman, Shokbarov Yeraly, Itskov Igor Современное состояние сейсмостойкого строительства в Республике Казахстан Current State of Seismic Construction in the Republic of Kazakhstan	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Ицков Игорь Itskov Igor Расчетные положения новых норм Республики Казахстан СП РК 2.03-30-2017 «Строительство в сейсмических зонах» Settlement Provisions of New Norms of the Republic of Kazakhstan 2.03-30-2017 "Construction in Seismic Zones»	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)

CONFERENCE PROGRAM

	Абдыбалиев М.К., Сыдыков А.Ж., Бегалиев У.Т., Ицков И.Е. Abdybaliev M.K., Sydykov A.Zh., Begaliev U.T. Itskov I.E. Особенности новых норм Кыргызской Республики в области Сейсмостойкого строительства Particulars of New Codes of Kyrgyz Republic in the Field of Earthquake Engineering	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Трекин Николай, Кодыш Э.Н., Келасьев Н.Г. Trekin Nikolay, Kodysh E.N., Kelasiev N.G. Использование резервов несущей способности железобетонных конструкций при кратковременном силовом воздействии Use of Reserves of Bearing Capacity of Reinforced Concrete Structures under Force Impact	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)

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	Тонких Геннадий Tonkih Gennadiy К вопросу использования периода собственных колебаний каркасных зданий при малоинтенсивных воздействиях To the Question of Using of the Period of Oscillation of Frame Buildings at Low-Intensity Exposure	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Лапин Владимир LapinVladimir Сравнительный анализ влияния сейсмоизоляции с помощью станции инженерно-сейсмометрической службы на зданиях Comparative Analysis of the Effect of Seismic Isolation by Means of Stations of Engineering Seismometric Service on Buildings	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Шокбаров Ералы Shokbarov Yeraly Паспортизация зданий и сооружений города Алматы Certification of buildings and structures of Almaty	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)

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	Курбацкий Евгений Kurbacky Eugeny Спектры максимальных реакций на землетрясения Spectra of the maximum reactions to the earthquakes	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
	Technical inform	Concert Hall Концертный зал	16WCSI & 13 RNCEE (13 РНКСС)
22:00-02:00 **Evening boat trip on the Neva river (16WCSI) (with Furshet)**			
Wednesday July, 3 / 3 июля, среда **Parallel Session, Orals 15 min.**			
Time/ Время	16 WCSI Session 1	16 WCSI Session 2	16 WCSI Session 3

CONFERENCE PROGRAM

	Pushkin-Peterhof Hall 1. Experimental and analytical study on buildings, bridges and other civil structures applying seismic response control technique Chairman: Benzoni Gianmario	Kronshtadt Hall 2. Design and application of seismic response control technique to buildings, bridges and other civil structures Chairman: Uzdin Alexander	Pavlovsk Hall 3.Observation and monitoring of buildings, bridges and other civil structures applying seismic response control technique 4. Research and development of seismic response control devices, which are innovative, or reliable and low-cost 5. Measures against seismic events beyond expectations such as mega-earthquakes, long period earthquakes and vertical motions 6. Standards for design, construction, maintenance Chairman: Medeot Renzo
09:00	Kostarev Viktor, Vaslyev P.S., Vayndrakh M.V., Nawrotzki P. Developing and Natural Scale Testing of the 3D BCS Base Isolation System	Honglei Wu, Changjia Chen, Jieming Ding Discussion for Key Issues of Isolation Technology Applied in Long-Span Complex Buildings	Ue H., Yamagami S., Misu M., Takayama M. Performance Verification of Seismic Isolation Devices Used in a Base-Isolated Building for 30 Years

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09:15	Nawrotzki P., Kostarev V., Siepe D., Morozov D. 3-D Base Control Systems for the Seismic Protection of Structures	Jian Xu, Xiaobing Wu, Jingwei Zhou, Dingsong Zhou, Jia Zhou Application of Viscous Dampers in Seismic Design of a Hospital in Sichuan	Gokce T., Yuksel E., Orakdogen E. The Development of a Seismic Isolaton Device for High Voltage Porcelain Isolators
09:30	Yerzhanov Syrymgali On Some Issues of Taking Account of the Interaction of Seismically Isolating Pile Foundations with Foundation Soil under Seismic Effects	Sun Z., Wang S.G., Liu W.Q., Du D.S., Zhang Z.T. Mid-story Seismic Isolation Design and Dynamic Analysis of SOHO Ginza	Gokce T., Sahin B., Sezer B. Determination of Dynamic Properties of Bowstring R/C Bridges by Using Ambient Vibration Measurements
09:45	Cavdar E., Ozdemir G. On the Maximum Ground Motion Direction and Response of Seismically Isolated Structures	Huber Peter Seismic Isolation Protection System for the 1081-Bed Eskişehir City Hospital in Turkey	Gokce T., Sahin B., Orakdogen, E., Yuksel E. Seismic Response Prediction and Ground Motion Selection by Using Intensity Measures for Base Isolated Buildings

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10:00	Sato Daiki Estimation Method of Tensile Strain of Laminated Rubber Bearings and Bending Moment of Foundation Beam for Seismically Isolated Building	Cao S.L., Wang Z., Xu Y., Jia L.Y. Seismic Design of a Widened and Reconstructed T-beam Girder Bridge	Lee B. H., Yeh F. Y., Chen C. C., Shiao S.Y., Chang K. C. Influence of Vehicle Impact Load on Isolated Bridge
10:15	Furinghetti M., Pavese A. Comparison Between Radial And Bidirectional Responses of a Base Isolated Building Equipped With Concave Surface Slider Devices	Wang Z., Xu Y., Chen L., Yan H., Cao S.L., Jia L.Y. Seismic Isolation Design of the Main Bridge of Songpu Bridge	Adzhemyan A., Benzoni G., Lomiento G. Experimental Model for Double Concave Sliding Bearings
10:30	Li Z.J., Li X.H., Xu X.L., Huang W.G., Cheng M.M. Parameter Sensitivity Analysis of Isolated Bearings of Continuous Girder Bridge under Far-field Long Period Ground Motion	Sorace S., Terenzi G. Dissipative Bracing and Base Isolation Design Solutions for New Prefab R/C Structures	Kotsuki S., Switched Resistance Oil Damper Depending on Deformation as a Measure against Very Large Earthquakes

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10:45	Jiang H.J., Li S.R. Study of RC coupled shear wall with replaceable components	Terenzi G., Costoli I., Sorace S., Spinelli P. Application of an Energy-based Design Procedure to the Design of Fluid Viscous Devices in a Dissipative Bracing-based Seismic Retrofit Intervention	Simbort E.G. Application of Base Isolation for Retrofitting of Educational Building with Masonry Walls in Peru
11:00	Chalarca B., Filiatrault A. Seismic Performance of Steel Moment-Resisting Frame Retrofitted with Linear and Nonlinear Viscous Dampers	López-Almansa F., PiscalArévalo C.M. Proposal of a design code for seismic isolation of buildings in Colombia	Simbort E.G., Pinto G. Improvement of Seismic Performance in Educative RC Building Using Innovative Earthquake – Resistant System
11:15	Yakut A., Akyuz U., Cabuk E., Murota N., Suzuki S. Comparision of Modeling Approaches for High Damping Rubber Bearings	Dicleli M., Salem-Milani A Performance Based Design of Seismic Isolated Bridges in Cold Climates using Multi Directional Torsional Hysteretic Damper and Lubricated Flat Sliding Spherical Bearings	Yanagi M.Y., Shimizum S., Suzuki R.S., Yasunaga A.Y., Furuhashi T.Y. The Characteristics of the Rubber Bearing with Tin Plug
11:30-12:00 Coffee Break/Кофе-брейк **Foyer of the Congress Hall/ Фойе Конгресс-холла**			

CONFERENCE PROGRAM

	Chairman: (on the discussion)	Chairmen: Simbort Enrike Kostarev Viktor	Chairman: Huber Peter
12:00	Ozdemir S., Yakut A. A Comparative Study on Methods of Analyses For Seismically Isolated Buildings	Mavronicola E., Komodromos P. Investigation of potential pounding of base isolated buildings under strong near-fault earthquake excitations	Ishii K., Kikuchi M. Mechanical behavior of sliding bearings for seismic isolation under cyclic loading
12:15	Shuguang W. Shaking Table Tests of Masonry Structures Strengthened with External Prefabricated Reinforced Concrete Wall and with Adding-story Isolation	Suryadi T., Sihite T. Seismically Isolated Structure with Lead Rubber Bearing Case Study: Elevated Toll Jakarta-Cikampek II Project	Kikuchi M., Ishii K., Kato H., Nakamura M. An Analytical Model for Low-shear Modulus High-damping Rubber Isolation Bearings under Large Shear Deformation
12:30	De Domenico D., Deastra P., Ricciardi G., Sims N.D., Wagg D.J. Improved Seismic Base Isolation Combined with Fluid Inerter and Tuned Mass Damper	Bongiovanni G., Buffarini G., Clemente P., Saitta F. Retrofit of Existing Buildings with Seismic Isolation: Design Issues and Applications	Lin J.L. Top-story mass dampers for seismic control of inelastic asymmetric-plan buildings

CONFERENCE PROGRAM

12:45	De Domenico D., Ricciardi G., Montanini R. Quattrocchi A., Borsellino C., Benzoni G. Experimental investigation on the temperature rise of double curved surface sliders and its implications on the hysteretic behavior	Bal I. E., Smyrou E., Sadan O. B., Tuzun C. Use of Base Isolation Systems against Induced Earthquakes: Case of Groningen	JIanzhong Li, Nailiang Xiang Simplified Method of Designing an Innovative Seismic Isolation System for Highway Bridges: Analytical Study and Experimental Validation
13:00	Cavdar E., Ozdemir G. On the Maximum Ground Motion Direction and Response of Seismically Isolated Structures	Jagtap P. S., Jain R., Matsagar V. A. Seismic Performance of Floor-Mounted Secondary Systems Housed in Real-Life Base-Isolated Building on Double Curvature Friction Pendulum System	Takayama M., Morita K. Finite Element Analysis of Laminated Rubber Bearing Compressed by Steel Column with Smaller Cross Section Area than Rubber Bearing
13:15	Morita K., Takayama M. Experimental Study on Structural Characteristics of Foundations Attached to the Laminated Rubber Bearing	Pinto G., Simbort E.G. , Gonzales E., Ticona M. Seismic Performance of Curved Isolated PC Bridges Based in Displacement	
13:30	Technical inform	Technical inform	Technical inform

CONFERENCE PROGRAM

14:00-15:00 **Lunch (Restaurant «Bering») Обед (Ресторан «Беринг»)**			
	Chairman: Takayama Mineo	Chairman: Belash Tatiana	Chairman: (on the discussion)
15:00	Wang Jue, Ding Zhou Simplified Model for the Seismic Analysis of a Soil- Long Pile Group-Structure System	Pinto G., Quispe J.P. Seismic Response Control of Cable-Stayed Bridge Incorporate energy dissipation systems	Kinoshita T. Suggestion of Damping Systems for Chandeliers
15:15	Aijun Ye, Lianxu Zhou Experimental Investigation on Transverse Steel Damper Seismic System for Cable-Stayed Bridges under Earthquake Sequences	Sadan B., Tuzun C., Gokce T., Sahin B. Seismic Retrofit Design of Buildings of a School Campus in Istanbul By Dissipative Towers	Chung-Han Yu, Shiang-Jung Wang, Kuo Chun Chang Beyond Design Performance of Viscoelastic Damper
15:30	Wang K.J., Chuang M.C., Tsai K.C., Li C.H., Chin P.Y., Chueh S.Y. A Hybrid Simulation on a Steel Panel Damper Substructure with Online Model Updating	Kaya M. Techniques for Seismic Strengthening of Historical Monuments	Wijanto S., Sengara I.W., Lim E., Andriono T. The Mw 7.4 Palu Earthquake of September 28, 2018

CONFERENCE PROGRAM

15:45	Wang Y.M, Ma A.C, Tan P. Eccentricity Influence on Coupling Response and Damage Amplification of Curved Bridges in Earthquakes	Chen H., Chen Y., Tan P. Response Spectrum Method for the Design of Isolated Buildings	Bhaiya V., Bharti S.D., Shrimali M.K., Datta T.K. Semi-Active Control Using MR Dampers for Random Ground Motion
16:00	Di Cesare A., Ponzo F.C., Lamarucciola N., Nigro D. Preliminary Nonlinear Analyses of Post-tensioned Timber Framed Building with Dissipative Bracing Systems	Sartori M., Barone S. Alibeyköy and Kagithane Viaducts: Advanced Seismic Protection Solutions In High Seismicity Region	Lu Lyan-Ywan, Lin Ging-Long, Hsiao Kun-An, Wong Ka Fung, Chen Yi-Siang An Inertial-type Vertical Isolation System with a Smart Friction Damper for Seismic Protection of Equipment
16:15	Du YF., Shi C. Wang Y.L. Spectral Characteristics of Ground Motion and Analysis of Dynamic Robustness of Base-isolated Structures	Barone S., Sartori M., Suryadi T., Zivanovic I. Lead Rubber Bearings: a Prominent Application of EN 15129:2009 anti-seismic devices standard beyond Europe	Azinović B., Kramar M., Pazlar T., Kržan M. Shear Response of Isolated Angle Brackets for Cross Laminated Timber Buildings
16:30	Shrikhande M. Friction Damper System for Seismic Response Reduction	Sartori M., Barone S. Seismic Isolation And Post-Tensioning: A Complete Solution for the New Trieste Harbor Logistic Platform	Liu Z.J., Lin T.K., Lu L.Y. Sung Y.C. Development and Application of a Variable Stiffness Isolation System Considering Ground Motion Characteristic

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16:45	Technical inform	Technical inform	Technical inform
17:00-22:00 Technical trip for participants of 16WCSI & 13 RNCEE (13 PHKCC)			
Wednesday, July, 3 / 3 июля, среда SPESIAL SESSION ISO WG-13 meeting			
09:00-17:00	ISO WG SESSION	Vyborg Hall	Eng
Thursday, July, 4 / 4 июля, четверг Parallel Session, Orals 15 min.			
	Chairman: Saito Taiki	Chairman: (on the discussion)	Chairman: Hamaguchi Hiroki
09:00	Karalar M., Dicleli M. Performance of Steel Framed Buildings Equipped with Viscous Fluid Dampers under Near-Fault Ground Motions with Directivity	Kammouh O., Silvestri S., Palermo M., Cimellaro G. Crescent-shaped Brace for Structural Control of Buildings	Inoue Y., Kushibe A., Umemura K., Sawaguchi T., Otsuka H., Chiba Y. Tensile and Low-cycle Fatigue Properties of Fe-15Mn-4Si-10Cr-8Ni Alloy for Fatigue-Resistant Seismic Dampers
09:15	Dicleli M., Karalar M. Optimum Properties of Seismic Isolation Systems in Highway Bridges to Minimize Isolator Displacements or Substructure Forces	Emri Igor, Bek M., Von Bernstorff B., Gusev B.V., Yin Y.L., Chang K.C. The New Generation Earthquake Isolation – a Breakthrough in Performance	Li Che, Xue Yan-tao, Yan Wei-ming Study on Damping Effect of Variable Friction Damper with Butterfly Hysteretic Curve

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09:30	Karalar M., Dicleli M. Comparative Assessment of the Efficiency of Seismic İsolation for Seismic Retrofitting of Highway Bridges in Regions of Low-to-Moderate Seismicity	Zelleke Daniel H., Saha S. K., Matsagar V. Base-Isolation for Response Control of Buildings under Multi-Hazard Condition	Kushibe A., Inoue Y., Umemura K., Nakamura T., Sawaguchi T., Ohtsuka H., Chiba Y. Cyclic Loading Tests of Fatigue-resistant Fe-Mn-Si-Based Alloy Seismic Damper
09:45	Sharma V., Shrimali M.K., Bharti S.D., Datta T.K. Seismic Energy Dissipation in Semi-rigid Connected Steel Frames	Smirnova Luybov Sukonnikova T. V. The Experience of Bridge Seismic Isolation in Russia	Cimellaro G.P., Domaneschi M., Warn G. A new Vertical Base Isolation System
10:00	Zhi Jun Lyu Numerical Evaluation of the Seismic response of steel storage rack Beam-to-Column Connections by Finite Element Analysis	Pavlidou C., Komodromos P. Influence of Earthquake Characteristics on the Peak Seismic Response of a Base Isolated Steel Building	Pourmasoud M.M., Lim J., Hajirasouliha I., McCrum D. A Multi-Directional Isolation System for Multi-Storey Buildings under Coupled Horizontal and Vertical Seismic Excitations
10:15	Sadan B., Erdik M., Tuzun C., Ozcanli M.E. Tensile Behavior of Rubber Isolators and Solutions to Overcome Tension Problem	Technical inform	Wake T., Kikuchi M., Ishii K. New Evaluation Formulae for Shear Strength of Lead-Rubber Bearings

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10:30	Mori T., Maruyama K., Kato H., Murota N. Deformation-History Integral Type Hysteresis Model Considering Performance Change for High-Damping Rubber Bearings		Ogino N.O., Kikuchi M.K., Okamoto M.O. High-performance Oil Dampers for Seismically Isolated Structures to Counter Extremely Strong Earthquake Ground Motions
10:45	Tuzun C., Sadan B., Erdik M., Murota N., Suzuki S., Akkar S. A Feasibility Study of Seismic Isolation Application in Residential Buildings in Turkey		Sharma V., Shrimali M. K., Bharti S. D., Datta T. K. Energy Dissipation and Seismic Response Evaluation of Semi-rigid Steel frames at Various Performance Levels
11:00	Kolesnikov A. Calculation of structures with seismic isolation using LIRA 10.8		Hamaguchi H., Yamamoto S., Wake T., Kikuchi M. A Seismic Isolation System with High Safety Margin in Earthquakes Exceeding Design Level

CONFERENCE PROGRAM

11:15	Jeong Y.H., Song J.K., Hong J.Y., Lee C.J. Seismic Fragility Analysis of Existing Old Bridges Retrofitted by Seismic Isolation System in South Korea		
	Technical inform		Technical inform
	11:30-12:00 Coffee Break/Кофе-брейк **Foyer of the Congress Hall / Фойе Конгресс-холла** **12:00-12:30 POSTER SESSION** **Foyer of the Congress Hall / Фойе Конгресс-холла**		
	Chairman: Demin Feng		
12:30	Ye D.H., Chen Y.Y., Qian Z.C., Huang X.Y., Tan P. Seismic Performance of Nonlinear Energy Sink with Negative Stiffness and Sliding Friction		
12:45	Verma A., Sahoo D.R. Slow-cyclic Test of Steel Plate Shear Wall with Floor Slab		

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13:00	Ghowsi A. F., Sahoo D. R. Pushover Analyses of Steel self-Centering Buckling-restrained Braced Frames		
13:15			
13:30			
13:45	Technical inform		

14:00-15:00
Lunch (Restaurant) Обед (Ресторан)

15:00-19:00
Sightseeing tour of Saint-Petersburg (16WCSI)

19:00 - 24:00
Close Ceremony

Poster Session 01-05 July
Foyer of the Congress Hall/ Фойе Конгресс-холла

1. Behrami R., Ristic D., Hristovski V., Ristic J.
The New Uniform VF-energy Dissipation Device: Refined Modelling
2. Bhandari M., Gupta A., Bharti S. D., Shrimali M. K.
Seismic Performance of Base-isolated Frame Subjected to Near-field Earthquakes
3. Bhandari M., Jain A.K., Shrimali M.K., Datta T.K.
A New Lateral Load Pattern for the Pushover Analysis of Base-isolated Buildinf Frame
4. Bharti S. D. , Bhandari M., Jaswant N., Arlekar Murty C V R, Ram Niwas Sharma
Seismic Performance of Fixed Base and Base-isolated Building Frame
5. Bharti S. D. , Bhandari M., Shrimali MK, Datta T.K., Ram Niwas Sharma, C V R Murty
Seismic Performance Evaluation by Capacity Spectrum Method for Base-isolated Frames
6. Chaulagain Nabin Raj, Sun Chang Ho, Kim Ick Hyun

CONFERENCE PROGRAM

Seismic Fragility Analysis of Spherical Storage Tank with Simplified Finite Element Model
7. Chen H., Chen Y., Tan P.
Response Spectrum Method for the Design of Isolated Buildings
8. Dongsheng D.
Evolutionary Power Spectral Model for the Fully Non-stationary Ground Motions and its Engineering Application
9. JieGao
Experimental Study of Seismic Behavior of Precast Concrete Layered Slab and Beam to Column Interior Jonts
10. Luo D.Y., Sun J.G., Liu C.G., Cui L.F., Wang Z., Lü Y.
Study on Seismic Response of Isolated LNG storage Tank Considering Insulation
11. Lü Y., Sun J.G., Sun Z.G., Cui L.F., Wang Z., Luo D.Y.
Research on Variable Curvature Rolling Isolation of Horizontal Storage Tanks
12. Mendo A., Fernández-Dávila V.
Proposal for the Design Displacement Estimating of Seismic Isolation Systems in Peru
13. Ristic J., Ristic D., Behrami R.
The New Uniform VF-energy Dissipation Device: Prototype Testing
14. Shuguang W.
Shaking Table Tests of Masonry Structures Strengthened with External Prefabricated Reinforced Concrete Wall and with Adding-story Isolation
15. Villalba-Morales J. D., Benavent-Climent Amadeo, Lopez-Almansa Francisco, Escolano-Margarit David
A Heuristic Approach for Optimal Design of Brace-type Hysteretic Dissipators for Seismic Protection of Framed Buildings
16. VolkanOzsarac, Shaghayegh Karimzadeh, Aysegul Askan
Comparison of Structural Responses for a Base Isolated Building under Real and Simulated Records
17. Vern S., Shrimali M.K., Bharti S.D., Datta T.K.
Response Control of Base Isolated Liquid Storage Tank under Bi-directional Earthquake
18. Wu A.C., Tsai K.C., Chen L.W.
Experimental Study on Out-of-plane Stability of Buckling-restrained Braces
19. Nefize Shaban, Shaghayegh Karimzadeh, Aysegul Askan
Investigation on the Effectiveness of Dampers for Retrofitting Through Seismic Response Analyses under Real and Simulated Motions

CONFERENCE PROGRAM

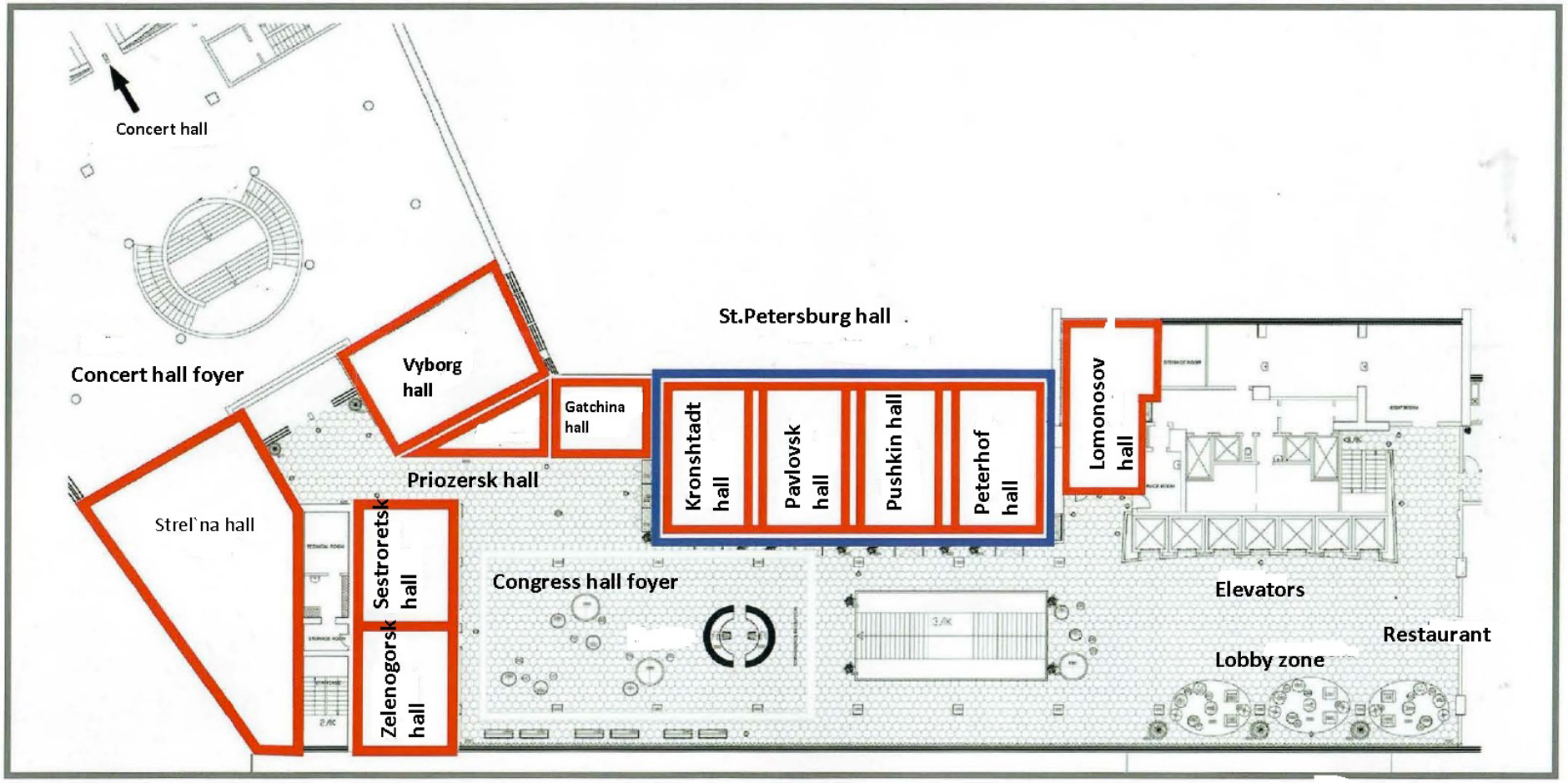
Registered, but yet unpaid reports			
	Session 1	Session 2	Session 3,4,5,6
	Jian Wang, Jinping Ou Hybrid Control to Enhance Wind and Seismic Performance of Twin Tall Buildings with a Sky Bridge	Antonopoulos T.A., Anagnostopoulos S.A. Seismic Protection of Existing Open Ground Story RC (Pilotis) Buildings: A Proposed Simplified Model for Optimum Partial Strengthening Solutions	Noemi Bonessio, Giuseppe Lomiento Cellular materials for seismic isolation
	Meng X. Dynamic Response of Liquid Storage Tank with Bearing Isolation on Elastic Soil	Elias S., Rupakhety R., Olafsson S. Effectiveness of Non-Linear Tuned Mass Absorbers and Tuned Liquid Absorbers for Control of Buildings under Earthquakes	Reyna R., Munoz A., Zavala C., Diaz M. Numerical Simulation of Low-Cost Seismic Isolator Using Different Hysteresis Models
	Wei Gong, ShishuXiong, Ping Tan Shaking Table Test of Pseudo-negative-stiffness Control of a Base Isolated Building Employing MR Damper	Ulker O., Erdik M. O. Structural Design of the 430.000 Sqm Hospital Supported on 1552 Seismic Isolators	Mohamed Noureldin, Kim Jinkoo Seismic Fragility Evaluation of Structures Retrofitted with Self-Centering Pre-Cast Concrete Frames
	Yang C.Y., Ma Y.C. Applying hybrid test method in studying seismic response of frame structure with self-centering energy dissipation device	Ulker O., Erdik M. O. Retrofit of a 100 Meter Tall Stack Using Tuned Mass Supported on Seismic Isolators	Kou Miyamoto An Extended Equivalent-input-disturbance Approach for Active Structural Control Focusing on Absolute Acceleration and Inter-story-drift Angle

CONFERENCE PROGRAM

	Guan Z. G. Experimental investigation on seismic behavior of bridges with pile-group foundations allowing uplift and rocking of pile cap	Garrido C.A., Fernández-Dávila V.I. Seismic Response Evaluation of Asymmetric RC Buildings Isolated with LRB and TFP Systems	Peng T.B., Ni Y.H. A New Seismic Design Method of Simply Supported Girder Bridges for Very Rare Ground Motions in the Transverse Direction
			Zulfikar A.C., Yilmaz C., Nagaoka T., Takahashi O. The Effect of Long Period Ground Motions on High-Rise Buildings and Use of Damping Devices
Friday, July, 5 / 5 июля, пятница			
Time/ Время	**Event/ Мероприятие**	**Venue/Место проведения**	**Conference/Конференция**
10:00 - 13:00	ASSISi meeting	St. Petersburg Hall	16WCSI
10:00 - 13:00	The Round Table Discussion	Strel'na Hall	13HKCC
Saturday, July, 6 / 6 июля, суббота **Departure of the conference participants**			

CONFERENCE VENUE

HOTEL ST. PETERSBURG CONGRESS HALL



DR. GIANMARIO BENZONI

DEPARTMENT OF STRUCTURAL ENGINEERING
UNIVERSITY OF CALIFORNIA, SAN DIEGO

Dr. Gianmario Benzoni graduated from the Politecnico di Milano, Italy, in 1981. He was a professor in the Department of Structural Engineering at the Politecnico di Milano and visiting scholar at the California Institute of Technology. He joined the Department of Structural Engineering at the University of California San Diego in 1994. He is currently Full Research Scientist.

He serves as Director of the Caltrans SRMD Testing Facility at UCSD, a unique testing facility for performance characterization of full scale seismic isolators and energy dissipators.

Dr. Benzoni is responsible for research activity in the field of seismic protection of existing and new building and infrastructures. He was Principal Investigator of the experimental characterization of dissipation devices for the California Toll Bridge Project of the Department of Transportation.

He is Editor-In-Chief of the oldest European International Journal on Earthquake Engineering (Ingegneria Sismica) and is co-Founder and current President of the Anti-Seismic Systems International Society (ASSISi).

Dr. Benzoni is author of more than 200 scientific publications on Earthquake Engineering research topics like seismic behavior of masonry buildings, structural health monitoring, seismic vulnerability and risk evaluation, experimental tests on R.C. bridge components and dynamic behavior of seismic isolators and energy dissipators.

RENE LAGOS

UNIVERSITY OF CHILE
RENE LAGOS C. – CIVIL ENGINEER UNIVERSITY OF CHILE (1978).

He is Chairman and C.E.O. of René Lagos Engineers, and leads the firm's High-rise Buildings and Seismic Design Group. He has been responsible for the structural design of more than 1,500 projects, representing over 12,000,000 m2, ranging from multi-story buildings up to 64 stories, to complexes of affordable housing. Hundreds of these buildings have 20 stories or more, with developments up to 700,000 m^2 (8 million ft^2).

PROFESSIONAL ACTIVITIES: Among the most prominent projects, in the area of high rise buildings are:
The Tallest Building in South America: Costanera Center Complex, in Santiago Chile, with 4 Towers and 700,000 m2. The Main Building with 64-story and 300 meters high, plus two 42 story and one 30 story towers.
The Tallest Residential Building with Seismic Base Isolation in the Americas: Ñuñoa Capital, in Santiago Chile, Two towers with 32 stories above the isolation level.
Telefónica Building, in Santiago Chile, a 33 story building, 140m high.
Swissotel Tower, in Guayaquil Ecuador, a 45 story building, 180 meters high.
Atacama 1 Thermo-Solar Tower, 250 meters high in the Atacama Desert, Chile.
Capital Fort Tower 3, in Sofia, Bulgaria. Peer Review of a 48-story tower, 202 meters high.
ACADEMIC ACTIVITIES:
At the School of Engineering, University of Chile in Santiago has been External Expert Professor, teaching structural analysis and seismic design of concrete buildings courses, also has been Guiding Professor of several Theses in Structural Engineering for undergraduates in Civil (Structural) Engineering.

NOTEWORTHY:
President of the Chilean Association of Civil-Structural Engineers, AICE. (2011-2015)
Co-Author, "Seismic Performance of High-rise Concrete Buildings in Chile", co-authored with Marianne Kupfer, Jorge Lindenberg, Patricio Bonelli, Rodolfo Saragoni, Tomas Guendelman, Leonardo Massone, Ruben Boroschek, and Fernando Yañez for the International Journal of High-Rise Buildings CTBUH, September 2012, Vol 1, No 3.
Co-Author, "RC Building Damage and Implications for U.S. Codes" co-authored with John W. Wallace, Leonardo M. Massone, Patricio Bonelli, Jeff Dragovich, Carl Lüder, and Jack Moehle, EERI, Earthquake Spectra – Chile Special Issue, 2012

American Concrete Institute Convention – Chicago USA, March 2010: Guest Speaker: "Tall Concrete Buildings in Chile and Their Seismic Performance During the February 2010 Chilean Earthquake" and "Structural Design of a 300 meters Tower in a High Seismic Zone"
Fourth SEWC (Structural Engineering World Congress) Como, Italy, April 2011
Keynote speaker: "Performance of High Rise Buildings Under the 2010 Chilean Earthquake".
Structural Concrete in the Americas and Beyond – 7th International Workshop, March 16-17, 2012, Dallas TX U.S.A.
Guest Speaker: "Successful Performance of Concrete Buildings during the Chilean Earthquake of February 27, 2010".

AKIRA WADA, DR. ENGINEERING

PROFESSOR EMERITUS
EXPERT EARTHQUAKE ENGINEERING SPECIALIST
TOKYO INSTITUTE OF TECHNOLOGY

Dr. Akira Wada, recipient of the 2011 Fazlur R. Khan Lifetime Achievement Medal and Professor Emeritus of the Tokyo Institute of Technology, is considered to be a Japan's leading expert in structural engineering with a specific focus on seismic structural design, base isolation and damping. Dr. Wada's contributions to the field of science and technology and connections in Japanese academic and government circles make him uniquely qualified to lead and consult on a wide variety of projects.
Since becoming Professor at the Tokyo Institute of Technology in 1989, Dr. Wada has held a number of important positions, including serving as President of ANCER and chairing the CTBUH Japan Chapter since its formation in 2010. In 2014, he was elected President of the Japan Seismic Isolation Association. He also has served as President of the Architectural Institute of Japan (AIJ, 2011.6-2013.5).

FILED OF EXPERTISE
(Years / Institution / Activities)
Structural Engineer at Nikken Sekkei LTD.
(Tokyo, 1970.4-1981.12, structural design of tall buildings and space structures)
Associate Professor at Tokyo Institute of Technology
(Tokyo, 1982.1- 1989.10, structural design of architectures and buildings)
Professor at Tokyo Institute of Technology
(Tokyo, 1989.11-2011.3, structural design of architectures and buildings and earthquake engineering
Research experience
Buckling Restrained Bracing System (1978- now, Tokyo Institute of Technology and Nippon Steel Cooperation, basic concept, structural design and tests)
Damage Controlled Structures for Earthquake Prone Countries (1990-now, Tokyo Institute of Technology and MIT, basic concept and actual structural applications to many buildings)
Seismic Isolation Technology (1982-now, Nikken Sekkei Ltd., Tokyo Institute of Technology and Architectural Institute of Japan, basic concept and structural Design)

AWARDS
Fazlur R. Khan Lifetime Achievement Medal of CTBUH (Council on Tall Buildings and Urban Habitat) (2011.11)
Special Award of Japanese Society of Steel Construction (2006.11)
The Prize of Architectural Institute of Japan for Engineering (2003.5)
The Prize of Architectural Institute of Japan for Research Thesis (1995.5)

ANDREAS J. KAPPOS

SECRETARY GENERAL OF THE EUROPEAN ASSOCIATION OF EARTHQUAKE ENGINEERING (EAEE)
ASSOC. EDITOR OF THE BULLETIN OF EARTHQUAKE ENGINEERING
DIRECTOR OF THE RESEARCH CENTRE FOR CIVIL ENGINEERING STRUCTURES, CITY, UNIVERSITY OF LONDON

Andreas Kappos currently holds a dual appointment at City, University of London and at the Aristotle University of Thessaloniki. Prior to joining City University (in March 2013) he was a Professor at Department of Civil Engineering, of the Aristotle Univ. of Thessaloniki since 2002, and Head of the Structures Section from 2008 to 2010. He has first joined the Department as a lecturer in 1988, after having completed his PhD studies in 1986. In 1983-1984 he was a Visiting Research Fellow at the Univ. of California, Berkeley. From 1995 to 1999 he worked at the Dept. of Civil Engineering, Imperial College London (UK), first as a lecturer and later as a Reader of Earthquake Structural Engineering.

He has long been working in the field of Earthquake Structural Engineering, in particular analysis procedures for structures (reinforced concrete and masonry buildings, and bridges) subjected to earthquake loading, and developed several methods and models for seismic assessment (both deterministic and probabilistic) of these structures, as well as design procedures based on the use of modern analysis tools. He was also involved in experimental work on the behaviour of reinforced concrete members subjected to cyclic loading, with emphasis on structural walls with special types of reinforcement and/or retrofitted using fibre-reinforced polymers (FRPs) and, more recently steel-reinforced polymers (SRPs). He developed new approaches for the assessment of the seismic vulnerability of existing structures and the associated losses and was involved in several projects on seismic risk assessment and earthquake scenarios for European cities.

He is the author or co-author of three books in English, and another two in Greek, edited three collective work volumes, and has contributed several chapters to books edited by others. He has published extensively in the field of Earthquake Structural Engineering (over 300 papers in refereed journals and conference proceedings), and his work was recognised internationally (over 2000 citations in Scopus h-index=30, over 5000 citations in Google Scholar, h-index 40).

In addition to his academic activities, he has been involved in several consultancies on topics like the seismic design of bridges and buildings, the assessment and retrofit of damaged structures, and various aspects of use of concrete in bridges, tunnels, and other civil engineering works.

Andreas Kappos is the Secretary of the European Association of Earthquake Engineering (EAEE) since 2010 and the Coordinator of the EAEE Working Group on Bridges since 2004. He has also served as a member of a number of scientific committees dealing with seismic design and assessment (he recently led the Project Team that drafted Eurocode 8 Part 3).

ATILLA ANSAL

VICE-PRESIDENT OF THE EUROPEAN ASSOCIATION FOR EARTHQUAKE ENGINEERING
CHAIRMAN OF GEOIST, GEOTECHNICAL EARTHQUAKE ENGINEERING AND CONSULTANCY INC.
CHAIRMAN OF CIVIL ENGINEERING DEPARTMENT OF ÖZYEĞIN UNIVERSITY

He received his Ph.D. in Geotechnical Engineering from Northwestern University, USA in 1977. He was promoted to full Professorship in 1988 in Istanbul Technical University. He moved to Kandilli Observatory and Earthquake Research Institute of Bogaziçi University in 2002. Since March 2012, he is professor in the Engineering School of Ozyegin University and Chairman of Civil Engineering Department.
He has been the Secretary General of European Association for Earthquake Engineering during 1994-2014 and President during 2014-2018. He is the Editor in Chief of the Bulletin of Earthquake Engineering and the book series on "Geotechnical, Geological and Earthquake Engineering" by Springer since 2002.
His main areas of interest are microzonation methodologies, earthquake scenarios, effects of geotechnical factors on earthquake damage, cyclic behaviour of clays and sands, liquefaction, variability of strong ground motion characteristics. He published about 250 articles in conference proceedings, journals, books and as technical reports in English and Turkish. He was the recipient of the Third Ord.Prof.Dr. Hamdi Peynircioglu Lecture Award in 1988, given by the Turkish National Committee on Soil Mechanics and Foundation Engineering, the Third Prof.Dr.Rıfat Yarar Lecture award in 2015, given by Chamber of Turkish Civil Engineers and Earthquake Engineering Committee of Turkish Earthquake Foundation and he was the 15th Prof. Nonveiller Lecturer elected by the Croatian Geotechnical Society.

ALESSANDRO MARTELLI

UNIVERSITY OF BOLOGNA (ITALY)

Dr. Alessandro Martelli got his master degree in Chemical Engineering at the University of Bologna (Italy) in 1973 (summa cum laude) and his PhD in Nuclear Engineering at the University of Karlsruhe (Germany) in 1977 (full marks). At the Karlsruhe Nuclear Centre (Germany), initially with an Euratom grant, then as consultant, from 1974 to 1977. At General Atomic Company in San Diego (California, USA), delegated by General Atomic Europe (Zürich, Switzerland), from 1977 to 1978. At the Saclay Research Center of the Commissariat à l'Energie Atomique (CEA) from 1978 to 1979. At the Italian National Committee for Nuclear Energy (CNEN), now Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), from 1979 to November 19, 2012 (date of retirement).
Before retiring, Assistant of the ENEA Director General for the development of anti-seismic technologies (from September 20, 2012) and previously Director of the Bologna Research Centre of ENEA and ENEA coordinator of the promotion, development and technology transfer activities in Northern Italy (from April 2010 to September 19, 2012); former Head of the ENEA Section on "Prevention and Mitigation of Natural Risks".
Engineer in charge of the structural safety certification (until 2012 mostly on behalf of ENEA) of several important, new or retrofitted, Italian buildings protected by seismic isolation or energy dissipation systems. Consultancy and technical judgment on the seismic safety of buildings (in particular of schools). Expertise for ITER (International Thermonuclear Experimental Reactor) on the "Seismic qualification of ITER emergency chillers".
Professor of Seismic Engineering at the PhD school of the Polytechnic of Bari (from 2011 to 2016) and, previously (from 1998 to 2011), at the Faculty of Architecture of the University of Ferrara; various further courses on seismic engineering in Italian and Chinese Universities; Vice-Chairman of the International Academic Advisory Committee of the Western China Foundation for New Technology and New Researchers of Disaster Mitigation in Civil Engineering since 2009.
Member of the Italian IPPC ("Integrated Pollution Prevention and Control") Commission, appointed by the Italian Minister of Environment; collaborator of other Italian Ministries (e.g. Scientific Research and University) and (from 2008 to 2013) of the 8th Commission on Environment, Territory and Public Works of the Italian Parliament.
Representative of the Commission "Sismica – GLIS" in the Board of ANTEL (Associazione Nazionale Tecnici Enti Locali) since its foundation in 2017. President of the Italian association GLIS (Isolation and Other Anti-Seismic Design Strategies) since its foundation in 1989 to its closure in 2017. Founding President, present Vice-President, Treasurer e Coordinator of the UE and Other Western European Countries Territorial Section of the Anti-Seismic Systems International Society (ASSISi).
Member of the Organizing and/or Technical-Scientific Committees of 180 conferences or seminars (95 national events and 85 international events); author or co-author of about 600 publications.

KEYNOTE LECTURE

UNCERTAINTIES IN SITE SPECIFIC RESPONSE ANALYSIS

ANSAL ATILLA, Ozyegin University, Turkey, Istanbul
TONUK GOKCE, MEF University, Turkey, Istanbul
KURTULUS ASLI, Ozyegin University, Turkey, Istanbul

Definition of the uniform hazard acceleration response spectrum on the ground surface has primary importance for performance-based design of structures and assessment of seismic vulnerabilities in urban environments. The approach requires a probabilistic local seismic hazard assessment, probabilistic definition of representative site profiles down to the engineering bedrock, and probabilistic 1D or 2D equivalent or nonlinear, total or effective stress site response analyses depending on the complexity and importance of the structures to be built. Thus, a site-specific response analysis starts with the probabilistic estimation of local seismicity and earthquake source and path characteristics that would yield probabilistic uniform hazard acceleration response spectrum on the engineering bedrock outcrop. Thus, site specific response analyses need to produce a probabilistic uniform hazard acceleration response spectrum on the ground surface.

The major uncertainties in site-specific response analysis arises from the variability of (a) local seismic hazard assessment, (b) selection and scaling of the hazard compatible input earthquake acceleration time histories, (c) soil stratification and corresponding engineering properties of encountered soil and rock layers, and (d) method of site response analysis.

The uncertainties related to local seismic hazard assessment, even though it has significant effect on the outcome of the site-specific response analyses, will not be considered in this study.

The second source of uncertainties are related to selection and scaling of the hazard compatible input earthquake acceleration time histories. One option is to select large number of acceleration records compatible with the local earthquake hazard in terms of fault mechanism, magnitude and distance range recorded on stiff site conditions to account for the variability in earthquake source and path effects. It was observed that if the number of selected acceleration records are in the range of 20-25, the calculated mean response spectrum is consistent with only minor changes with additional input records.

However, hazard compatibility with respect to magnitude and source to site distance ranges may also be considered as one source of variability. Bazzuro and Cornell (2004) observed that the match with engineering bedrock uniform hazard spectrum is more important than the hazard compatibility with respect to magnitude and source to site distance compatibility. It was observed that the importance of source to site distance compatibility varies with the adopted scaling procedure based on a parametric study conducted to observe the effects of source to site distance compatibility.

The other source of variability is the scaling procedure adopted to modify the selected earthquake acceleration records to match with the uniform hazard acceleration response spectrum calculated on the engineering bedrock outcrop. The scaling procedure may have three goals, (a) to obtain the best match with respect to rock outcrop target uniform hazard acceleration spectrum, (b) to match the target acceleration spectrum within the considered period range (c) to decrease the scatter in the acceleration spectra after scaling. Parametric studies were conducted to observe the effects of different scaling parameters and procedures.

The third source of uncertainty are site conditions with respect to soil stratification and engineering properties of soil layers. Site conditions may play an important role in modelling site response (Li and Assimaki, 2010). Thus, one option may be conducting site response analyses for large number of soil profiles for the investigated site to assess design acceleration spectra with respect to different performance levels. One may also consider using Monte Carlo Simulations to increase the number of soil profiles to account for the possible variability of site conditions.
The fourth source of uncertainty stems from the adopted method of site response analysis. There has been significant amount of work done related to the sources of variability and bias in site response analysis. Kaklamanos et al. (2013) conducted a detailed study based on the data obtained in the KibanKyoshin network (KIK-net) to determine the critical parameters that contribute to the uncertainty in site response analysis. They observed that 1D equivalent-linear site-response method generally yields underprediction of ground motions, except in the range of 0.5–2s, where the bias is slightly negative. Relative to empirical site amplification factors, site specific ground response analyses offer a reduction in the total standard deviation at short spectral periods.
In general, site-specific response analyses are deterministic computations of site response given certain input parameters. The results of these calculations need to be merged with the probabilistically derived ground motion hazard for rock outcrop site conditions. Bazzurro and Cornell (2004) recommended a convolution method for combining a nonlinear site amplification function with a rock hazard curve to estimate a soil hazard curve. The principal advantage of this approach is that uncertainties in the site amplification function are directly incorporated into the analysis. Another more simplified approach may be to evaluate site response analyses results adopting a probabilistic interpretation.
Site-specific probabilistic ground-motion estimates should be based on the full site-amplification distribution instead of a single deterministic median value. A probabilistic methodology using siteamplification distributions to modify rock ground-motion attenuation relations into site specific relations prior to calculating seismic hazard need to be considered. The use of a completely probabilistic approach can make about a 10% difference in ground motion estimates over simply multiplying a bedrock probabilistic ground motion by a median site-amplification factor even larger differences at smaller probabilities of exceedance.
However, site response is considerably more complex including surface waves, basin effects (including focusing and basin edge-generated surface waves), and topographic effects. Thus, 1D site-specific response analyses may not always be effective for accurately modelling and/or predicting site effects, however, in comparison to alternatives of GMPEs and empirical amplification factors, site response analysis would model the probable surface uniform hazard spectrum more adequately.

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KEYNOTE LECTURE

PERFORMANCE-BASED DESIGN OF SEISMICALLY ISOLATED BRIDGES

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A performance-based design procedure is presented for seismically isolated bridges equipped with linear or nonlinear viscous dampers (VDs). Accounting for multiple performance objectives, the proposed method initially identifies the critical hazard level and 'near-optimal' alternatives of the isolation system in terms of both economy and performance, based on the inelastic response of a single-degree-of-freedom system. By incorporating nonlinear response history analysis (NLRHA) of the multi-degree-of-freedom (MDOF) system in a number of successive design steps that correspond to different performance levels (PLs), it subsequently leads (in a non-iterative way) to a refinement of the initial design solution through the control of a broad range of material strains and deformations. The efficiency of the proposed design methodology is demonstrated by applying it to an actual bridge that was previously designed for ductile behaviour. Assessment of the design using NLRHA for spectrum-compatible motions indicates that the introduction of nonlinearity in viscous dampers can effectively reduce their size (i.e. reduced damper force demand) without significantly affecting the overall bridge response. Furthermore, enhanced seismic performance and cost reduction in the substructure design emerge, thus, rendering base-isolation an appealing design alternative.

KEYNOTE LECTURE

RECENT APPLICATIONS OF SEISMIC ISOLATION IN ITALY

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This paper presents a state-of-the-art on seismic isolation in Italy and the most important applications. Those to new strategic and public buildings are shown, as well as to new residential buildings, pointing out the very good behavior shown by the seismically isolated structures during real seismic events. Then, attention is focused on the retrofit of existing buildings, which represents the real challenge for the future. The most interesting applications to existing reinforced concrete, masonry and historic structures are shown, pointing out the specific challenges for each case. Finally, recordings obtained during the seismic sequence that struck Central Italy since August 24th, 2016, are presented and discussed. These are useful for analyzing the behavior of base isolation systems and their effectiveness under low energy earthquakes.
The application of seismic isolation for new buildings is quite easy and almost always possible. It is also economically convenient, at least in medium and high seismicity areas both for reinforced concrete buildings and masonry buildings. Actually, the real challenge of seismic isolation is protection of existing buildings, especially in countries where maintenance of old structures is an important issue. It is worth reminding that, when using base isolation, the period of vibration can be chosen so as to allow input of low spectral amplitude, while the superstructure remains substantially in the elastic range. This possibility also allows for limiting or even avoiding the conventional retrofit intervention in the superstructure. In this paper the design issues for the application of base isolation in the retrofit of existing buildings are first discussed for the two cases of reinforced concrete and masonry buildings. These refer to the positioning of the isolation devices in plan and elevation and the transferring of the vertical actions during the building phases. Then the most relevant applications in Italy for existing reinforced concrete and masonry buildings are also shown. Finally, an isolation system is presented, which was set up for cultural heritage structures but is very suitable also for industrial plants.

INTRODUCTION

In 1976 the Somplago viaduct, of the Udine-Tarvisio freeway in the Northern-East Italy, was completed. It had sliding devices on the piers and rubber bumpers between the deck and the abutments, able to absorb the seismic effects. As a matter of fact, the viaduct behaved very well and had no damage under the seismic events that hit Friuli Region on May 6th, 1976 (M = 6.5), when it was not yet fully completed, those of September 11th (magnitude M = 5.3 and 5.6, respectively) and those of September 15th, 1976 (M = 5.9 and 6.0, respectively). All these events had the epicenter only a few kilometers from the viaduct.
This was the first application of seismic isolation in Europe for a bridge and one of the first in the world. This successful application caused an immediate rapid extension of the application of anti-seismic systems to new Italian bridges and viaducts. The devices used were mainly dampers and Shock Transmitter Units (STUs). The bridges and viaducts protected by such systems numbered already 150 at the beginning of the 1990's: this ensured, at that time, worldwide leadership to Italy for the number and importance of anti-seismic systems applied to bridges and viaducts.
The fire-command building in Naples had already been designed without accounting for seismic actions, when Southern Italy was hit by the November 23rd, 1980, Campano-Lucano earthquake (M = 6.9). After the event, the area was considered seismic and the original design was retrofitted by just inserting Neoprene Bearings (NBs)

at the top of the reinforced concrete towers as supports for the reticular steel beam, and floor dampers and STUs inside the building (structural design by F.M. Mazzolani). Similar devices were used also for a second fire-command building nearby, which was opened for use in 1985.
At the beginning of the 1990s, the Telecom Italia Centre of the Marche Region at Ancona was completed. In total, 297 High Damping Rubber Bearings (HDRBs) were used and impressive on-site release tests were performed on one of the five buildings (structural design by G. Giuliani, acceptance certificate by A. Martelli).
Seismic isolation was also used for masonry buildings, as in the residential building in Corciano, composed of two blocks of two and four floors, respectively (structural design by A. Parducci). The isolation system is made of 18 HDRBs (diameter = 500 mm), placed between the reinforced concrete foundation and the superstructure. The superstructure is reinforced masonry, with hollow bricks, because at the time of construction the Italian code did not allow normal masonry buildings of four levels or more in high intensity seismic areas.
The progress of applications of new anti-seismic technologies (including energy dissipation systems) in buildings was slower in the following years; however, the trend accelerated after the 2002 Molise earthquake (M = 5.9) and 2009 L'Aquila (M = 6.3) earthquake. Nowadays Italy is the fifth country in the world and the first country in Western Europe for the overall number of applications of passive anti-seismic devices (Clemente & Martelli 2019, Clemente & Martelli 2017). In several applications, the isolators used were HDRBs and plane surface Sliding Devices (SDs), often used in parallel to optimize the dynamic behavior of the structure. Lead Rubber Bearings (LRBs), which enable a higher damping (up to an equivalent damping ratio of 25-28%), are used especially for bridges and viaducts. Finally, single and double Curved Surface Sliders (CSSs) were introduced in Italy after the 2009 L'Aquila earthquake and are now widely used in buildings.
It is worth reminding that the use of bas isolation allows designing Zero Earthquake-Damage Buildings, with obvious positive results in terms of sustainability and resilience (Clemente et al. in press). Furthermore, the convenience of bae isolated buildings, also limited to the construction cost, was demonstrated both for reinforced concrete (Clemente and Buffarini 2010) and masonry buildings (Clemente et al 2016). The importance of a reliable definition of the seismic input is to be stressed (Clemente et al. 2015).
In this paper a state-of-the-art on seismic isolation in buildings in Italy is presented. The attention is particularly focused on the reconstruction works after the recent seismic events but also applications to improve the seismic capacity are shown.

APPLICATION OF SEISMIC ISOLATION IN THE RECOSTRUCTION AFTER RECENT SEISMIC EVENTS

The use of the anti-seismic systems in Italy was very limited up to 2003, due to the absence of a suitable technical code. After the 2002 Molise earthquake the Italian seismic code was revised under the Ordinance 3274/2003 issued by the Prime Minister's Office in March 2003, and there was a significant increase in applications of seismic isolation. In San Giuliano di Puglia were realized:

- The new Francesco Jovine School in San Giuliano di Puglia (Figure 1), which was the first school in Italy to be designed with base isolation. It is composed by two buildings rising up from a single base deck, which is seismically isolated by means of 61 HDRBs and 13 SDs (seismic isolation design by P. Clemente, G. Buffarini, M. Dolce and A. Parducci, acceptance certificate by A. Martelli). The first two vibration modes the structure just translates along the two main orthogonal directions, respectively, with a period of 2.19 s. The maximum displacement for the design earthquake is 240 mm. The decoupling between the horizontal motion of the structure and that of the soil is guaranteed by the very high stiffness of the elevated structure with respect to the stiffness of the isolation system. The school was opened to activities in 2008. Successive studies demonstrated the suitability of the buildings for being used as strategic ones in case of earthquakes or other natural disasters (Clemente et al. 2009).
- The C8R residential building (structural design by M. Castrataro, acceptance certificate by P. Clemente), seismically isolated by 13 HDRBs and 2 SDs. The first

two vibration modes the structure had a period of 2.01 s. The building was completed in 2007 (Figure 2).

• The C20R residential building (seismic isolation design by P. Clemente, acceptance certificate by G. Buffarini), seismically isolated by 25 HDRBs and 12 SDs. The first two vibration modes the structure had a period of 2.01 s. completed in 2011 (Figure 3).

• The building A of the Francesco Romita High School in Campobasso, which was reconstructed, after demolition of the pre-existing unsafe building. It was seismically isolated by means of 12 HDRBs and 10 SDs. The works were completed in 2012 (Figure 4).

Among the strategic buildings, it is worth mentioning the new Civil Protection Centre of Umbria Region at Foligno, where several strategic buildings have been seismically protected by means of base isolation. Among these, it is worth mentioning the building that hosts the Operative Centre, which has a very interesting architectural design in the form of a hemispherical shape (Figure 5, structural design by A. Parducci, acceptance certificate by A. Martelli). It is 22 m high and has four floors above the ground and an underground floor. Its base diameter is about 31 m. The superstructure is formed by ten arch elements equally spaced along the perimeter, with the springing at different heights. For all of them, the upper springings are connected to a ring beam at the top of the building; the lower springings are all connected to a ring beam at the first floor. The arches are interconnected by two other ring beams at the intermediate floors. A prestressed concrete cylinder, containing all the building facilities, is suspended to the top ring. It is also connected to the other floors and continues down in the underground floor without other supports. The superstructure is supported by ten HDRBs (diameter = 1.0 m, horizontal stiffness = 1310 kN/m, equivalent damping = 10%) deployed along the perimeter, which yield a fundamental frequency of the isolated structure of about 0.38 Hz. The isolation devices transfer the loads to the foundations, located under the lower springing of the ten arches and composed by concrete plinths, each supported by four piles.

The use of seismic isolation increased rapidly after L'Aquila earthquake of April 6th, 2009, starting from the buildings for temporarily hosting the homeless residents (C.A.S.E. project). These consisted in pre-fabricated houses, made of reinforced concrete, steel or wood, each placed on an isolated reinforced concrete slab (21m x 57m in plan, 50 cm thick) supported by 40 CSSs manufactured in Italy (Saitta et al 2018), installed at the top of the columns, rising up from the foundation plate, which had the same size as the slab (Figure 6).

Afterwards, seismic isolation was largely used in the reconstruction in L'Aquila and the surrounding towns, both for new and existing buildings. Thus, the number of Italian seismically isolated buildings increased from about 70 before L'Aquila earthquake to more than 400 by 2013 (with over 30 applications to school buildings). A further incentive to the use of seismic isolation for reconstructions was the 2012 Emilia earthquake (Martelli et al. 2017).

One of the first building completed in L'Aquila after the 2009 earthquake was the ANAS (Italian National Agency for Roads Construction) building, seismically isolated by means of 60 HDRBs (Figure 7).

OTHER APPLICATIONS OF SEISMIC ISOLATION

Among the most interesting applications, outside the areas hit by recent earthquakes, are:

• The new primary school at Marzabotto, Bologna (seismic isolation design by P. Clemente and M. Forni, acceptance certificate by A. Martelli), isolated by means of 28 HDRBs and 14 SDs, for which the additional cost due to isolation was of 96,000 €, over a total cost of 5,000,000 €. It was completed in 2010.

• Several school buildings in Tuscany. Among these, the new kindergarten and primary school at Mulazzo, Massa Carrara, which was isolated by means of 14 LRBs (diameter = 600 mm) and 15 SDs, with a period of 2.0 s. The structure was completed in 2012.

• The new Del Mare Hospital in Naples, a very irregular structure both in plan and elevation (structural design by B. De Risi and C. Mascolo, acceptance certificate by E. Cosenza), which has been seismically isolated by means of 327 HDRBs of three different types (122 with diameter = 600 mm and shear elastic modulus = 0.8 MPa;

108 with diameter = 650 mm and 97 with diameter = 800 mm, all with shear elastic modulus = 1.4 MPa; so the horizontal stiffness varies from 1.5 to 4.9 kN/mm). The fundamental period is 2.32 s and the maximum lateral displacement is 240 mm. The use of seismic isolation involved significant benefits compared to a traditional design, such as the reduction in longitudinal reinforcement steel of about 40% for beams and columns and a very high level of safety of both structural and non-structural elements, including medical equipment present at various floors, while fulfilling performance requirements related to operating state limitations (Di Sarno et al. 2008).

• The headquarters of the association "Fratellanza Popolare – Croce d'Oro" at Grassina, Florence (structural design by S. Sorace, acceptance certificate by A. Martelli), a L-shaped building used for civil defense that was isolated by means of SDs under each column and fluid-viscous devices with silicone matrix along the perimeter, whose mechanical properties determine the rigidity and damping characteristics of the system itself (Figure 8, Martelli et al 2017).

• A commercial building in Augusta, which has a rectangular shape with a length of 35.70 m, a width of 16.00 m, a maximum height above the ground of 10.50 m and a basement story with a clear height of 3.60 m; the hybrid seismic isolation system consisted of 16 HDRBs and 20 SDs. The building was subjected to a series of push and sudden release tests in March 2013, with low amplitudes to ensure that no damage would occur in the finished structure. During the tests, the displacements at the isolation level were measured along with the accelerations at each floor of the building (Oliveto et al. 2013).

• A residential building in Spadafora Street at Messina, the tallest seismically isolated building in Italy at the time of construction, completed in 2014 (Figure 9, structural design by M. Marino, acceptance certificate by A. Martelli), composed of 8 floors plus an underground floor, used as garage. It was isolated by means of 22 LRBs and 2 SDs. The vicinity of an old building to the new isolated one pointed out the issue of protection of the seismic joints from materials coming from the adjacent structures in case of their collapse during an earthquake.

• The "120 Forlanini" residential building in Ragusa completed in 2014 (structural design by C. Mezzasalma), with a reinforced concrete structure and an isolation system composed by 17 HDRBs (diameter = 450 mm, total rubber thickness = 126 mm) and 18 SDs, which ensured a fundamental period of the five floors superstructure equal to 3.0 s and a maximum displacement of 250 mm.

• the "Balza Akradina" residential building in Siracusa completed in 2015 structural design by N. Impollonia), with a reinforced concrete structure and an isolation system composed of 8 HDRBs (diameter = 500 mm, total rubber thickness = 102 mm) and 4 SDs. The fundamental period of the five floors superstructure is 2.4 s and the maximum displacement is 200 mm.

• the Eurosky building in Rome (Figure 10), where 30 SDs and 28 LRBs (diameter = 800 mm, horizontal stiffness = 5,800 kN/m, equivalent damping = 25%) were used to obtain a tuned mass damper (TMD) at the twenty-seventh floor, using the upper three floors as mass; pretensioned vertical bars were also used to avoid rocking effects.

The interest for use of masonry in new buildings is related to the fact that masonry can guarantee a longer durability, testified by ancient constructions, and a better performance in terms of energy efficiency. It is clear that seismic isolation can contribute to the revival of masonry in structures, greatly reducing the seismic effects to the structure. To assess the potential of brick masonry buildings, ENEA and ANDIL (the Italian association of brick manufacturers) organized a research project, which led to the design of a brick masonry building with seismic base isolation, to be used as a strategic structure. Seismic isolation allowed more freedom in the architectural design with obvious good results in terms of functionality and use of space. In addition, the building is a net-zero energy building (NEZB) and has an eco-friendly connotation, thanks to the use of brick materials and low environmental impact systems (Buffarini et al. 2013).

RETROFIT OF EXISTING BUILDINGS

The real challenge of seismic isolation is protection of existing structures, especially in countries such Italy where maintenance of old structures is an important issue

(Bongiovanni et al. 2019, Saitta et al 2017). It is worth reminding that base isolation yields a very high level of safety and that the period of vibration can be chosen so as to allow input of low spectral amplitude, while the superstructure remains in the elastic range. This possibility also allows for limiting or even avoiding the conventional retrofit intervention in the superstructure.

One of the first applications of seismic isolation in existing buildings in Italy was done in a residential building in Latini Street at Fabriano (structural design by G. Mancinelli, acceptance certificate by A. Martelli), which suffered damage to non-structural elements during the 1997-98 Marche-Umbria seismic sequence. The isolators were inserted between the existing plinths and the new ones built below them.

The Multifunctional Center at Rione Traiano in Naples, was retrofitted by inserting 630 HDRBs in the columns and in the outer walls, above the foundation level. The works were completed in 2005. The same technique was used also for the retrofit of two, four-story reinforced concrete residential buildings in Solarino, Sicily (structural design by G. Oliveto and M. Granata, Oliveto et al. 2004).

After L'Aquila earthquake, seismic isolation was largely used also for retrofits. One of the most interesting interventions was that of the «Leonardo complex" in L'Aquila (Figure 11). The structure consists of three structurally independent buildings, resulting in an approximately «L-shaped» building, each with four stories above the ground and a basement. During the 2009 L'Aquila earthquake the structure exhibited widespread damage to the masonry infill walls, especially at the ground floor, with cracking at the joints due to hammering and limited capillary cracks at the joints of the reinforced concrete frame. The buildings were retrofitted by using CSSs placed at the top of the basement columns (Castellano 2015).

A similar technique was used for the the residential building in Tigli Street at Pianola, L'Aquila (Figure 12), which had been severely damaged by the 2009 L'Aquila earthquake. The structure was composed of three blocks, which were first studied by means of experimental vibration analysis (Buffarini et al. 2011, Mancinelli et al. 2011), in order to identify their dynamic characteristics. Then, the three blocks were joined at the first floor and 42 HDRBs and 62 SDs were inserted at the top of the columns just below the first floor and below the stairs (structural design by G. Mancinelli, acceptance certificate by A. Martelli).

Seismic isolation has been largely used after the L'Aquila earthquake for the retrofit of masonry buildings. The most interesting applications concern historic buildings, e.g.:

- The Palazzo Ciuffini-Cricchi-Volpi, a masonry building located in the historical centre of L'Aquila, which was badly damaged by the 2009 earthquake, and then retrofitted with seismic isolation (structural design by R. Vetturini); specifically, 28 HDRBs (diameter = 550 mm, total rubber thickness = 105 mm) and 25 SDs were used. The choice of the isolation period was governed by the displacement, which had to be limited because of the presence of an adjacent building (Figure 13). The isolated period was 2.02 s and the maximum displacement 146 mm. The isolators were placed between two new sub-foundations made of reinforced concrete beams.
- The historical masonry building called "La Silvestrella" in L'Aquila, which was also seriously damaged by the 2009 L'Aquila earthquake. The structure had been built in the early years of the twentieth century and was kept in its original configuration, without changes or superfetation. Therefore, it represents an uncommon example of eclectic, fantastic, grotesque architecture. A traditional strengthening intervention, which respected its historical value and guaranteed a suitable safety level, was not possible in practice, so it was decided to use seismic isolation (structural design by R. Vetturini). The executive phases were the following. The superstructure was first consolidated and protected. Then, two sub-foundations were built, one above the other and the devices were places in between (Figure 14). The upper one consisted in continuous concrete beams, while the lower one was composed by plinths, which were successively connected by means of a reinforced concrete plate. The isolators were first connected to the upper sub-foundation, where suitable steel elements had been previously positioned. Then jacks were positioned under them, which allowed loading the isolators, by means of injection of epoxy resin. A steel floor above the isolation interface guaranteed the rigid connection, but also formed a new floor. Finally, 25 HDRBs (diameter = 450 mm, total rubber thickness = 126 mm, damping ratio = 13%) and 23 SDs were used, yielding a fundamental period of 2.35 s and a maximum displacement of 300 mm (Mezzi et al. 2015).

• the "Emiciclo building" in L'Aquila, which is the main branch of the Abruzzo Region Council (Figure 15, structural design by R. Vetturini, G. Di Marco, L. Zazzara, W. Cecchini and A. Bottone, consultancy by A. Borri); the building was seismically isolated by means of 61 HDRBs and 47 SDs, which allow a maximum displacement if 300 mm.

Recent retrofitting works realized not after earthquakes are the following:

• The Quasimodo School at Riposto, Catania, which was seismically isolated in 2009 by means of 33 HDRBs and 16 SDs. It was the first Italian application of seismic isolation in existing schools, with a retrofit cost of only 45 €/m^3 (structural design by F. Neri).

• The IACP building at Calatabiano, Catania, built at the beginning of 1980s with a rectangular shape in plan (size 35.5m x 11.25m), three floors above the ground plus an underground floor. The carrying structure was composed of reinforced concrete frames and brick-concrete floors, and the foundation was a plate stiffened by a grid of beams. The structural elements were in very bad conditions, due to the carbonation of concrete and the steel corrosion. The retrofit was done by means of seismic isolators at the top of the columns at the underground floor (structural design by F. Neri). The columns of the underground floor were first enlarged, both to improve their strength and to allow the insertion of the devices, and additional beams were built just above the isolators. Next, thirty-three CSSs were used, the fundamental period is now 2.71 s, the maximum design displacement is 220 mm.

• The civic tower in Rieti, which was retrofitted by inserting a TMD at its top (Figure 16). The old covering was first demolished and substituted by a new concrete slab, not connected to the perimeter walls, but supported by a steel structure with elastomeric isolators at its base.

Seismic rehabilitation of historical constructions is an important issue, especially in countries like Italy where these are highly vulnerable even against moderate seismic events, but also because of the daily presence of numerous tourists. Traditional techniques are not suitable and an adequate rehabilitation should guarantee the preservation of the original monument characteristics, identity and historical value. Therefore, the use of new technologies, such as seismic isolation, is advisable. Actually, this technique has already been used for retrofitting historical buildings in countries like the USA, Japan and New Zealand.

For seismic isolation of entire ancient buildings, a new system was developed by Clemente, De Stefano and Barla (Clemente and De Stefano 2011, Clemente et al. 2011, Clemente et al. 2012a, Clemente et al. 2012b), called "Seismic Isolation Structure for Existing Buildings" (SISEB). It consists of an isolated platform to insert under the foundations of the building, without touching the building (Figure 17). A discontinuity between the foundations and the soil is created by inserting horizontal pipes and positioning the isolation devices at their horizontal diametric plane. In order to facilitate successive placement operations, the pieces of pipe have a particular shape and are composed by two portions, the lower and the upper cylindrical sectors, respectively, which are connected by means of removable elements. Then, the building is separated from the surrounding soil, in order to allow horizontal displacements during an earthquake. So the structure is seismically isolated, but not by means of interventions that could modify its architectural characteristics, which is very important for historical buildings. Even the underground levels are not modified, but can be part of the seismically protected structure (De Stefano et al. 2015).

It is stressed that anti-seismic devices may also be used to reconstruct cultural heritage buildings that have been fully destroyed by earthquakes. Obviously, this is not a retrofit operation, but the original materials (stones) can be used for the external walls, in order to preserve the original external appearance and features of the structure. In this case, the installation of anti-seismic devices is advisable, so as to avoid collapse in future earthquakes. An example of this kind was the reconstruction of the "Clock Tower" of the Castle of Gemona del Friuli, Udine, completed in 2016 (structural design by F. Cioppettini, acceptance certificate by A. Martelli). It had been fully destroyed by the already mentioned Friuli earthquakes of May and September 1976. An inner steel frame was inserted, which supports all floors and the roof bell. It was strengthened with Buckling Restraint Braces (BRADs), in order to limit its lateral deformation and prevent hammering against the external reconstructed masonry walls (from which it is separated by an adequate transverse gap).

EXPERIMENTAL SEISMIC BEHAVIOUR OF BASE ISOLATED BUILDINGS IN ITALY

The suitability of seismic isolation has been demonstrated during strong earthquakes, when base isolated buildings exhibited an excellent behavior, preserving the structures, the non-structural elements and their contents (Clemente 2017, Clemente et al 2017).

In Japan, during the 1995 Hyogo-ken Nanbu earthquake (M = 7.3), two isolated buildings in the epicentral area, near Kobe, reported no damage during the quake. One of these was the communication minister in Sanda City (Figure 18), which was about 30 km far from the epicenter. It had been isolated by means of low damping rubber bearings and elasto-plastic energy dissipators. The monitoring systems allowed to state that the ratio between the acceleration peak at the top and that on the basement was about 1/9, so with a significant reduction of the seismic action.

The reinforced concrete building in Ojiya City (Figure 19), Japan, completed in 1994 and isolated by means of rubber bearings and sliders, supported very well the 2004 Mid Niigata earthquake (M = 6.8); the peak acceleration was 0.725g at the base and 0.194g at the top, with a reduction ratio of about 1/4.

Most of the 118 isolated buildings affected by the 2011 Tohoku earthquake, located in the Tohoku area or in other Japanese sites, behaved quite well, even though they had been designed to withstand less severe earthquakes (Matsuda et al. 2012). Among these, the 4-storey National Western Art Le Corbusier Museum in Tokyo, retrofitted in 1999 by inserting high damping natural rubber bearings in a sub-foundation; this isolation system reduced the PGAs in the two horizontal directions from 0.19 and 0.27 g at the base to 0.08 and 0.10 g at the top during the 2011 Tohoku quake. It is worth reminding that also seismic isolated bridges and viaducts, most of those protected by rubber bearings (LRBs and HDRBs), showed an excellent behavior during the quake, but a certain number of them was then destroyed by the subsequent tsunami, due to deck rotation toward the upstream side, resulted from the uplifting force (Saito 2015).

In China, two concrete seismic isolated buildings and even a 6-storey masonry building showed an excellent behavior during the 2008 Wenchuan earthquake (MW = 7.9). During the Lushan earthquake (MW = 7.0) of April 20th, 2013, two primary school buildings, one close to the other, showed a quite different behaviour, as demonstrated by the recordings obtained by means of the seismic monitoring systems installed in them. In the first one, which was conventionally founded, the peak ground acceleration value of 0.2g was amplified to 0.72g at the top; in the second building, which was protected by means of a base isolation system, the acceleration peak was equal to 0.12g (Zhou et al. 2015). The same happened for the county hospital, composed of two buildings with conventional foundations and one with base isolation (Figure 20). The two buildings with conventional foundations suffered damage to partitions, roof and equipment contained, and were unusable after the earthquake; on the contrary, the seismically isolated block was the only hospital building of the county to be remain fully undamaged and operational: this allowed to heal thousands injured people, which was impossible in other hospitals in Lushan.

In California the University of Southern California (USC) hospital in Los Angeles showed a very good behaviour during the 1994 Northridge Earthquake (Ms= 6.8). It was about 30 km far from the epicentre and the ratio between the acceleration peak at the top and that on the basement was very low (Celebi 1996, Nagarajaiah and Sun 2000 and 2001).

Very few seismic isolated buildings in Italy are provided with monitoring systems. Among these:

- The new Jovine school at San Giuliano di Puglia, seismically isolated by means of HDRBs.
- The Operative Centre of the Civil Protection Centre of Umbria Region at Foligno, seismically isolated by means of HDRBs.
- The Forestry Building of the Civil Protection Centre at Foligno, seismically isolated by means of HDRBs.

Their seismic responses under low energy earthquake was analyzed. As a matter of fact, seismic isolation system could exhibit very different behavior under earthquakes of different energy at the site.

In the Jovine School at San Giuliano di Puglia the HDRB isolation system was not activated during the December 20th, 2013, earthquake (M = 3.8, epicenter distance =

11 km, depth = 25.7 km) and the structure behaved as a fixed base building. The recorded data showed the importance of the higher modes and of the deformability of the base deck when the isolation system is not put in action (Bongiovanni et al. 2015).
Also the seismic sequence that occurred in Central Italy since August 2016, gave the opportunity of studying the behavior of isolation systems under different low magnitude earthquakes (Clemente et al. 2019, Clemente et al 2016). In the second and third ones, seismically isolated by means of HDRBs, the recordings testified the good behavior of HDRBs also under low magnitude events. As a matter of fact, the system filtered the seismic waves even though the fundamental period of vibration was significantly lower than that assumed in the structural design and relative to the design earthquake. In Figure 21, the acceleration time histories recorded in the Operative Centre of the Civil Protection Centre of Umbria Region at Foligno during the main shock of October 30th, 2016, are shown.
In all cases, the importance of an accurate non-linear analysis of their behavior under earthquakes of different magnitudes has been pointed out, in order to guarantee that the seismic actions in the superstructures do not exceed those assumed in the design (Clemente et al. in press).
The importance of the monitoring of seismic isolated buildings is evident to assess the possible dynamic behavior of such structures during earthquakes and to gain experience on the general seismic behavior of such structures to be used in future design and analyses (Martelli and Clemente 2015). Furthermore, the importance of a real time monitoring is evident, especially for strategic structures.

CONCLUSIONS

Italy was one of the first counties to study and use seismic isolation, both for new and existing buildings. The absence of a suitable technical code limited its application until 2003. After that year the number of applications increased and now base isolation is considered the most reliable technique to protect structures and their contents against seismic actions.
The actual behavior of base isolated buildings under strong earthquakes, obtained by means of monitoring systems, especially in Japan, USA and China, demonstrated the reliability of seismic isolation, which is certainly the best solution to preserve structure against earthquakes, especially those for which a high level of safety is required, but also residential buildings. The recordings obtained during the 2016-2017 seismic sequence in Italy, pointed out that the behavior of isolation devices could be quite different during low magnitude earthquakes. The importance of structural health monitoring for future improving and developments is evident.

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Figura 1. The new Jovine school at San Giuliano di Puglia and the foundation with the isolation devices

Figure 2. The C8R private buildings in San Giuliano di Puglia.

Figure 3. The C20R private buildings in San Giuliano di Puglia.

Figure 4. The new Francesco Romita school in Campobasso.

Figure 5. The Operative Centre of the new Civil Protection Centre of Umbria Region at Foligno.

Figure 6. One of the C.A.S.E. buildings in L'Aquila.

Figure 7. The new ANAS building in L'Aquila.

Figure 8. A fluid-viscous device with silicone matrix of the Fratellanza Popolare building at Grassina.

Figure 9. The residential building in Spatafora Street in Messina.

Figure 10. The Eurosky building in Rome (courtesy of Somma).

Figure 11. The "Leonardo complex" in L'Aquila (courtesy of FIP Industriale).

Figure 12. The "Via Tigli Building" in L'Aquila (courtesy of FIP Industriale).

Figure 13. Palazzo Ciuffini-Cricchi-Volpi in L'Aquila (courtesy of FIP Industriale and R. Vetturini).

Figure 14. The Vila Silvestrella in L'Aquila (courtesy of FIP Industriale and R. Vetturini).

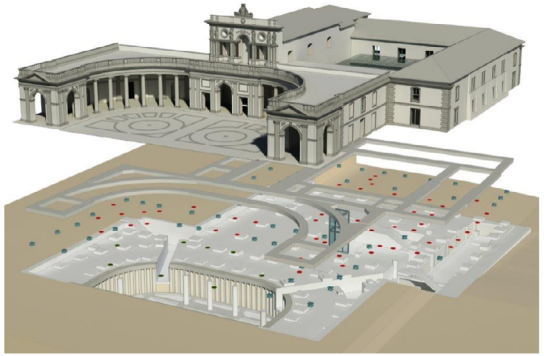

Figure 15. The Emiciclo building in L'Aquila (courtesy of Somma and R. Vetturini).

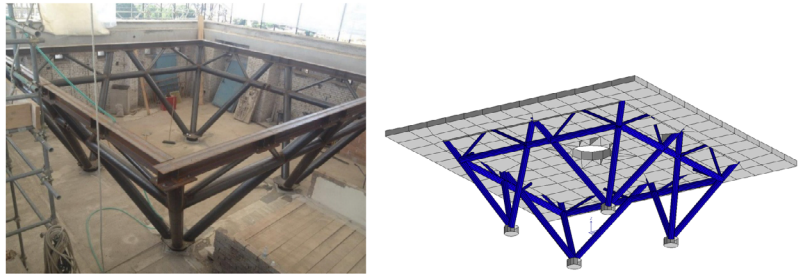

Figure 16. The TMD of the Civic Tower of Rieti (courtesy of Somma).

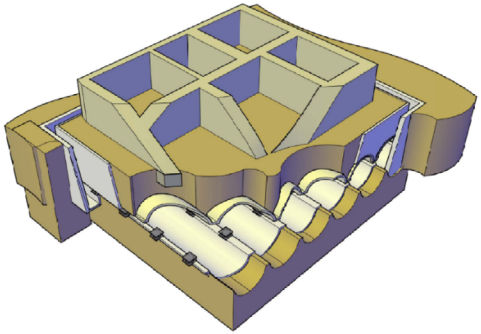

Figure 17. The seismic isolation structure for existing buildings developed by Clemente, De Stefano and Barla.

Figure 18. The communication minister in Sanda City, Japan.

Figure 19. The reinforced concrete building in Ojiya City, Japan.

Figure 20. The Lushan county hospital (China): damage suffered by the conventionally founded buildings and full integrity and operability of seismic isolated building.

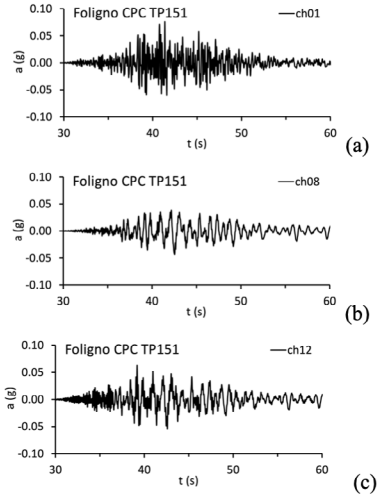

Figure 21. The Operative Centre Building at the Civil Protection Centre of Foligno, Italy: time histories recorded during the October 30th, 2016, earthquake (a) at the basement, (b) at the floor just above the isolation system and (c) at the top of the building.

KEYNOTE LECTURE

SEISMIC RESILIENCE IN CONCRETE HIGH RISE BUILDING DESIGN: THE CHILEAN PERSPECTIVE

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Chile is known to be one of the most seismic countries in the world. On the last 100 years, 13 earthquakes of magnitude 8.0 or higher have occurred in the country with an average of one every 8 years.
This short interval between large earthquakes has led the Chilean practice to assume that every building will experience at least one large magnitude earthquake during its life time. Also, the general good structural behavior observed, has conditioned the Chilean society to expect for their buildings immediate occupancy performance level under these extreme events, despite the fact that the Chilean Code declares a scope of life safety performance level.
The presentation will review the concepts and strategies behind the Chilean practice of seismic design of reinforced concrete buildings in order to limit damage, including conventional type structural systems and the use of seismic protection systems which have proven to be effective to provide near resilient structural performance under extreme seismic events. It will also present an overview of the future challenges and the possible strategies to fully achieve this objective.
The conclusion based on statistical evidence from recent strong earthquakes in Chile, indicate that resilience is a consequence of limiting damage, understanding that operational performance and life safety are different challenges that require different strategies to be solved and that both strategies must be met simultaneously and not alternatively in order to provide society with resilient and safe buildings.

KEYNOTE LECTURE

RECENT EARTHQUAKES AND NEW CONCEPTS FOR EARTHQUAKE-RESISTANT DESIGN

WADA A., Recent Earthquakes and New Concepts for Earthquake-resistant Design, Japan, Tokyo

Over the last 100 years or so, engineers have developed methodologies for design and technologies for earthquake-resistant structures. A prevailing design approach today is to allow for inelastic deformations of a structural system in a strong earthquake. While this approach likely ensures life safety, a large number of buildings are typically damaged to the extent that they require significant retrofit or need to be demolished. This leads to significant costs and extensive community disruption. In 2016 in Japan, one of the most technologically advanced countries in the world, the Tainan earthquake in February and the Kumamoto earthquake in April resulted in about 10,000 buildings being tagged as collapse risks and they had to be abandoned by their 100,000 occupants. Learning from this and prior earthquake experiences, we have changed our philosophy for earthquake-resistant design for the 21th century. The presentation will focus on these new trends in seismic design.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

EXPERIMENTAL MODEL FOR DOUBLE CONCAVE SLIDING BEARINGS

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Keywords: *seismic base isolation, sliding friction bearing*

This study deals with the modeling of sliding friction seismic isolation devices. Recent large scale experimental tests confirmed the need for accurate models to account for the friction performance in the ranges of loads, velocity and displacement expected during a seismic excitation. An existing experimental model previously validated for single concave isolators is here extended to double concave sliding isolators. Full-scale mono-directional tests on a set of double concave friction bearings in are used to validate and calibrate the model. The friction model includes three independent functions to account for the effects of applied vertical load, velocity, and cycling effects associated to heating. The applicability of the model to the double concave isolators is discussed, in comparison with earlier results of single concave isolators.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

PUSHOVER ANALYSES OF SELF-CENTERING BUCKLING-RESTRAINED BRACED FRAMES OF SAC BENCHMARK BUILDINGS

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Keywords: *Buckling-restrained braces; Drift response; Pushover analysis; Seismic analysis; Self-centering braces*

Buckling-restrained braced frames (BRBFs) are used for the purpose of the lateral load-resisting system in seismically active regions. The symmetrical hysteresis, high ductility, and good energy dissipation made this system preferable to the conventional concentrically braced systems. Extensive study has been done for BRBFs design IBC 2012 and uniform hinges distribution through the height of the floors at different stages of the pushing. Since the excessive residual drift in BRBFs is a disadvantage in BRBFs which need to develop a new system, as such self-centering buckling-restrained braced frames (SC-BRBFs) for better energy dissipation capacity, the absence of compressive buckling behavior of races, high ductility, and reducing residual drift response. This study is focused on the pushover analysis of SC-BRBFs. The same design as BRBFs has been considered for SC-BRBFs to evaluate a comparative study with BRBFs. Three medium to rise study frames, namely, three-story, nine-story, and twenty stories are considered for this study. The frames are designed as per current seismic code AISC 341–2010 provisions by considering the SC-BRBs as the combination of the buckling-restrained brace (BRB) and shape-memory alloy (SMA) rods. These frames are modeled and analyzed using a computer software OpenSees. The main parameters investigated are a pushover drift response, failure mechanism, and hinge mechanisms. The analysis results for SC-BRBFs showed better performance as compared to conventional BRBs with the higher ductility and drops at higher stages.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

EXPERIMENTAL INVESTIGATION ON TRANSVERSE STEEL DAMPER SEISMIC SYSTEM FOR CABLE-STAYED BRIDGES UNDER EARTHQUAKE SEQUENCES

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Keywords: *Shake table test; Cable-stayed bridges; Isolation system; Transverse steel damper; Earthquake sequences*

In current transverse seismic design of cable-stayed bridges, the conventional transverse fixed system is often adopted in engineering practices. In this system, rigid constrains are applied at deck-bent (or pier) and deck-tower connections for providing enough stiffness to carry traffic and wind loads, which inevitably increases seismic demands at bents (or piers), towers and foundations. In this regard, these components are always designed with sufficient capacity for large seismic excitations. This uneconomic strategy renders the demands of transverse isolation systems for cable-stayed bridges. To address aforementioned issues and improve the seismic performance of cable-stayed bridges in transverse direction, the authors recently developed a transverse steel damper (TSD) and proposed a new transverse isolation system. Since multiple strong aftershocks may occur shortly after a destructive main shock, the seismic performance of cable-stayed bridges under multiple earthquake excitations needs to be investigated. Therefore, a series of experiments on a 1/35-scale model of Sutong Bridge with a main span of 1088m are conducted on a four-shake-table testing system, in which earthquake sequences are adopted as excitations. Two types of transverse structural systems are considered. One is an isolation system using TSDs as energy dissipation devices, and the other is conventional transverse fixed system. Test results show that (1) the isolation system significantly reduces lateral horizontal force demands at the deck-bent/tower connections because of the decline of deck accelerations, and reduces curvature demands at bent/tower bottoms and displacement demands along tower shafts, meanwhile limiting the relative displacement at deck-bent/tower connection to an acceptable level for practice. (2) Residual deformations of TSD under earthquake sequences are recorded, but it has little impact on seismic performance of cable-stayed bridges. (3) In general, the TSDs seismic system is experimentally validated to be a reliable and efficient seismic strategy for cable-stayed bridges.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

SEISMIC PROTECTION OF EXISTING OPEN GROUND STORY RC (PILOTIS) BUILDINGS: A PROPOSED SIMPLIFIED MODEL FOR OPTIMUM PARTIAL STRENGTHENING SOLUTIONS

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Keywords: *Reinforced concrete buildings, Open ground story, Inelastic earthquake response, Seismic Protection, Optimum partial strengthening, Steel bracing*

Optimum partial strengthening of existing open ground story (pilotis) buildings is examined using a simple stick model with one element per story. The proposed simplified MDOF system is used only for estimates at the level of the open ground story, for calculation of the global structural response of the building under design level earthquakes, before and after a partial strengthening. It incorporates the well known structural fuse concept, while its parameters are determined on the basis of simplified calculations using global structural properties such as the elastic story stiffness, the story mass and base shear capacity of the building. The latter can be easily evaluated under some common engineering assumptions.The model is applied to the partial retrofitting of three RC buildings subsequently assessed by means of nonlinear dynamic analyses, using detailed mathematical models with plastic hinge idealizations. A parametric study is conducted to determine practical ranges of the basic strengthening parameters. It appears that from a practical engineering viewpoint, the proposed partial strengthening of vulnerable old pilotis type buildings can be quite effective and greatly facilitated with the proposed simplified procedure permitting fast evaluation of many retrofitting alternatives.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

SHEAR RESPONSE OF ISOLATED ANGLE BRACKETS FOR CROSS LAMINATED TIMBER BUILDINGS

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KRAMAR M., Section for Timber Structures, The Slovenian National Building and Civil Engineering Institute, Slovenia, Ljubljana
PAZLAR T., Section for Timber Structures, The Slovenian National Building and Civil Engineering Institute, Slovenia, Ljubljana
KRŽAN M., Section for Timber Structures, The Slovenian National Building and Civil Engineering Institute, Slovenia, Ljubljana

Keywords: *Sound isolation bedding; isolated steel angle bracket; shear behavior; experimental assessment; equivalent viscous damping*

In cross laminated timber (CLT) buildings, acoustic behavior presents a major concern due to low frequency noise transmission. To reduce the disturbing sound transmission over the flanking parts, special elastic layers with fine celled structure are being used between the CLT wall and CLT slab together with isolated angle bracket connections. However, the seismic response of the developed isolated connection and the influence of isolation bedding on the seismic response of CLT structures have not yet been studied. In the paper, shear tests on small specimens of CLT panels placed on polyurethane elastomer isolation bedding and fastened to CLT floor with innovative isolated steel angle bracket, developed by the company producing isolation material, are presented. Altogether 5 monotonic and 10 cyclic shear tests were performed. Specimens with four types of bedding material varying in stiffness and compression load range were tested and compared with tests on specimens of panels and floors connected with isolated steel bracket without any bedding. It was shown that the hysteretic response had strong pinching effects, while on the other hand the presence of sound isolation bedding has small influence on the overall shear behavior of the system.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

USE OF BASE ISOLATION SYSTEMS AGAINST INDUCED EARTHQUAKES: CASE OF GRONINGEN

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Keywords: *induced seismicity, base isolation design*

Groningen, the largest gas field on-land, experiences several induced earthquakes, the most damaging one being in 2012 the Huizinge earthquake of magnitude 3.6. The maximum recorded horizontal PGA is 0.11g in the area. Due to soft soil properties, as well as high seismic vulnerability of the local construction, even such small earthquakes can incur damage on houses that are mostly made of unreinforced masonry. Several base isolation projects have been completed in the Groningen area by designing the isolators for the design level earthquake. The more frequent and smaller earthquakes, however, which have been the main source of public concern in the area, are not taken into consideration. This paper, by making use of a representative case study, investigates whether base isolation is an effective answer to this kind of question where small repetitive earthquakes are major part of the problem. The present study also evaluates what type of isolation system would provide the optimum solution for the case of Groningen induced earthquakes or in similar cases. Performance of different isolator types are compared. Smaller and frequent earthquakes as well as design-level earthquake motions have been considered in the nonlinear response history analysis.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

LEAD RUBBER BEARINGS: A PROMINENT APPLICATION OF EN 15129:2009 ANTI-SEISMIC DEVICES STANDARD BEYOND EUROPE

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Keywords: *Base Isolation; Anti-seismic Devices; Lead Rubber Bearing (LRB); EN 15129:2009; CE marking*

The dynamic response of seismically-isolated buildings and infrastructures is mainly controlled by the anti-seismic devices provided in structures. For this reason, these special devices must be accurately engineered and manufactured to be compliant to the design characteristics provided by the designer. In this context, the European Standard EN 15129:2009 is one of the most advanced worldwide code which specifies functional requirements, general design rules of the devices for seismic design situations, material characteristics, manufacturing and testing requirements, as well as assessment and verification of constancy of performance, installation and maintenance requirements. Moreover, the EN15129:2009 is integrated with other harmonized standards for CE marking to ensure anti-seismic devices conformity and access to the entire European market. For this reason, this standard is increasingly adopted even in non-European countries, with the aim of imposing and ensuring high levels of quality and performance of the devices. This paper illustrates the application of European Standard to an extraordinary project outside Europe: the Jakarta-Cikampek elevated toll.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

DEVELOPMENT OF SEISMOISOLATION IN RUSSIA

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Keywords: *seismoisolation, Russia, development, damping, optimization, seismic input*

Five sources of seismoisolation development are considered. They are seismic isolation enthusiasts, Central Research Institute of Building Structures in Moscow, Saint-Petersburg scientific school headed by Professor O.A.Savinov, experts of the Defense Ministry and private firms that have arisen on the ruins of scientific institutions of the socialist construction industry. It is stressed that there is only one firm in Russia, CKTI-Vibroseism, which is able to carry out the whole work complex of using seismoisolation in different projects. Main results obtained by the experts of the above-mentioned scientific schools are considered. The most important result is damping optimization for different types of isolating foundations. Another important result is working out seismic input models with the dependence of peak ground acceleration on the predominant input period. Some examples of seismoisolation for different structures are also considered.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

SEMI-ACTIVE CONTROL USING MR DAMPERS FOR RANDOM GROUND MOTION

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Keywords: *MR Damper, LQG, Kalman Filter, Semi-active Control, Sliding mode control, Clipped optimal control*

A simulation based semi-active control strategy of building frames subjected to random ground motions is presented. The control strategy has the following attributes namely, i) it is suitable for online implementation, ii) it meets the ideal condition for the use of Kalman filter for state estimation by converting the input excitation to Gaussian white noise, and iii) it can accommodate site specific random ground motion defined by a PSDF. In order to meet the requirement of site specific input ground motion and to meet the ideal condition for the use of Kalman filter, the state vector of the state is augmented by Clough and Penzien double filter variables and Gaussian white noise is provided as the input to the system (called VB-2). The structure is also anlayzed for the simulated ground motion from the PSDF directly applied to the structure (called VB-1). For both cases, only partial observation of the state is used. Three control algorithms are used namely, i) LQG with clipped optimal algorithm (LQGCL), ii) Sliding mode control with clipped optimal control (SMCL) and iii) Passive-on control. The results of the study show that i) there is a significant difference in results between the systems VB-1 and VB-2, ii) LQGCL provides comparatively better control and iii) development of control strategy for site-specific ground motion requires careful consideration of online implementation.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

RETROFIT OF EXISTING BUILDINGS WITH SEISMIC ISOLATION: DESIGN ISSUES AND APPLICATIONS

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Keywords: *seismic isolation, seismic retrofitting, isolation devices, existing buildings*

The real challenge of seismic isolation is the protection of existing structures, especially in countries such Italy where maintenance of old structures is an important issue. It is worth reminding that base isolation yields a very high level of safety and that the period of vibration can be chosen so as to allow input of low spectral amplitude, while the superstructure remains in the elastic range. This possibility also allows for limiting or even avoiding the conventional retrofit intervention in the superstructure. While the positioning of the isolation devices in plan in existing buildings follows the same rules already discussed for new buildings, the positioning in elevation is influenced by the existing foundation layout and the presence of architectural and structural constraints, such as stairs and elevators, and their geometry. Furthermore, a fundamental issue is the temporary transfer of loads during the various operations until the final loading of the isolators, usually pursued by means of flat jacks injected with epoxy resin. In the following, some applications are shown. In this paper the basics for the application of seismic isolation in reinforced concrete and masonry existing buildings are discussed and some interesting recent applications in Italy are shown.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

SEISMIC DESIGN OF A WIDENED AND RECONSTRUCTED T-BEAM GIRDER BRIDGE

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Keywords: *double deck bridge; widening and reconstruction; seismic isolation design.*

The approach bridge of the Songpu Bridge was a continuous double-deck bridge, due to the continuously increased traffic pressure, the upper deck needs to be widened from the original two lanes to six lanes, and the lower deck is changed to non-motor vehicle lanes and sidewalks. The approach bridge is widened by splicing new T beams on both sides of the old bridges. The newly built superstructure and substructure both connect the corresponding parts of the old bridge. However, the load capacity of the old and new piers is different because the reinforcement ratio of the old pier is less than that of the new piers, and the old bridge was designed 40 years ago, hence the seismic performance needs to be checked by doing this. This paper presents the seismic design of the widened and reconstructed approach bridge, and analyzes the old-new structure connecting methods that affect the seismic behavior of the whole bridge. The result shows that seismic isolation could be the best option for widened and reconstructed bridge.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

ON THE MAXIMUM GROUND MOTION DIRECTION AND RESPONSE OF SEISMICALLY ISOLATED STRUCTURES

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Keywords: *maximum direction, seismic isolation, bidirectional analysis, lead rubber bearing*

This study investigates the dependency of the orientation of ground motions at which the maximum isolator displacement of seismically isolated structures occurs. For this purpose, a set of near-field ground motion records are selected and modified by rotating through 90° with intervals of 10°. The original and rotated forms of ground motions are used to perform nonlinear response history analyses. The seismic isolation system of the analyzed structure is composed of lead rubber bearings (LRBs). To determine the effect of seismic isolation characteristics on the maximum orientation of ground motions, isolation period and characteristic strength-to-weight ratio are the parameters considered in the analyses. Moreover, the significance of employing a deteriorating or a non-deteriorating hysteretic representation for modeling of LRBs on the orientation of maximum ground motion direction is addressed. Results revealed that maximum ground motion direction for a seismically isolated structure changes due to change in seismic isolation characteristics and the hysteretic representation of isolator unit.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SEISMIC PERFORMANCE OF STEEL MOMENT-RESISTING FRAME RETROFITTED WITH LINEAR AND NONLINEAR VISCOUS DAMPERS

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Keywords: *Fluid viscous dampers, linear viscous dampers, nonlinear viscous dampers, collapse capacity, steel structures.*

The implementation of linear and nonlinear fluid viscous dampers allows an improvement of the seismic performance of a structure. Nevertheless, the velocity coefficient which governs the hysteretic behavior of the nonlinear viscous dampers modifies the seismic response and consequently the seismic performance of the structure. One steel moment resisting frame building of six stories was selected from the SAC Steel Project in California. This building, incorporating brittle beam-column connections common in the pre-Northridge earthquake designs, was retrofitted with different configurations of viscous dampers to improve its seismic performance. Linear and non-linear viscous dampers were designed by following two different design approaches:
1. equivalent lateral distribution design approach for which proportional damping is preserved and
2. uniform distribution design approach in which similar dampers are introduced at every level of the structure. An incremental dynamic analysis was carried out with the FEMA P695 far-field ground motion set. The seismic performance was evaluated in terms of collapse capacity, median peak inter-story drifts, and median peak damper forces. The results showed a considerable improvement of the seismic performance with the implementation of fluid viscous dampers. However, the design approach and the velocity coefficient modified the seismic response affecting the demand on the structure.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

BEYOND DESIGN PERFORMANCE OF VISCOELASTIC DAMPER

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Keywords: *Viscoelast ic Damper, Beyond Design Performance, Dynamic Test , Fraction Differential Model*

The actual performance and damage of viscoelastic dampers under maximum considered shaking or greater earthquakes as well as their residual performance under aftershocks was rarely discussed before. In this study, four coefficients of the fraction differential model considering ambient temperature, temperature rising, cyclic soften, and strain hardening effects were firstly characterized from performance test with shear strain levels less than 300%. Secondly, VE dampers were tested with larger shear strain levels, until 1000%, to realize their ultimate performances. In between each large shear strain level, the performance test under 300% shear strain was performed to further understand their residual performance after damage. The fraction differential model was also adopted for characterizing their post-damage behavior. The result shows that the stiffness and damping coefficient of VE dampers decrease proportionally with varying shear strain levels from 600% to 840%, and can still remain half of the original values after 840%. Thirdly, VE dampers were tested subjected to seismic response histories which can be numerically analyzed in an off-line manner. Either before or after damage, the predictions by the fraction differential model have a very good agreement with the test results.

4.RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

A NEW VERTICAL BASE ISOLATION SYSTEM

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Keywords: *vertical vibration, base isolation, 3d base isolation, passive control*

A three-dimensional (3-D) base isolation system to control both the horizontal and vertical components of ground motion is presented in this paper. The system is adopting a negative stiffness device (NSD) that can be considered as an adaptive passive protection system, which can apparently change the stiffness of the structure. This work is focused on studying through numerical simulations the mitigation performance of the NSD against strong earthquakes in the vertical direction. The base isolation arrangement consists of elastomeric bearings acting both in the horizontal and vertical direction and NSDs acting only in the vertical direction. So, a 3-D base isolation is achieved, where it is assumed that the NSDs affect the vertical stiffness of the system only. Numerical analyses show that the presence of NSDs reduces the vertical acceleration in the structure. Nevertheless, accordingly with the passive control theory, the relative displacements increase. Therefore, it seems advisable a supplemental damping to mitigate this effect. Thanks to the presence of rubber isolators, it is possible to employ their inherent damping without introducing specific dampers in the vertical direction.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

IMPROVED SEISMIC BASE ISOLATION COMBINED WITH FLUID INERTER AND TUNED MASS DAMPER

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Keywords: *fluid inerter; seismic base isolation; tuned mass damper; earthquake protection; optimal design.*

Introduced by Smith in 2002 [1], the inerter is gaining popularity in the field of vibration control. The inerter is a two-terminal device whose resisting force is proportional to the relative acceleration of its terminals. As such, the inerter contributes to the inertial properties of the system to which it is connected, acting as an additional, apparent mass, which can be much higher than the actual physical mass of the device due to a peculiar mass-amplification effect. This peculiarity can be usefully employed to improve the performance of tuned mass damper (TMD) systems in earthquake engineering applications, by increasing the relevant mass ratio. Recently, a hydraulic realization of the inerter, called fluid inerter, was developed [2], which exploits the inertia of a fluid passing through a helical tube surrounding a cylinder equipped with piston. The fluid inerter has an inherent damping due to the pressure drops occurring in the helical channels induced by the fluid viscosity [3], which is convenient for structural control purposes. Aim of this contribution is to present an improved seismic base isolation combined with a fluid inerter and TMD that exploits the aforementioned advantageous properties of the device for an optimized structural control purpose.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

EXPERIMENTAL THERMO-MECHANICAL BEHAVIOR OF DOUBLE CURVED SURFACE SLIDERS UNDER BIDIRECTIONAL EXCITATION

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Keywords: *curved surface sliders; friction pendulum isolators; heating phenomena; seismic isolation; bidirectional motion; temperature measurements.*

Curved surface sliders (CSS) are seismic isolators widely used for seismic protection of buildings and bridges. The friction coefficient of these isolators is far from being constant during an earthquake event. In reality, it is a complex function of axial load, sliding velocity and heating phenomena at the sliding interface. Among these effects, the most important source of variation of the friction coefficient is the temperature rise arising at the sliding surfaces, which causes significant degradation of the mechanical performance. Experimental investigations focusing on the mutual interaction between mechanical and thermal behavior are very few [1,2], and generally limited to single CSS under monodirectional motion, whereas bidirectional interaction may affect the thermo-mechanical behavior [3–5]. Aim of this contribution is to complement the previous experimental studies by considering a more general testing scenario. In this work, a double (not single) CSS is tested under bi-directional (not monodirectional) excitations at the laboratory CERISI of Messina, Italy. Temperature measurements are obtained through thermocouples embedded into the sliding surface, at a certain depth below the sliding interface. The mechanical and thermal response is monitored experimentally, and different considerations on bidirectional interaction and double sliding surface are made when critically analyzing the experimental results.

CERTIFICATION SYSTEM OF SEISMIC ISOLATION DEVICES IN JAPAN

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Keywords: *building code, certification system, seismic isolation devices, lead rubber bearing, viscous damper*

In Japan, the building law has revised to include the seismic isolation technology into the building code in 2000. Notification (Kokuji) 2009 and 1446 stand for seismic design code and certification system of seismic isolation devices, respectively. All seismic isolation devices have to be certified by MILT (Ministry of Land, Infrastructure, Transport and Tourism) before using. In 2015, a factory production control certification system was introduced due to one company's falsifying routine test data problem. Since there is no independent testing laboratory in Japan, all the type or routine test data is usually conducted by the manufacturer themselves. In 2017, changes of characteristics of seismic isolation devices have to be considered in the design due to the long-period and long-duration ground motions. In Table 1, the comparison of certification system between Japan and EN15129 is shown. The designated authorities known as notified inspection bodies are opened to private companies now which have been limited to public institutions before. The devices have been roughly classified into three kinds: bearings, dampers and restoring spring. The Japan Society of Seismic Isolation has published a 750 pages catalog in 2009 to include all manufacturers for reference. In this paper, certification details of lead rubber bearings and a kind of viscous fluid damper are introduced. The contents of LRB include following categories: Dimensions, Ultimate critical properties, Vertical properties, Horizontal properties, Dependency properties and Creep. The contents of fluid damper include Materials, Dimensions, Ultimate critical properties and Damping properties.

1. EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

PRELIMINARY NONLINEAR ANALYSES OF POST-TENSIONED TIMBER FRAMED BUILDING WITH DISSIPATIVE BRACING SYSTEMS

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Keywords: *Post-tensioned timber framed buildings; Dissipative bracing systems; Shaking table tests; Non-linear dynamic analyses.*

Self-centering rocking mechanisms combined with dissipative bracing systems is a passive control technology that can prevent structural and non-structural damages and minimize residual drifts during strong earthquakes. A shaking table campaign has been performed on a 2/3 scaled, 3-dimensional, 3-storey post-tensioned timber framed (Pres-Lam) building with dissipative bracing systems at the structural laboratory of the University of Basilicata. The test structure has been subjected to ground motions scaled to various intensities. In this study a numerical provisional model of the Pres-Lam braced structure has been developed based on lumped plasticity approach. This paper focuses on preliminary results of nonlinear dynamic analyses of a selected ground motion at 25% and 100% of PGA levels that correspond to a Service Level Earthquake (SLE) and a Design Base Earthquake (DBE). Numerical outcomes have been compared with shaking table test results, providing a suitable representation of the global and local seismic response.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

OPTIMUM PROPERTIES OF SEISMIC ISOLATION SYSTEMS IN HIGHWAY BRIDGES TO MINIMIZE ISOLATOR DISPLACEMENTS OR SUBSTRUCTURE FORCES

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Keywords: *Seismic isolation, optimization, displacement, force, bridge*

In this study, closed form equations as functions of the isolator, bridge and ground motion properties are formulated to calculate the optimum characteristic strength, Qd and post-elastic stiffness, kd, of the isolator to minimize the maximum isolator displacement (MID) and force (MIF) for seismic isolated bridges (SIBs). For this purpose, first, sensitivity analyses are conducted to identify the bridge, isolator and ground motion parameters that affect the optimum values of Qd and kd. Next, for the identified parameters, nonlinear time history analyses of typical SIBs are conducted to determine the optimum values of Qd and kd for a wide range of values of the parameters. Next, nonlinear regression analyses of the available data are conducted to obtain closed form equations for the optimum values of Qd and kd to minimize the MID and MIF. The equations are then simplified for various site soil conditions. It is observed that the optimum Qd and kd are highly dependent on the site soil condition. However, the effect of the bridge substructure stiffness on the optimum Qd and kd and the effect of the structural or supplemental damping on the optimum kd are found to be negligible. Furthermore, the optimum Qd is found to be a linear function of the peak ground acceleration.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

PERFORMANCE BASED DESIGN OF SEISMIC ISOLATED BRIDGES IN COLD CLIMATES USING MULTI DIRECTIONAL TORSIONAL HYSTERETIC DAMPER AND LUBRICATED FLAT SLIDING SPHERICAL BEARINGS

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Keywords: *seismic isolation, bridge, cold climate, design*

The seismic and in-service performance of seismic isolation bearings is significantly affected by cold climates. The stiffness of rubber isolators and dry surface friction coefficient of curved surface sliding isolators increases considerably at extreme cold temperatures. An alternative design approach is presented in this paper where a special type of hysteretic damper with re-centering capability in combination with spherical sliding bearings with lubricated sliding surface are used together to minimize cold temperature effects. In this specific design arrangement, the dampers are attached to the deck using elongated holes (gaps), which are sized to accommodate the thermal displacements and hence to keep the dampers from being activated during thermal displacements. The gaps are sized based on the expected maximum thermal displacement in each pier. The gap length will thus be different for different piers. With this arrangement, the number of dampers engaged during an earthquake depends on the magnitude of the displacements. The distinct feature in this design is: (i) preventing the engagement of dampers under thermal displacements during service life without using shock transmitters and (ii) sequential engagement of dampers as a function of the magnitude of the seismically induced displacements. This paper presents a sample application of this methodology in the design of a major viaduct. The performance goals of the bridge require no damage at 475-year return period earthquake and repairable damage at 2475-year return period earthquake. The cold temperature test results of the isolation system, the design features of this seismically isolated bridge and the results of nonlinear time-history analyses are presented in this paper.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SIMPLIFIED MODEL FOR THE SEISMIC ANALYSIS OF A SOIL- LONG PILE GROUP-STRUCTURE SYSTEM

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A simplified semi-analytical approach based on Thin Layered Method (TLM) and Chebyshev nested lumped-parameter model (LPM) is presented for the seismic analysis of a soil-long pile group-structure system subjected to earthquake waves. The force-displacement relationship between the unbounded soil and the long pile group is described by dynamic impedances which are obtained by the TLM. A nested lumped-parameter model based on the complex Chebyshev model is proposed to incorporate the frequency-dependent impedances with conventional governing equations for time history analysis of superstructure. The time history analysis of a 15-story superstructure supported by a 3 ´3 long pile group under seismic excitation is presented to show the stability and advantages of the present model.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SPECTRAL CHARACTERISTICS OF GROUND MOTION AND ANALYSIS OF DYNAMIC ROBUSTNESS OF BASE-ISOLATED STRUCTURES

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Keywords: *base-isolated structure; spectral characteristics; progressive collapse; horizontal increment collapse; dynamic robustness*

Spectral characteristics, one of the three parameters measuring effect of ground motions, has great significance on structural damage and progressive collapse. At present, the description of spectral characteristics is not unique. The study on the effect of spectral characteristics on structural response, damage and progressive collapse is not sufficient.

According to the mechanical behavior of base-isolated structures subjected to seismic action, the calculation formula and evaluation index of dynamic robustness of base-isolated structure were proposed in order to analyze the structural dynamic robustness under earthquake. A base-isolated structure was analyzed using Perform-3D. The effect of spectral characteristics and peak acceleration of ground motion on dynamic robustness of base-isolated structures was investigated. The results demonstrate that the evaluation index of dynamic robustness could be used to quantitatively analyze the ability of base-isolated structures to resist lateral collapse under earthquake action. A random robustness index was proposed based on the reliability theory considering double randomness of both structure and seismic signals. When the spectral characteristics is close to the natural frequency of the structure, the dynamic robustness of the structure is smaller. While if one considers either randomness of structures or randomness of seismic signals only, the progressive collapse resistant ability of the isolated structure may be overestimated.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

EFFECTIVENESS OF NON-LINEAR TUNED MASS ABSORBERS AND TUNED LIQUID ABSORBERS FOR CONTROL OF BUILDINGS UNDER EARTHQUAKES

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Keywords: *Buildings, Earthquake, Vibration Control*

This study investigates the effectiveness of non-linear tuned mass absorbers (n-TMA) and tuned liquid absorbers (TLA) for control of buildings under earthquake ground motions. A tall building is modelled with rotational degrees of freedom reduced by static condensation. The n-TMA and TLA are included in the model to investigate their effectiveness in mitigating seismic vibration. The coupled equations of motion are formulated and solved using numerical methods. The performance of the n-TMA and TLA in response mitigation of the uncontrolled building (NC) are evaluated while subjected to several near-fault earthquake ground motions. The design parameters affecting the efficiency of the n-TMA and TLA controller schemes and are varied to find the optimum configuration. It is noticed that n-TMA and TLA are efficient for seismic response mitigation tall buildings. As compared to the TLA, the n-TMA shows more robust performance for controlling earthquake responses of tall buildings.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

THE NEW GENERATION EARTHQUAKE ISOLATION – A BREAKTHROUGH IN PERFORMANCE

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Keywords: *Vibration-isolation, Impact-isolation, Granular viscoelastic materials, Energy dissipation, Effect of pressure*

In this paper, we demonstrate performance of the new generation vibration isolation based on the patented Dissipative bulk and granular systems technology. This technology uses polymeric materials in granular form to enhance their dynamic properties by exposing them to «self-pressurization», which shifts material energy absorptions maximum towards lower frequencies, to match the excitation frequency and/or rate of dynamic loading to which a mechanical system is exposed. In the case of TPU materials the stiffness and energy absorption capability of an isolation may be increased between 10 to 100 times.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

STATE OF THE ART ON APPLICATION, R&D AND DESIGN RULES FOR SEISMIC ISOLATION AND ENERGY DISSIPATION IN TURKEY

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Keywords: *Turkey, Seismic Isolation, Hospital, Design Code*

This paper provides a brief survey of the structures in Turkey with passive structural control. The utilization of the technique of seismic isolation for new structures and retrofit of existing structures is developing at a high rate in the country. As of 2018 there exist about 120 structures with seismic isolation. The list includes buildings, airport terminals, LNG storage tanks, highway and railway viaducts, stadium, hospitals and schools. Most of the recent activity seems to have focused on viaducts and hospital buildings as the Ministry of Health made it mandatory to use seismic isolation for public hospitals in the high earthquake hazard zones of Turkey. As of 2018, 23 health projects are complete or under construction with total investment of more than USD 23 billion. The Basibuyuk Training and Research Hospital in Istanbul, retrofitted with seismic isolation, encompasses 750 beds in 113.000 square meter floor area and is the largest hospital in the world retrofitted with a seismic isolation system consisting of 688 lead rubber and 154 sliding bearings. The newly built Adana Integrated Health Campus (City Hospital) has 430,000 square meter floor area and houses 1500 beds. With an isolation system composed of 1552 triple curved surface friction sliders, the hospital is currently the largest base isolated hospital in the world. A new seismic isolation design code for buildings is prepared along the lines of relevant ASCE and EC codes. Essential features of this new seismic isolation code are provided with a comparison with European, Japanese and US Codes.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

COMPARISON BETWEEN RADIAL AND BIDIRECTIONAL RESPONSES OF A BASE ISOLATED BUILDING EQUIPPED WITH CONCAVE SURFACE SLIDER DEVICES

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Keywords: *Concave Surface Slider devices, bidirectional motion, Non-Linear Time History Analyses, Friction coefficient.*

Concave Surface Slider devices have been more and more investigated in last years, and several issues have been pointed out by several experimental campaigns. Frictional properties at sliding interfaces can be considered as functions of some important response parameters, such as sliding velocity, contact pressure, temperature rise and dissipated energy. Such dependencies can be defined, through the execution of unidirectional tests, according to the most common standard codes for anti-seismic devices; even though a general seismic event is represented by two individual displacement time series along orthogonal directions, resulting into a non-radial path, in most cases bidirectional tests can be substituted by a radial motion along an orthogonal directions with respect to previous unidirectional tests. This assumption may lead to some discrepancies in the response of a structural system, when a non-radial earthquake is applied. In this work the outcomes of a wide experimental campaign have been analyzed for the characterization of the frictional properties of a Double Concave Surface Slider device, subjected to both unidirectional and bidirectional motions. Such response characterizations have been implemented for Non-Linear Time History Analyses of a case study building structure, in order to evaluate differences between radial rather than general earthquake simulations.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

SEISMIC RESPONSE EVALUATION OF ASYMMETRIC RC BUILDINGS ISOLATED WITH LRB AND TFP SYSTEMS

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Keywords: *Isolated building, Triple pendulum bearing, Elastomeric, Eccentricity*

We present the evaluation of the torsional effect in isolated buildings of reinforced concrete from eccentricities of stiffness in the superstructure. In recent years new isolation devices have been developed, one of the most current and that has presented a good performance is the Triple pendulum bearing (TPB). However, it is necessary to verify its good behavior against eccentricity effects. So a comparative analysis with the Lead Rubber Bearing (LRB) is proposed. The buildings in study are of 5 stories, which have characteristic parameters of uni-directional normalized eccentricity, fundamental period and degree of torsional coupling. For the isolation system, parameters related to the period and damping of the system are considered, and the torsional coupling of the system is considered to be 1. The structures were requested using 11 registers of real bi-directional seismic accelerations and analyzed by a non-linear time history. The influence of the parameters was analyzed from the global responses such as maximum displacements, shear forces and torques. In general, greater control of the eccentricities of the TFP isolator was observed.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

PUSHOVER ANALYSES OF STEEL SELF-CENTERING BUCKLING-RESTRAINED BRACED FRAMES

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Keywords: *Buckling-restrained braces; Drift response; Pushover analysis; Seismic analysis; Self-centering braces*

Buckling-restrained braced frames (BRBFs) are used as the lateral load-resisting systems in the seismically active regions. The symmetrical hysteresis, high ductility, and good energy dissipation made this system more preferred to the conventional concentrically braced systems. However, BRBs exhibit the excessive residual drift response in major seismic loading. Self-centering buckling-restrained braced frames (SC-BRBFs) should exhibit the desired energy dissipation capacity, the absence of compressive buckling behavior of braces, the high displacement ductility, and the reduced residual drift response. This study is focused on the evaluation of nonlinear behavior of three building frames with self-centering BRBs, in which shape memory alloy (SMA) rods are used along with BRB. A design procedure has been presented to proportion the SMA rods and BRB core plates in a building frame. Three low-to-high rise study frames, namely, three-story, nine-story, and twenty story are considered for the performance evaluation. These study frames are modelled and analysed in a computer software OpenSees. Nonlinear static (pushover) analysis has been conducted on the study frames to investigate the lateral strength, displacement ductility, and hinge mechanisms. The analysis results of SC-BRBFs are compared to those of the conventional BRBFs.

STANDARDS FOR DESIGN, CONSTRUCTION, MAINTENANCE

SEISMIC RESPONSE PREDICTION AND GROUND MOTION SELECTION BY USING INTENSITY MEASURES FOR BASE ISOLATED BUILDINGS

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Keywords: *Intensity measures, seismic response prediction, base-isolated buildings, near-fault, ground motion selection*

Base isolation has become a widely applied technique for protecting buildings located in highly seismic risk areas. The seismic response of base-isolated buildings is usually evaluated through non-linear dynamic analysis. A suitable set of ground motions is needed for representing the earthquake loads and for exciting the structural model for nonlinear time history analysis. The earthquake record selection method may lead to distinct results from each other based on the intensity measures used for scaling the records to the defined earthquake intensity level. Evaluation of the most commonly used intensity measures with respect to their capability to predict the seismic response of base-isolated buildings is presented in this paper. Two residential building with different height is selected for the investigation of intensity measure efficiencies. Structures are five and eight story r/c frame. Two sets of accelerograms, consisting of ordinary and near-fault records, are used in the analyses and in the evaluation of the intensity measures.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

THE DEVELOPMENT OF A SEISMIC ISOLATON DEVICE FOR HIGH VOLTAGE PORCELAIN ISOLATORS

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Keywords: *Earthquake safety, seismic isolation, low-cost isolation, post-insulator, polyurethane spring*

High voltage porcelain insulators are vulnerable components of the electrical substations during strong earthquakes. It is rather hard to repair them in service. Dependently, it will be useful to reduce the internal forces on the insulators to increase their seismic safety. A new low-cost seismic isolation device that is mounted underneath of HV post-insulator is being proposed here to provide period elongation and supplementary damping. Seismic isolation device consists of four polyurethane springs that are positioned between two circular stainless-steel plates. The plates are connected each other by pre-stressed steel rod positioned at their center. Experimental and numerical studies were conducted on rigid and seismically isolated 550 kV porcelain post insulator. A set of historical earthquakes selected according to IEEE-693 were utilized in the dynamic tests. The results of the experiments were used to verify the numerical models for further complementary assessments. The developed seismic isolation device meets the requirements given by IEEE-693 for the seismic base isolators and it reduces the internal forces of high voltage porcelain post insulator severely compared with the rigid type connection.

OBSERVATION AND MONITORING OF BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

DETERMINATION OF DYNAMIC PROPERTIES OF BOWSTRING R/C BRIDGES BY USING AMBIENT VIBRATION MEASUREMENTS

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Keywords: *Structural health monitoring, ambient vibration test, existing concrete bridge*

Ambient vibration measurement technique is non-destructive and easily applicable method in order to determine the dynamic characteristics of the structures. The aim of the research is to determine the dynamic properties of the existing bridges. Two different bowstring type historical concrete bridge is investigated. The First bridge which is namely Kavuncu Bridge is constructed as a single span bridge with 30m span length and 7.0 m width in 1945, and the second one is which is namely Ali Çetinkaya Bridge is constructed as seven span bridge with 35 m span length and 6.2 m width in 1937. The dynamic response parameters such as the natural frequencies, damping ratios and mode shapes are extracted from the ambient vibration records. Finite element models of the bridges are generated. The ambient vibration measurement and numerical model results are compared.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

EXPERIMENTAL INVESTIGATION ON SEISMIC BEHAVIOR OF BRIDGES WITH PILE-GROUP FOUNDATIONS ALLOWING UPLIFT AND ROCKING OF PILE CAP

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Keywords: *Bridges; rocking pile foundations; experimentation; hysteresis; residual deformation;effective damping*

The paper describes an experimental investigation of the fundamental hysteresis properties of bridges with rocking pile-group foundations. Two large-scale mass-column-foundation models with rocking pile-group foundation and conventional foundation, respectively, were designed, constructed and tested under quasi-static cyclic loading. An effective pile model with shorter pile length and an additional end plate was presented, which provides comparable base condition and approximate response estimation of the piles. Special considerations were also taken for the details in pile heads to pile cap connection. The testing results show that less damage was incurred to the piles of the rocking foundation. Compared with the reference model with conventional foundation, residual drift ratio was decreased by up to 88 % and nearly 60 % initial stiffness was retained for the post-earthquake functionality following a maximum drift cycle of 6 %. It is pointed out that the traditional definition of stiffness degradation using the scant stiffness corresponding to the peak force and displacement for each loading cycle is no longer suitable in evaluating the residual stiffness of resilient structures. A new definition directly related to the critical functional load was proposed instead in this study.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

A SEISMIC ISOLATION SYSTEM WITH HIGH SAFETY MARGIN IN EARTHQUAKES EXCEEDING DESIGN LEVEL

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Keywords: *seismic isolation, rubber bearing, slider bearing, extreme earthquake, seismic safety*

The authors have been proposing a new bearing called QTB (Quake-Thru Bearing) which consists of a conventional LRB (Lead Rubber Bearing) and a newly developed slider bearing in series. Friction coefficient of the slider bearing part is optimally provided to start sliding just before LRB gives a hardening property with the shear strain of around 250%. The bearing behaves as a conventional LRB which is just friction connected to building structure at either of upper or lower end, when subjected to design level earthquakes or smaller, while the sliding behavior keeps LRB away from hardening and shear break in earthquakes beyond expectations. Hence, supporting a superstructure only by the proposed bearings will enable the whole SI building to protect from any structural damage regardless of the input ground motion level. In this paper, concept of the bearing and a seismic isolation system applying the proposed bearings, research and development process of the proposed bearing, and the design overview of the first building to apply the proposed bearings, are briefly mentioned, respectively.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

SEISMIC ISOLATION PROTECTION SYSTEM FOR THE 1081-BED ESKIŞEHIR CITY HOSPITAL IN TURKEY

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Keywords: *Isolation, Curved Surface Sliders, contiunued functionality*

The Eskişehir City Hospital with a mass of 530,000 t is located 250 km south east of Istanbul in a highly seismic zone with up to 0,6g PGA. To prevent fatalities and enable continued functionality after the maximum considerable earthquake (MCE), it was decided to apply seismic isolation with 980 pcs. pendulum isolators. The structural design requires to limit the base shear on isolator top level for the MCE event down to less than 13% of dead load. On the upper building floor levels max. 0,2W shear was specified. For these shear level requirements the isolator performance was adjusted to 3,5 s effective period and 26% damping. With strict quality supervision, third party prototype testing at EUCENTRE in Pavia and with third party production testing at University Munich, the reliability and durability of the isolators to resist up to five or more MCE events without damages was proven. The design approach for this project is unique in a way that absolute no damages to the structure, to the content and the seismic isolators have been acceptable for the MCE event. The hospital must be ready for service immediately after the earthquake to be granted with suitable seismic isolators.

4. RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

TENSILE AND LOW-CYCLE FATIGUE PROPERTIES OF FE-15MN-4SI-10CR-8NI ALLOY FOR FATIGUE-RESISTANT SEISMIC DAMPERS

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Keywords: *Fe-Mn-Si-based alloy, Tensile strength, low-cycle fatigue property*

Steel seismic dampers have a large load capacity, high stiffness, and outstanding cost-performance ratio. These dampers are indispensable for economical vibration control structures. As a new problem, high-rise buildings are likely to resonate with the long-period ground motion and large-amplitude cyclic deformation is induced in the seismic dampers. In earthquake-prone countries, conventional steel dampers are difficult to overcome this problem as their fatigue-resistance properties are insufficient. To provide a new steel seismic damper with superior fatigue resistance against large-amplitude cyclic deformations, a Fe-15Mn-4Si-10Cr-8Ni alloy with enhanced low-cycle fatigue resistance was developed. This study aims to confirm the tensile and low-cycle fatigue properties of this alloy under relevant temperature and frequency conditions for use in seismic dampers. The results of tensile strength tests indicated that this alloy has a small yield-tensile ratio, a large elongation, and undergoes stable deformation. From the results of the symmetric tensile-compressive low-cycle fatigue tests of this alloy, this alloy has an outstanding fatigue life in comparison with steels that is used for the conventional steel dampers under broad conditions. Based on these results, we confirm that the tensile and low-cycle fatigue properties of this Fe-15Mn-4Si-10Cr-8Ni alloy make it suitable for use in seismic dampers.

4. RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

MECHANICAL BEHAVIOR OF SLIDING BEARINGS FOR SEISMIC ISOLATION UNDER CYCLIC LOADING

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Keywords: *Temperature dependency, Friction coefficient, Sliding bearings, Seismic isolation, Loading test, Hybrid analysis*

This research focuses on the thermal-mechanical coupled behavior of sliding bearings under a large number of cyclic loadings. First, we conducted loading tests of sliding bearings. Two scaled test specimens were used for the tests, and two displacement patterns, one unidirectional and one circular, were applied for each specimen. To get a high temperature in the sliding surface, imposed axial stress was set to 1.5 times as high as the standard design pressure, and the loading frequency was set to 0.33 Hz. Second, we proposed a numerical model for sliding bearings after identifying the friction coefficient from the test results. The model is a combination of a mechanical model and a thermal conductivity analysis model. Using the newly developed model, simulation analysis of the loading tests was performed. The analysis result shows a good agreement with the test results, and that validates the accuracy of the numerical model. Finally, earthquake response analyses of seismically isolated structures supported by sliding bearings and elastomeric bearings were conducted. The results indicated that the heat generation in the sliding surface greatly affected the responses of the isolators. By considering the thermal-mechanical coupled behavior, the response deformation increased because the friction coefficient decreased.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

SEISMIC PERFORMANCE OF FLOOR-MOUNTED SECONDARY SYSTEMS HOUSED IN REAL-LIFE BASE-ISOLATED BUILDING ON DOUBLE CURVATURE FRICTION PENDULUM SYSTEM

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Keywords: *Base-isolation, Double Curvature Friction Pendulum System, Secondary System, Seismic, RC Building*

Investigations on seismic performance of floor-mounted secondary system (SS) housed in a base-isolated building on double curvature friction pendulum system (DCFPS) are presented in this study. The real-life reinforced concrete (RC) building is considered here for commercial use, requiring uninterrupted business activity even during and after earthquakes. Especially, during and after the earthquakes proper continual functioning of the non-structural lightweight SS is highly essential in this building to avoid social chaos and economic losses. Hence, a study on evaluating the performance of the SS in the RC building isolated using the DCFPS is conducted and compared with a conventional fixed-base building. Non-linear dynamic time history analysis is conducted to determine response of the coupled system of the base-isolated building housing SS. It is observed from the response that the base isolation significantly enhances seismic performance of the SS through reduction in the floor acceleration. The seismic design force for the SS reduces in comparison with that in the fixed-base building counterpart. Parametric studies are conducted with variation in parameters such as, mass and stiffness of the SS apart from their spatial location to investigate seismic performance. It is concluded that acceleration-sensitive SS are well-protected within the base-isolated building.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SEISMIC FRAGILITY ANALYSIS OF EXISTING OLD BRIDGES RETROFITTED BY SEISMIC ISOLATION SYSTEM IN SOUTH KOREA

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Keywords: *old bridges, seismic isolation, bearing damage, fragility analysis, Nonlinear response history analysis, seismic retrofit*

The last two earthquakes that occurred Gyeongju and Pohang city areas have left the necessity for the seismic design and rehabilitation not only buildings but infrastructures. In order to retrofit the aseismic capacity of existing old bridges, the most commonly used retrofit method was a seismic isolation system such as lead-rubber bearing (LRB). Damages in the bridges by the last two earthquakes usually occurred in the bearings, anchor, and concrete mortar on pier. The purpose of this study is to develop seismic fragility function according to degree of aging and degree of seismic retrofit for old bridges. Existing old bridges are 3D modeled and analyzed with OpenSEES program provided by Pacific Earthquake Engineering Research Center (PEER). The seismic fragility curves were constructed from the nonlinear response history analysis by applying the nonlinear model characteristics of the structural elements according to the degree of aging and the degree of seismic retrofitting. From the analysis results in this study, it can be observed that the seismic fragility increases with the degree of aging, and the seismic fragility tends to decrease as the degree of seismic retrofit increases.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

HYBRID CONTROL TO ENHANCE WIND AND SEISMIC PERFORMANCE OF TWIN TALL BUILDINGS WITH A SKY BRIDGE

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Keywords: *twin tall buildings, hybrid control, switchable damper, friction pendulum bearing*

The present paper studies the hybrid control of twin tall buildings with a sky bridge subjected to wind and earthquake excitations. The friction pendulum bearings are always employed to release the connecting action for the coupled structure subjected to seismic excitation. However, such design cannot ensure adequate performance subjected to other loading scenarios. When the sliding friction coefficients are small, the bearings under the strong wind load may be set in motion with very slow velocity of sliding once the wind load overcomes the breakaway friction. Such motion may result in accumulation of residual displacements during the passage of strong wind. Moreover, temperature effect will induce the undesirable thermal stress in the sky bridge due to initial sliding restriction. Therefore, a hybrid control scheme combining the friction pendulum system and switchable dampers is proposed as a more holistic approach to ensure adequate performance among different loading scenarios. The switchable dampers provide the velocity-dependent damping force for the temperature effect, small and moderate seismic load, and have the capacity to provide the displacement-dependent damping force for the severe wind and seismic load.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

STUDY OF RC COUPLED SHEAR WALL WITH REPLACEABLE COMPONENTS

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Keywords: *RC coupled shear wall, replaceable coupling beams, replaceable corner components, design method, pushover analysis*

During past earthquakes the coupling beams and the bottom of wall piers in RC coupled shear walls easily suffered severe damage which is repaired hardly or costly. A new type of coupled shear wall with replaceable coupling beams and replaceable corner components at the bottom of wall piers is put forward. During the strong earthquake the damage is expected to mainly concentrate on the replaceable components in the wall. The function of the structural wall can be quickly restored by replacing the replaceable parts after the earthquake. The design method for the new wall is proposed. Two RC coupled shear walls, one new wall and one conventional wall, were designed. The responses and the damage process of two shear walls were analyzed and compared by numerical simulation. The results show that the lateral stiffness and load carrying capacity of the new shear wall are similar to that of the conventional shear wall. For the new wall, the replaceable coupling beams yields first, then the replaceable corner components yields. The damage concentrates on the replaceable components, and slight damage occurs in other parts. Compared with the conventional shear wall, the seismic performance of the new shear wall is improved significantly.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

SIMPLIFIED METHOD OF DESIGNING AN INNOVATIVE SEISMIC ISOLATION SYSTEM FOR HIGHWAY BRIDGES: ANALYTICAL STUDY AND EXPERIMENTAL VALIDATION

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Keywords: *innovative isolation system; highway bridges;simplified design method; design example; shake table testing validation*

Since the sliding of laminated-rubber bearings and the concrete shear key failure were mostly observed for small to medium-span highway bridges in the 1999 Chi-Chi earthquake and the 2008 Wenchuan earthquake, an innovative isolation system composed of laminated-rubber bearings and yielding steel dampers was developed, designed and implemented in these bridges to improve their seismic performance during an intense earthquake. This study investigated the seismic performance of the proposed isolation system analytically and experimentally. By idealizing the bridge system as a simple series-parallel combination of bridge components (e.g. superstructures, bearings, steel dampers, substructures), several new parameters were defined and their correlated parametric formulations were derived accordingly. Based on this, a simple yet efficient step-by-step method of designing this innovative isolation system was presented, followed by the validation through a design example and shake-table testing. The design example showed that the proposed design method was feasible and easy to perform with only a small number of iterations. Shake table tests validated the reliability and effectiveness of this design method for designing the proposed isolation system for highway bridges with satisfactory seismic performance.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

DISCUSSION FOR KEY ISSUES OF ISOLATION TECHNOLOGY APPLIED IN LONG-SPAN COMPLEX BUILDINGS

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Keywords: *torsional control; temperature effects; wind-resistant design; boundary constraints; vertical seismic action*

High seismic precautionary intensity areas are widely distributed in China. Along with the rapid development on urbanization process, the requirements for quality and safety of buildings are constantly increasing. Long-span buildings are generally public-type buildings and characterized by dense crowds, high importance, and complex shapes. Thus these buildings have strict requirements for seismic performance and large demand for reduction of earthquake actions. At present, the development of isolation technology is relatively advanced and its application in long-span buildings can effectively reduce earthquake actions and improve seismic performance of structures, so that long-span buildings can effectively play the function of post-earthquake disaster relief. In this paper, the key issues in the application of isolation technology in long-span complex structures are discussed, including torsional control, temperature effects, wind-resistant design, boundary constraints, vertical seismic action, and the layout of the playing field on isolation layer of stadium structure, which can provide reference for related programs.

1.EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SHAKING TABLE TESTS OF A MINIATURE BUILDING WITH FRICTION TYPE ISOLATORS

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Keywords: *Isolation, Isolators, FIP-D, Building, Mexico, Test*

Shaking table tests were conducted in a previous research at the National University of Mexico (UNAM) on a miniature steel building, EM2, using a strong ground motion record. This building represented a conventional building. In this study, a second test unit, EM2-I, was tested in the same shaking table with the same ground motion used in the previous research. Test unit EM2-I had a superstructure identical to test unit EM2 but was isolated with isolators of the friction pendulum type. Measured maximum interstory drifts were equal to 5.3 % and 0.97 % for test units EM2 and EM2-I, respectively. The maximum seismic coefficient measured in the isolated superstructure was equal 18 % of the maximum value for this parameter measured in test unit EM2. Implications of the results found in this research are discussed in the paper showing the importance of using isolated structures as an efficient solution for resisting strong earthquakes.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

CRESCENT-SHAPED BRACE FOR STRUCTURAL CONTROL OF BUILDINGS

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Keywords: *hysteretic damper, steel damper, passive control, optimal design*

The primary objective of the «performance-based seismic design» is to provide stipulated seismic performances for building structures. However, a certain degree of design freedom is needed for matching a specific seismic response. This design freedom is not obtainable by the conventional lateral resisting systems because their stiffness and strength are coupled. Here, we put emphasis on the role of the unconventional lateral resisting systems in adding more flexibility to the design. In this paper, we seek to explore the seismic design of moment-resisting frame structures equipped with an innovative hysteretic device, known as «crescent-shaped brace." One conspicuous feature of this device is its distinctive geometrical configuration, which is responsible for the enhanced nonlinear force-displacement behavior exhibited by the device. A new performance-based approach for the seismic design of the crescent-shaped brace is proposed. The performance of the device is evaluated, and its application in multistory shear-type structures is investigated. Two case studies were established to illustrate the design methodology. The first is a new two-story RC structure, and the second is an existing three-story RC structure. Nonlinear time history and pushover analyses are performed to evaluate the behavior of the controlled structures. The analyses show that for each of the two case studies, the acceleration–displacement capacity spectrum conforms to the performance objectives curve. This finding confirms the validity of the proposed design approach and the effectiveness of the new hysteretic device in resisting lateral forces.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

COMPARATIVE ASSESSMENT OF THE EFFICIENCY OF SEISMIC İSOLATION FOR SEISMIC RETROFITTING OF HIGHWAY BRIDGES IN REGIONS OF LOW-TO-MODERATE SEISMICITY

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Keywords: *bridge, friction pendulum bearing, seismic isolation, soil-structure interaction, nonlinear analysis, seismic retrofitting, cost*

In this paper, the economical and structural efficiency of friction pendulum bearings (FPB) for retrofitting typical seismically vulnerable bridges in the State of Illinois is studied. For this purpose, a bridge was selected by the Illinois Department of Transportation (IDOT) to represent typical seismically vulnerable bridges commonly used in the State of Illinois. A comprehensive structural model of the bridge was first constructed for seismic analysis. An iterative multi-mode response spectrum (MMRS) analysis of the bridge was then conducted to account for the non-linear behavior of the bridge components and soil-bridge interaction. The calculated seismic demands were compared with the estimated capacities of the bridge components to determine those that need to be retrofitted. It was found that the bearings, wingwalls and pier foundations of the considered typical bridge need to be retrofitted. In this paper, the economical and structural efficiency of friction pendulum bearings (FPB) for retrofitting typical seismically vulnerable bridges in the State of Illinois is studied. For this purpose, a bridge was selected to represent typical seismically vulnerable bridges commonly used. A comprehensive structural model of the bridge was first constructed for seismic analysis. An iterative multi-mode response spectrum (MMRS) analysis of the bridge was then conducted to account for the non-linear behavior of the bridge components and soil-bridge interaction. The calculated seismic demands were compared with the estimated capacities of the bridge components to determine those that need to be retrofitted. It was found that the bearings, wingwalls and pier foundations of the considered typical bridge need to be retrofitted. A conventional retrofitting strategy was developed for the bridge and the cost of retrofit was estimated. Next, the bridge was further studied to develop appropriate techniques for upgrading its seismic capacity using FPB to eliminate the need for seismic retrofitting of its vulnerable substructure components. It was observed that the use of FPB mitigated the seismic forces and eliminated the need for retrofitting of the substructure components of the bridge. An average retrofitting cost using FPB was calculated and found to be less than the cost of conventional retrofitting considered in this study. Thus, FPB may successfully be used for economical seismic retrofitting of typical bridges in the State of Illinois or in regions of low to moderate risk of seismic activity.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

PERFORMANCE OF STEEL FRAMED BUILDINGS EQUIPPED WITH VISCOUS FLUID DAMPERS UNDER NEAR-FAULT GROUND MOTIONS WITH DIRECTIVITY

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Keywords: *steel, frame, bracing, damper, seismic, near-fault*

This study is aimed at comparing the seismic performance of steel chevron braced frames (CBFs) with and without fluid viscous dampers (FVDs) as a function of the characteristics of the near-fault (NF) ground motion and FVD parameters. For this purpose, comparative nonlinear time history (NLTH) analyses of single and multiple story CBFs with and without FVDs are conducted using NF ground motions with various velocity pulse periods scaled to have small, moderate and large intensities. Additionally, NLTH analyses of single and four-story CBFs with FVDs are conducted to study the effect of the damping ratio and velocity exponent of the FVD on the seismic performance of the frames. The analyses results revealed that the seismic performance of the CBFs without FVDs is very poor and sensitive to the velocity pulse period and intensity of the NF ground motion due to brace buckling effects. Installing FVDs into the CBFs significantly improved their seismic performance by maintaining their elastic behavior. Furthermore, FVDs with smaller velocity exponents and larger damping ratio are observed to be more effective in improving the seismic performance of the CBFs subjected to NF earthquakes. However, FVDs with damping ratios larger than 50% do not produce significant additional improvement in the seismic performance of the CBFs.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

TECHNIQUES FOR SEISMIC STRENGTHENING OF HISTORICAL MONUMENTS

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Keywords: *Bed Joint Reinforcement, Historical monuments, post-tensioning, pre-stressing, seismic strengthening, shape memory alloy devices, shock transmitters*

Abstract— Due to the complexity of their geometry, the variable and unpredictable characteristics of original materials used in their creation, heritage structures are peculiar and a multi-disciplinary approach is required in any intervention project for historical monuments with a proper assessment to determine their specific needs, a correct diagnoses to decide on the techniques of intervention. Apart from the traditional techniques like bed joint reinforcement, the intervention to historical buildings may benefit from several other modern methods which may be described as innovative techniques to improve their performance under existing and additional loads like seismic loads. Among them are pre-stressing & post-tensioning, use of shape memory alloy devices and shock transmition units, shoring, drilling, and the use of stainless steel or titanium.There are several examples of seismic strengthening with traditional and innovative techniques around the world, which will be discussed in this paper in detail, including their pros and cons. Keywords— Bed Joint Reinforcement, Historical monuments, post-tensioning, pre-stressing, seismic strengthening, shape memory alloy devices, shock transmitters, tie rods

4.RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

AN ANALYTICAL MODEL FOR LOW-SHEAR MODULUS HIGH-DAMPING RUBBER ISOLATION BEARINGS UNDER LARGE SHEAR DEFORMATION

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Keywords: *seismic isolation, elastomeric isolation bearing, hysteresis model, material nonlinearity, geometrical nonlinearity*

Low-shear modulus high-damping rubber seismic isolation bearings have been developed in Japan. These types of elastomeric isolation bearings offer many advantages. The use of these elastomeric isolation bearings in seismic isolation systems eliminates the need for other types of damping devices because their elastomer possesses damping properties. The simplicity of this system is such that their use is expected to spread widely. Furthermore, their use gives the structure a lower fundamental frequency than that obtained from regular-shear modulus ones. In general, the lower the horizontal stiffness of the isolation device, the smaller the response acceleration in isolated buildings. Low-shear modulus elastomeric isolation bearings can be easily applied to even lightweight structures. Thus, these types of elastomeric isolation bearings have great potential for applying seismic isolation technology to a wide range of building types. In light of these advantages, the study reported here focused on low-shear modulus high-damping rubber isolation bearings. Horizontal loading tests were conducted under large shear deformation and at different axial load levels to identify the mechanical characteristics of low-shear modulus high-damping rubber bearings. The shear moduli of the compounds of those high-damping rubber bearings were 0.3 MPa. The effect of the axial load was clearly apparent in the measured hysteresis properties. For the purpose of predicting coupling behavior under large horizontal deformation and axial load, an analytical model was developed. It was constructed by combining two analytical models previously proposed by the authors. One is a mechanical model that comprises a shear spring at mid-height and a series of axial springs at the top and bottom boundaries. The effect of the axial load was taken into account by introducing a P-delta effect into the mathematical formulation of the mechanical model. This enabled the model to capture the buckling or stiffening behavior because the material and geometrical nonlinearities were included. The other model is a hysteresis model of the shear-force/deformation relationship of the high-damping rubber bearings to be used in the shear spring in the mechanical model. This model is based on empirical model parameters established by analyzing the bearing test results. Empirical formulae were carefully identified from the test results. To confirm the validity of the proposed analytical model, the results of bearing loading tests were analyzed. The results were in good agreement with the experimental test results. The proposed analytical model was shown to be capable of accurately expressing the effect of large

shear deformation and axial load on the hysteresis loops for low-shear modulus high-damping rubber isolation bearings. The proposed analytical model is advantageous because the shear hysteresis model used need not incorporate the effect of the axial load since the effect of the axial load on shear behavior is implicitly captured by the material nonlinearity of the axial springs and the geometrical nonlinearity in the model. This advantage is particularly useful for accurately simulating the seismic behavior of an isolated building in which large overturning forces cause significant variation in the vertical load on the elastomeric isolation bearings.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE,OR RELIABLE AND LOW-COST

SUGGESTION OF DAMPING SYSTEMS FOR CHANDELIERS

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Keywords: *Damping System Chandelier energy dissipation*

Chandeliers hanging from floor slabs or beams swing during earthquakes. When the chandelier swings greatly, there is a possibility that users of the building don't have a peace of mind. In the worst case, the chandelier may fall. The authors suggested two types of damping systems that can reduce response of chandeliers. The first system is effective when the distance between the floor slab and the ceiling is large. The second system is simple version of rigid type. This system can be applied even if ceiling space is narrow, however the effect is small compared to rigid type. The common feature of the systems is that energy dissipation system is put only between the floor slab and ceiling. Since the energy dissipation system is put in the ceiling space, it does not hinder the appearance of the chandelier. The authors investigated the effect of the types of supplemental damping systems with time history response analysis. It was confirmed that maximum response of a chandelier with the energy dissipation system was reduced to less than half compared to that without the measures.

SEISMIC ISOLATION, DEVELOPING AND TESTING OF DEVICES

DEVELOPING AND NATURAL SCALE TESTING OF THE 3D BCS BASE ISOLATION SYSTEM

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Keywords: *sesmic isolation, optimization, testing, probabilistic, dterministic analysis*

This paper presents a new equivalent-input-disturbance (EID) approach for active structural control of a building with a special focus on suppressing the absolute acceleration and the inter-story-drift angle of a building. An EID is a signal on the control input channel that has the same effect on the output of a system as disturbances do. A conventional EID approach only considers the relative displacement and the relative velocity of a building. However, the conventional EID does not consider the absolute acceleration and the inter-story-drift angle despite these are important for active structural control of a building. A conventional EID system consists of an EID estimator, state feedback controller and a state observer. However, these parts are designed by trial-and-error method. Thus, it is difficult to design the control system if a building has high degree-of-freedom (DOF). This paper devises an extended EID (EEID) approach that considers not only the absolute acceleration but also the inter-story-drift angle of a building, and presents a designing method for the EEID control system. In this paper, a 11 DOFs building model that employs a base isolation and three kinds of earthquake accelerogram are used to demonstrate the validity of our method.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

CYCLIC LOADING TESTS OF FATIGUE-RESISTANT FE-MN-SI-BASED ALLOY SEISMIC DAMPER

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Keywords: *Fe-Mn-Si-based alloy, Seismic damper, Long-duration and long-period ground motion, Cyclic loading tests*

Recently, awareness of the importance of damage control measures against the long period, long-duration seismic response of high-rise buildings has increased. Therefore, performance requirements for seismic dampers installed in vibration-controlled buildings have increased dramatically, and durability to cyclic deformation has become essential. Against this background, we developed fatigue-resistant seismic dampers made of a Fe-15Mn-4Si-10Cr-8Ni damping alloy are designed to counteract long-period ground motion. This study aims to verify the deformation performance and fatigue resistance of this seismic damper. To examine the fatigue endurance of the seismic dampers, we performed cyclic loading tests. These results revealed that the developed damper has significantly better fatigue life than conventional steel dampers and offers outstanding deformation performance and durability under low-cycle fatigue. Developed shear panel and brace type seismic dampers made of this alloy were installed on steel structure buildings in Japan. Structural analysis revealed that it is possible to achieve an extra-high-grade vibration control with performance margins that allow the building to with withstand long-period, long-duration ground motion, and repeated after-quakes.

OBSERVATION AND MONITORING OF BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

COMPARATIVE ANALYSIS OF THE EFFECT OF SEISMIC ISOLATION BY MEANS OF STATIONS OF ENGINEERING SEISMOMETRIC SERVICE ON BUILDINGS

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Keywords: *seismic isolation, accelerogram, seismic station*

Studies on the effectiveness evaluation of seismic isolation systems of various types are performed in KazNIISA JSC at the permanently operating special test site. In 1989, stations of engineering seismometric service were installed on three constructed houses with the same supra-foundation part (9-storeyed large-panel houses of the series 15In recent years, rapid urbanization, associated with large waves of urban population growth, has been imposing crucial demands on city transportation infrastructure. Therefore, an increasing number of elevated expressways, typically long-pier bridges, were erected in the city platform to ease urban transportation pressure. However, high traffic volume of such expressway bridges can cause significant vibration. To investigate the influence of the bridge-traffic-induced vibration, this study monitored the acceleration of an isolated bridge located for 24 hours in a row. The acceleration measurements were then analyzed using the fast Fourier transformation method and a system realization method, and the system parameters of both the bridge and building were thus calibrated. Furthermore, the bridge-deck-to-pier displacement and bridge deck acceleration were measured to explore how vehicle transportation affects the structural performance of the bridge deck and pier. The results may be used as a reference for future improving the bridge-traffic-caused vibration problem.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

PARAMETER SENSITIVITY ANALYSIS OF ISOLATED BEARINGS OF CONTINUOUS GIRDER BRIDGE UNDER FAR-FIELD LONG PERIOD GROUND MOTION

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Keywords: *Far-field Long Period Ground Motion; Isolated Bridge; Bearing Parameters; Sensitivity Analysis; Seismic Response*

With the rising in the number of isolated bridge and the adverse effects under the far-field long period ground motion appearing, the seismic response of isolated bridge under the far-field long period ground motion has attracted more and more attention. In this paper, some parameters related to the seismic response characteristics of the isolated bridge, such as bearing shear, bearing deformation, displacement at pier top and pier bottom shear, are taken to control the behavior of the isolated bridge. Parameter sensitivity analysis of different isolation devices of continuous girder bridges under far-field long period ground motion are carried out. Conclusions are as follows: as the increasing of the yield force of bearing, the longitudinal seismic response of bridge increases and tends to be stable, while the transverse seismic response of bridge decreases first and then increases; as the increasing of the initial shear stiffness nda hardening ratio of isolated bearings, the seismic response of bridge increases; as the increasing of the effective horizontal stiffness of bearings, bridge seismic response increases first and then decreases. According to the study of bridges that are similar to the bridges in supported project, the optimal parameters of isolated bearings in bearing design are provided as the initial shear stiffness is 1.37E4 KN/m, yield force is between 100 KN and 300KN, and the hardening ratio is between 0.08 and 0.15.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

TOP-STORY MASS DAMPERS FOR SEISMIC CONTROL OF INELASTIC ASYMMETRIC-PLAN BUILDINGS

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Keywords: *tuned mass damper, asymmetric-plan building, self-mass damper, seismic control, inelastic seismic response*

Self-mass dampers, which use intrinsic parts of structures as tuned mass dampers, are economically advantageous in terms of the materials and space required. This study proposes using the top story of a two-way asymmetric-plan building as a self-mass damper, referred to as a top-story mass damper (TSMD), for suppressing the vibrations of the first triplet of vibration modes of the building. The first triplet of vibration modes are the first translational dominant mode in each of the two horizontal directions and the first rotational dominant mode in the vertical direction. Furthermore, this study employs a pair of elastic TSMDs to alleviate the detuning effects caused by yielding of the main structure. One TSMD of the pair is responsible for suppressing the vibrations of the target building in elastic states. The other TSMD, which is designed based on the properties of collective force–deformation relationships, is responsible for suppressing the vibrations of the target building in inelastic states. The collective force–deformation relationships are the pushover curves of the target building when subject to the collective modal inertia force vectors of the first triplet of vibration modes of the building. Numerical examples are used to examine the seismic effectiveness of TSMDs.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

DEVELOPMENT AND APPLICATION OF A VARIABLE STIFFNESS ISOLATION SYSTEM CONSIDERING GROUND MOTION CHARACTERISTIC

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Keywords: *Potential energy, Semi-active control, near-fault earthquake, Minimum Energy Weighting, velocity energy*

In recent years, the research of isolation and mitigation system has become more and more important. In the traditional isolation and mitigation system, the control effect may be reduced because of unknown earthquake types. To have the best effect of response reduction, the systems have to be adaptive with the earthquake type. To achieve that, an upgraded algorithm, Feed-forward Predictive Earthquake Energy Analysis (FPEEA), is proposed by considering the energy of earthquake velocity to have the optimal response. The new algorithm quickly evaluates the velocity energy to have the optimal weighting of minimum energy weighting (MEW). With the optimal weighting of the potential energy and the kinetic energy, the PFEEA can reduce the structural responses efficiently. In order to demonstrate the performance of the proposed algorithm, a single-degree-of-freedom structure is used as a benchmark in both numerical simulation and experimental verification. With predicting the optimal weighting in advance, the type of earthquake can be defined before the main shock of earthquake comes. The results have shown that the dynamic response of the structure can be effectively alleviated. Comparing to the structural responses of the MEW method, the performance of the proposed algorithm is similar to MEW or even better. The shaking table test also demonstrates the feasibility of applying the proposed algorithm in practical application.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

AN INERTIAL-TYPE VERTICAL ISOLATION SYSTEM WITH A SMART FRICTION DAMPER FOR SEISMIC PROTECTION OF EQUIPMENT

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Keywords: *vertical isolation, inertia type, equipment protection, leverage mechanism, near-fault earthquake.*

Vertical seismic excitation may have a detrimental effect on nonstructural component, such as equipment, within a building structure. Seismic isolation may be an effective solution for the protection of equipment. Nevertheless, most existing isolation systems are for mitigating horizontal excitations only. Development of a vertical isolation system (VIS) is difficult, due to a conflict between the demands of static and dynamic isolation stiffness. In other words, a VIS must have sufficient rigidity to sustain the static weight of the isolated object, while it must also have sufficient flexibility to mitigate the dynamic responses under an earthquake. To overcome this difficulty, a novel semi-active VIS that consists of an inertia-type vertical isolation system (IVIS) and an imbedded piezoelectric friction damper (PFD) is proposed in this study. The primary difference between the IVIS and a traditional VIS is that the former has an additional leverage mechanism and a counterweight. Through the leverage mechanism, the counterweight will provide a static uplifting force and an extra dynamic inertia force, such that the effective vertical stiffness of the IVIS becomes higher in its static state and lower in the dynamic state. On the other hand, the PFD will provide a controllable friction damping force for the IVIS, in order to further reduce the vertical isolator displacement without affecting isolation efficiency. In order to verify its feasibility, a prototype of the proposed system was fabricated and tested on a shaking table in this study. It is shown the experimental results agree well with the theoretical ones. To further verify the isolation efficiency, the seismic responses of the proposed system subjected to 14 different vertical ground motions, including the ones with long-period near-fault characteristics, were simulated numerically. The numerical results show that, as compared to the responses of a traditional system, the proposed system is able to reduce an average of 80% of the peak isolator displacement in the 14 selected earthquakes. As for the reduction of acceleration response, the new system is particularly effective for near-fault earthquakes or near-resonant excitations, but is less effective for far-field earthquakes of more high-frequency contents, as compared with the traditional system.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

PROPOSAL OF A DESIGN CODE FOR SEISMIC ISOLATION OF BUILDINGS IN COLOMBIA

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Keywords: *Base isolation, design code, Colombia, Damping Modification Factor*

The current seismic design Colombian code (NSR-10) indicated that the base isolated building be designed according to USA documents, namely ASCE 7 or FEMA 450. Such regulations are better fitted to the US conditions, being not completely applicable to foreign countries, such as Colombia. The major inconsistency arises from the fact that in the US, the 1 s period lies always in the constant velocity branch of the spectrum; conversely, in Colombia (and in other Latin-American countries), soft soil conditions are common. In these soils, such period can belongs frequently to the plateau (constant acceleration) of the spectrum. Regarding the compatibility between the Colombian code and the American regulations, some confusing statements have led to misinterpretations. ON the other side, obviously, the DMFs (Damping Modification Factors) that are employed in the US cannot be considered in other countries, as are strongly dependent on the local seismicity. Finally, the US regulations are apparently oriented to essential buildings only, being excessively demanding for ordinary use; conversely, in Colombia, base isolation might be also useful for non-essential constructions. Given the above considerations, a draft proposal of a Colombian design code is under development. This document includes the aforementioned observations, particularly the developed DMFs.

2.DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

INVESTIGATION OF POTENTIAL POUNDING OF BASE ISOLATED BUILDINGS UNDER STRONG NEAR-FAULT EARTHQUAKE EXCITATIONS

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Keywords: *base isolation, structural impact, pounding, near-fault excitations*

Due to the finite width of the provided seismic gap around a base isolated building, there is a possibility of pounding with the adjacent moat wall or an adjacent building during stronger than expected seismic excitations. Although pounding between fixed-supported buildings has been extensively studied, very limited research work has been carried out for pounding of seismically isolated buildings, which exhibit quite different dynamic characteristics. This paper describes the research work that has been carried our, regarding both planar (2D) and spatial (3D) simulations and parametric studies, in an effort to better understand how potential structural pounding may affect the effectiveness of seismic isolation.

7. STANDARDS FOR DESIGN, CONSTRUCTION, MAINTENANCE

DEVELOPMENT AND REVISION OF THE EUROPEAN STANDARD EN 15129 ON ANTI-SEISMIC DEVICES

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Keywords: *Seismic Norms, seismic devices, seismic hardware*

CEN officially created the TC 340: Anti-seismic Devices with the task to proceed with the standardization of the seismic hardware for use in structures erected in seismic areas and designed in accordance with EUROCODE 8: Design of Structures for Earthquake Resistance, with the aim of modifying their response to seismic action. This European Standard specifies functional requirements and general design rules thereof, material characteristics, manufacturing and testing requirements, as well as acceptance, installation and maintenance criteria. This Standard covers all types of Seismic Hardware in existence and leaves a door open to future progress. This derives principally from the fact that the Standard is highly performance-oriented and this feature also constitutes per se a guarantee of equity between the various systems that may be used as alternatives.. Also, the paper elucidates the criteria adopted for the pending revision of the EN 15129. In conclusion, this document summarizes the experience gained in Europe over the past 40 years in the field of Anti-seismic devices, which is dealt with through the application of very advanced criteria. This favours progress inasmuch as it promotes loyal competition through clear and fair rules that protect the interests of the community.

SEISMIC ISOLATION

DYNAMIC RESPONSE OF LIQUID STORAGE TANK WITH BEARING ISOLATION ON ELASTIC SOIL

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Keywords: *Cylindrical liquid storage tank; Liquid-structure interaction; Base isolation; Soil-structure interaction; Lumped-parameter model; Seismic response*

The seismic response of a base-isolated liquid storage tank on the half-space soil is studied. The coupled dynamic system that accounts for the base isolation and soil-structure interaction (SSI) effect is developed to evaluate the security of the liquid storage tank. The continuous liquid in the flexible tank is lumped as convective spring-mass, impulsive spring-mass and rigid mass. The bearing isolation is described via the equivalent linear elastic-viscous damping model. The soil impedances are equivalent to the lumped-parameter system with frequency-independent coefficients. The governing equations of motion of the total system are solved using the Newmark's integration method. A comparison between the present results and the existing results is presented to show the accuracy and validation of the coupled model. The effectiveness of isolation system in reducing the response of broad/slender tanks considering the deformable soil is demonstrated by comparing the results of isolated versus non-isolated cases. Parametric studies are conducted for isolated broad/slender tanks on elastic soil to estimate the effect of isolation period, isolation damping ratio and soil stiffness on the tank responses. The study shows that the interaction of a base-isolated liquid storage tank and the flexible soil is significant.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

SEISMIC FRAGILITY EVALUATION OF STRUCTURES RETROFITTED WITH SELF-CENTERING PRE-CAST CONCRETE FRAMES

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Keywords: *Self-Centering, Seismic Fragility, Reinforced Concrete, Pre-Cast Concrete Frames*

In this research, a self-centering post-tensioned pre-cast concrete (SC-PC) frame is utilized for retrofitting RC structures. A simplified design procedure for the selection of the SC-PC frame is proposed. The seismic performance of the retrofitted structures is verified through two different approaches of incremental dynamic analysis (IDA) and fragility curves (FC). The first approach utilizes a full nonlinear time history (NLTH) analysis to obtain IDA and FC. The second is an approximate approach for obtaining the IDA and FC based on less number of time history analyses. The results of the study show that the SC-PC frame is effective in seismic retrofitting and significantly improves the structure seismic fragility and maintains the maximum inter-story drift ratios within the required limits. In addition, the results of the approximate approach for obtaining the IDA and FC show good agreement with those obtained from the full IDA and FC

MEASURES AGAINST SEISMIC EVENTS BEYOND EXPECTATIONS SUCH AS MEGA-EARTHQUAKES, LONG PERIOD EARTHQUAKES AND VERTICAL MOTIONS

SEISMIC METAMATERIALS FOR ISOLATING CRITICAL INFRASTRUCTURE FROM RAYLEIGH WAVES

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Keywords: *metamaterial, Rayleigh waves, seismic isolation, vertical inclusions*

Recent studies in the field of metamaterial physics have shown that the concepts applied to electromagnetic and acoustic waves on the nano and meso scales can also be extended and applied to seismic waves. Conventional base isolation techniques decouple the foundation from the superstructure and can substantially reduce the horizontal components of acceleration. However, achieving isolation in the vertical direction is not as simple and proposed methods currently are not practically feasible or are very expensive. The concept of metamaterials comes as a new and interesting approach to mitigate seismic waves even before they reach the structure. Most of the seismic energy is carried by the surface waves which end up causing majority of the structural damage. In this study, we demonstrate how Rayleigh waves can be attenuated when they interact with a barrier of vertical pile-like concrete inclusions arranged at a sub-wavelength scale in the soil medium. This interaction creates a band gap, blocking waves from passing the metamaterial barrier. We carry out the 2D time domain simulations in P-SV domain using SPECFEM2D, a spectral element code. The approach adopted in this study can be a potential anti-seismic barrier which will drastically reduce the seismic demands on structures.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

DEFORMATION-HISTORY INTEGRAL TYPE HYSTERESIS MODEL CONSIDERING PERFORMANCE CHANGE FOR HIGH-DAMPING RUBBER BEARINGS

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Keywords: *High-damping rubber bearings, Hysteresis model, Time history analysis, Performance change*

In the case of time history analysis to design seismically isolated structures, analytical modeling of isolated layer is important. There are many types of isolator devices, but all devices, more or less, show performance change. For example, production variation, temperature dependence, aging, repeated loading dependence and so on. Therefore, it is important to select proper hysteresis model which can represent the performance change accurately. In the past, authors proposed new hysteresis model for high-damping rubber bearings which can represent complex behavior of hi-damping rubber bearings. The model is called Deformation-History Integral type model (DHI model). However, it was not clear how to represent the performance change. In this study, method of representing the performance change is proposed.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

EXPERIMENTAL STUDY ON STRUCTURAL CHARACTERISTICS OF FOUNDATIONS ATTACHED TO THE LAMINATED RUBBER BEARING

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Keywords: *Seismic Isolation, Laminated rubber bearing, Reinforced concrete foundation, Confining effect*

Generally laminated rubber bearings are installed between a building and a foundation. When the laminated rubber bearing is deformed by shearing, a large stress part appears inside. It is generated in an inter-sectional area that an upper inner steel plate overlaps with a lower inner steel plate of the laminated rubber bearing, we call it an effective supporting portion. Consequently, it is necessary to consider it in designing for attachments of laminated rubber bearings and in constructing. This is also one of the reasons to set the upper limit of the design compressive stress for the laminated rubber bearing. The stress distributions of laminated rubber bearings have been confirmed by FEM Analysis, but there are few studies on the influence of the large stress of the effective supporting portion to reinforced concrete foundations. We conducted an experiment to confirm the internal stress of the concrete foundation under the laminated rubber bearing and discussed its structural characteristics.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

3-D BASE CONTROL SYSTEMS FOR THE SEISMIC PROTECTION OF STRUCTURES

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Keywords: *Base Control System, Damping, 3-D*

Earthquakes not only cause severe damage for structures, but also lead to outage of operation of important lifeline structures, as hospitals and power plants. Thus, seismic protection needs to be considered for civil structures as well as for important equipment and machinery within these structures. The arrangement of vibration isolation systems for buildings and machinery is state of the art. Elements consisting of helical steel springs are corresponding devices, used worldwide. Optimizing the parameters of these elements and arranging viscous dampers additionally, lead to a seismic control system, entitled as Base Control System (BCS). The horizontal and vertical flexibility of the springs and damping forces in all spatial directions yield a 3-dimensional seismic protection system. The present contribution explains the corresponding advantages in terms of significant reductions of acceleration levels, internal forces and in-structural response spectra due to seismic loading. Basics and optimization criteria for the layout of Base Control Systems are offered and several examples of machinery and buildings are presented showing the advantages and improved seismic behaviour of these structures. Selected pictures and numerical details document the effectiveness of the presented seismic mitigation strategies and are used to illustrate the general applicability of the 3-D Base Control Systems.

4. RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

CELLULAR MATERIALS FOR SEISMIC ISOLATION

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Keywords: *Metamaterials, cellular materials, additive manufacturing*

In recent years, there has been various research and development in Japan regarding seismic isolation structures for extreme earthquake motions including long-period earthquakes and inland earthquakes. Generally, it is possible to increase the number of dampers to suppress the displacement in order to counter increased displacement of the base isolation layer in the building. However, in that case, it is extremely possible that the seismic isolation effect will be reduced with reference to the standard design earthquake motion level specified in the seismic isolation design in Japan. The high-performance oil damper which is now being developed for seismically isolated structures aims at achieving a conventional seismic isolation effect in the design domain and avoiding collision with the retaining wall by suppressing displacement in the level of extreme ground motions. This is considered to be applicable not only to newly constructed base isolated buildings but also to improving performance of existing base isolated buildings. This report describes, as summarized below, the high-performance oil damper, experimental results by a prototype machine and results of examination by time history response analysis.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

A COMPARATIVE STUDY ON METHODS OF ANALYSES FOR SEISMICALLY ISOLATED BUILDINGS

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Keywords: *Response history analysis, Fast Nonlinear Analysis, Seismic Isolation*

The main objective of this study is to investigate the accuracy of response spectrum analysis (RSA) procedure for seismically isolated buildings. For this reason, a typical RC moment frame building was employed. The building was analyzed using RSA and Fast nonlinear analysis (FNA) procedures. The inter-story drift ratios and floor accelerations, that are known to affect both structural and non-structural components, were obtained from both analyses procedures and were then compared. The results revealed that RSA may underestimate both floor accelerations and inter-story drift ratios. It has also been observed that FNA procedure may be preferred as a time efficient alternative to obtain response of seismically isolated buildings since the only nonlinearity is generally assigned to isolators that are located in the isolation level.

2.DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

INFLUENCE OF EARTHQUAKE CHARACTERISTICS ON THE PEAK SEISMIC RESPONSE OF A BASE ISOLATED STEEL BUILDING

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Keywords: *Seismic isolation, incidence angle, near-fault, eccentricities.*

The peak seismic response of a base-isolated building depends not only on its structural characteristics, but also on the imposed seismic ground motion and its incidence angle. Thus, it is very important to study the behavior of a base-isolated building under seismic ground motions with different characteristics, to better assess how the latter can affect the effectiveness of seismic isolation. In this research work, the peak seismic response of a base isolated steel building is examined under various seismic ground motions, in an effort to enhance our understanding of how it can be affected by the characteristics of the imposed ground motion. In order to study the effect of near-fault seismic ground motions, different types of seismic records are imposed to the building under investigation, while the direction of the imposed earthquake excitations is also varied in order to examine the influence of incidence angles that can be different from the two major construction horizontal axes of the building. Furthermore, the influence of accidental mass eccentricities is also studied, according to relevant provisions in regulations for seismic design.

MEASURES AGAINST SEISMIC EVENTS BEYOND EXPECTATIONS SUCH AS MEGA-EARTHQUAKES, LONG PERIOD EARTHQUAKES AND VERTICAL MOTIONS

A NEW SEISMIC DESIGN METHOD OF SIMPLY SUPPORTED GIRDER BRIDGES FOR VERY RARE GROUND MOTIONS IN THE TRANSVERSE DIRECTION

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Keywords: *simply supported girder bridge; very rare ground motions; seismic design; seismic isolation; plastic hinge*

In most seismic design codes, usually two seismic hazard levels, i.e. Design Earthquake and Maximum Considered Earthquake are considered. Several disastrous earthquakes have proved that seismic safety evaluation may underestimate seismic risks, which would result in serious damage of bridge structures. Therefore, another higher level of seismic hazard named very rare ground motions is proposed to be considered in this paper for very important bridges. A new seismic design method of simply supported girder bridges in the transverse direction for Super Earthquakes is proposed at first. In the proposed method, seismic isolation bearings, tension-only braces and ductile piers are combined to improve the seismic performance and meet seismic requirements of very rare ground motions. Taking a simply supported girder bridge as a numerical analysis example, the proposed method is compared with two bridge seismic design methods adopted in current seismic codes and its parametric analysis is conducted. It's shown that the proposed seismic design method can combine the ductility capacities of piers and the functions of seismic isolation bearings and reduce all the concerned structural seismic responses in very rare ground motions effectively.

SEISMIC PROTECTION OF STRUCTURES

3-D BASE CONTROL SYSTEMS FOR THE SEISMIC PROTECTION OF STRUCTURES

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The objective of this paper is to show the efficiency of simplified seismic design methodologies based on displacements for isolated bridges, so that these methodologies can be incorporated into bridge design regulations for use by practice engineers. The first method called Directly Displacement Based Design (DDBD) uses the approach of the substitute structure, to model the structure in its inelastic range as an equivalent elastic system of SDOF. This method, in its procedure, uses the secant stiffness at the design response level (maximum displacement) and the concept of an equivalent viscous damping (greater than 5%) to consider the energy dissipated during the non-linear response of the bridge. The second method considered is the Inelastic Spectrum Method (ISM), which, unlike the previous method, uses the elastic stiffness for the SDOF model and the inelastic displacement response spectrum with a damping equal to 5%. Subsequently, through dynamic non-linear analysis or also called Inelastic Time – History analysis (ITH), the ability of both methods of seismic analysis based on displacements to predict the responses of both displacements and forces is reviewed.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

SEISMIC RESPONSE CONTROL OF CABLE-STAYED BRIDGE INCORPORATE ENERGY DISSIPATION SYSTEMS

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Keywords: *Cable-Stayed Bridge; Seismic Response Control; Energy Dissipation Systems; Time-History Analysis*

In the present work, the objective is to study the characteristics of different devices to improve the seismic behavior in cable-stayed bridges; so that the seismic response of a cable-stayed bridge is evaluated and compared, considering different connection configurations between the deck and piers. It was analyzed first considering (i) Strong deck-to-pier connection (SDPC), (ii) No connection (NC), (iii) Limited transfer force with viscous dampers (LTF-VD) and (iv) Limited transfer force with isolators plus viscous dampers (LTF-I + VD). For this, the three-dimensional model of a cable-stayed bridge was analyzed by means of a nonlinear dynamic analysis or nonlienar Time-History analysis. The results show that for the case (SDPC) the period of the system reduces, while the acceleration and forces increase; for (NC) show very large relative displacement between the deck and piers, finally for the cases (LTF-VD) and (LTF-I + VD) we can control the response to adequate level, being the best alternative for cable-stayed bridges in zones highly seismic.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

A MULTI-DIRECTIONAL ISOLATION SYSTEM FOR MULTI-STOREY BUILDINGS UNDER COUPLED HORIZONTAL AND VERTICAL SEISMIC EXCITATIONS

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Keywords: *Seismic Isolation, Multi-Directional Seismic Isolation, Vertical Stiffness, Response Accelerations*

Seismic isolation systems have been widely used to protect the structural and nun-structural elements under severe earthquakes. While the efficiency of conventional seismic isolation systems in decoupling the superstructure from the horizontal ground motions has already been demonstrated, there is no practical methodology to decouple the vertical components of the ground motions, which are especially important in near-fault earthquakes. This study aims to develop the concept of a new Multi-Directional Seismic Isolation (MDSI) system to enhance the seismic performance of structures under coupled horizontal and vertical earthquake excitations. The MDSI system consists of a typical seismic isolation unit (principally designed for horizontal ground motions) and a Super High Damping Rubber (SHDR) device with a tuned vertical stiffness to control vertical excitations without affecting the horizontal movements. The efficiency of the proposed system is demonstrated by improving the seismic performance of 3, 5, 8 and 12-storey buildings vertical and horizontal strong earthquake excitations. It is shown that MDSI can reduce the maximum vertical and horizontal accelerations in the multi-storey buildings by up to 40% and 20%, respectively, by reducing the vertical stiffness of the isolation system. This can result in a significant reduction of damage to non-structural elements and contents.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

NUMERICAL SIMULATION OF LOW-COST SEISMIC ISOLATOR USING DIFFERENT HYSTERESIS MODELS

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Keywords: *Seismic isolation, low-cost, hysteresis models, bouc-wen model*

Seismic isolation system is expensive to afford, especially in developing countries, to protect low and medium-rise buildings that are not categorized as essential buildings, such as dwellings, residential buildings or other common structures. Based on a previous research, where a prototype of low-cost seismic isolator, ABC, for its acronym in Spanish (Aislador de Bajo Costo), using recycled tire sheets was developed, three specimens were tested under cyclic lateral reversal loading, applying a constant axial load of 10tf, and a lateral displacement pattern with different levels of shear deformations up to the failure which occurs around 100% of shear strain of the specimens. This research aims to conduct numerical simulations to model the experimental hysteretic behavior of ABC by using different hysteresis models such as, bilinear model, modified bilinear model and bouc-wen model. The hysteresis models were calibrated by using the experimental data recorded and the average of the total energy dissipated per loop as a comparative parameter. From the simulations, the calibrated parameters for bouc-wen model gave the better approach in comparison with bilinear and modified bilinear model, however, the average damping factor was not so high, around 10%.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

SWITCHED RESISTANCE OIL DAMPER DEPENDING ON DEFORMATION AS A MEASURE AGAINST VERY LARGE EARTHQUAKES

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Keywords: *Seismic Isolation, Huge Earthquake, Oil Damper, Variable Resistance Force, Response Analysis*

Long-period ground motions caused by the estimated huge earthquake along the Nankai trough or Sagami trough bring large deformation to seismically isolated buildings. It is considered that response displacement over 1.0 m occurs on isolation layer if long-period pulse observed in 2016 Kumamoto earthquake input to seismically isolated building. If deformation on isolation layer exceeds the assumed clearance, building collides with retaining wall and excessive forces are introduced to the upper structure. One of measures to suppress these extreme large displacements on isolation layer is increasing amount of damper. However, too many dampers impair isolation effect against small and medium earthquakes which occur frequently. A solution to this problem is damper with variable resistance force. In order to realize this solution, oil damper, which can vary its damping coefficient depending on the deformation fully passively, was developed. Resistance force of this damper is small within the set displacement and switch to large over the set displacement. This paper reports basic characteristics of the damper and performance test results of full scale specimen. Advantage of the damper in earthquake response of isolated building is also shown by the results of dynamic response analyses.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

SEISMIC RETROFIT DESIGN OF BUILDINGS OF A SCHOOL CAMPUS IN ISTANBUL BY DISSIPATIVE TOWERS

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Keywords: *Retrofit, supplemental damping, viscous dampers, dissipative towers, school, steel*

Conventional retrofitting of buildings by adding shear walls, column jacketing etc. are highly destructive. The buildings need to be evacuated and service is interrupted during the construction period. Moreover, the added retrofitting elements obstruct the architectural usage. In order to reduce listed impacts of conventional retrofitting methods, external retrofitting methods which buildings can continue their service during construction period, are preferred. «Dissipative Towers» is an innovative patented system for seismic retrofitting of existing buildings without interfering with the internal spaces and without interrupting the functionality. The towers are constructed on a rectangular reinforced concrete base with a spherical hinge below that facilitates rotational demands. Viscous dampers are radially placed in the corners of the rectangular base. The tower is connected to the building at each story level with steel beams. During a seismic event towers move together with the building hence reduce the seismic demand by providing supplementary damping. In this paper, the design of the «Dissipative Towers» system for the buildings of a school campus in Istanbul is described. Seismic performances of the buildings before and after retrofit have been compared as result of nonlinear response history analysis in terms of story drifts, base shear and story accelerations.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

TENSILE BEHAVIOR OF RUBBER ISOLATORS AND SOLUTIONS TO OVERCOME TENSION PROBLEM

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Keywords: *seismic isolation, rubber isolator, disc springs, hdrb, lrb, tension*

Rubber isolators are widely used at seismic isolation projects worldwide for the earthquake protection. Commonly used types of rubber isolators are high damping rubber bearings (HDRB) and lead rubber bearings (LRB). Rubber isolators' behavior under combined compression and shear loading is well known and predicted. However, the tensile behavior is not assessed properly, and commonly neglected. Cavitation in rubber develops under tensile stress level of around 1–1.5MPa depending on the shear modulus of rubber compound. However, in the code approach the tensile forces on the rubber isolators are not generally permitted. In this paper, analytical studies and test data in the literature for tensile behavior of rubber isolators are summarized in the first place. Modifications to the structural system to reduce tensile forces on isolators are described in a recently constructed base isolated hospital in Turkey. The effectiveness of these modifications has been confirmed by nonlinear time history analysis. Finally, a simple, yet effective and low-cost solution, employing the Belleville washers, also known as disc springs, used in the connection details of isolator base plates are presented. The dynamic behavior of the isolators with this solution under combined shear and tension is discussed in the light of analytical results.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

ALIBEYKÖY AND KAGITHANE VIADUCTS: ADVANCED SEISMIC PROTECTION SOLUTIONS IN HIGH SEISMICITY REGION

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Keywords: *Seismic protection, railway viaducts, Displacement Dependent Devices, Friction devices*

Regions with high seismicity activity require advanced solutions to protect structures against earthquakes. Turkey is one of the highest seismic regions in the world as crossed by the Anatolian fault; its capital city, Istanbul, with more than 15 million inhabitants, has an ever-increasing demand of public transportation and connection between different parts of the city. The Alibeyköy and Kagithane viaducts are integral part of the new Istanbul metro line, both seismically isolated for full protection against most severe earthquakes. Both projects are an extraordinary worldwide example of advanced seismic protection techniques using different anti-seismic devices, providing base isolation and energy dissipation. The seismic protection is obtained through spherical bearings able to support vertical loads up to 60.000 kN with maximum displacement capacity in longitudinal and transversal directions equal to ±350 mm. The bearings are equipped with CE marked anti-seismic devices with high hysteresis capacity and high strength sliding material with frictional properties to improve the overall dissipation capacity. The hysteretic dampers are made by «E» and «C» shaped steel elements. Some of these bearings are equipped with lock-up devices to allow service movements and to activate the hysteretic dampers during the seismic event. The paper describes in detail the need of multi-functional solution covering the full range of products available for seismic protection and all the tests performed to qualify the behavior of the devices

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

SEISMIC ISOLATION AND POST-TENSIONING: A COMPLETE SOLUTION FOR THE NEW TRIESTE HARBOR LOGISTIC PLATFORM

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Keywords: *Harbor Logistic Platform; Post-Tensioning; Base Isolation; Structural Damping; Curved Surface Sliders; Full Scale Tests*

The growing of the goods traffic by shipping in Northern Italy stressed the need of having wide logistic platforms for the management of the goods, organizing their stock, ships docking and link with the main road and rail transport lines. The new investment in Trieste harbor has covered around 70.000 square meters of the existing bay and will improve the movement of goods from central Europe and Turkey for an estimated yearly turnover of 15 million Euros. The new logistic platform is 470 m long and 275 m wide and it is made by a post-tensioned concrete slab of 50 cm thickness. The platform is base isolated the structure with 850 CE marked curved surface sliders supplied by Freyssinet. This work describes the base isolation solution from the seismic analysis of overall structure up to the tests performed on the curved surface sliders as well as the complete package of expansion joints and post-tensioning system provided. This project is a great example of application of post-tensioning and seismic isolation techniques, a complete solution that allows to drastically reduce the shear force demand at the foundation level, a fundamental target for marine structures that require deep foundations.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

ESTIMATION METHOD OF TENSILE STRAIN OF LAMINATED RUBBER BEARINGS AND BENDING MOMENT OF FOUNDATION BEAM FOR SEISMICALLY ISOLATED BUILDING

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Keywords: *Laminated rubber bearing, Tensile strain, Superimposed horizontal and vertical responses, Constant energy rule, Stress redistribution*

We propose the estimation method of tensile strain for the laminated rubber bearing (LRB) and bending moment for foundation beam when the LRBs are pulled out. The validity of the proposed methods is demonstrated by comparing with the time history analysis result using a 24-story isolated base building model. When the tensile modulus of LRB is lower than the compressive elastic modulus, the method of the adding the time history analysis (ATA) results individually analyzed in the horizontal direction and the vertical direction cannot evaluate the tensile strain of LRBs and the bending moment of foundation beam. From the sum of two time-history analysis results in the horizontal-direction and the vertical-direction model having the same tensile modulus and compression modulus of LRB, it is confirmed that the proposed method which is using the constant energy rule (CER) can evaluate the tensile strain of LRB when the tensile modulus of the laminated rubber bearing is lower than the compression modulus. The bending moment of the foundation beam can be calculated by the sum of the bending moment calculated from the ATA method and the bending moment obtained from applying forced displacement of tensile strain calculated by using CER.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

ENERGY DISSIPATION AND SEISMIC RESPONSE EVALUATION OF SEMI-RIGID STEEL FRAMES AT VARIOUS PERFORMANCE LEVELS

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Keywords: *Seismic Performance, Semi-rigid, Far-field, Near-field earthquakes*

During the famous 1994 Northridge earthquake and 1995 Kobe earthquakes, the beam-column rigid connected steel moment-resisting frames were severely affected, especially at joints. As a consequence, the concept of semi-rigid (SR) frames for seismic energy dissipation attracted the attention of many researchers. This paper primarily focuses on performance based seismic behavior of SR frames under earthquake. Herein, the seismic performance of SR steel moment frames are investigated at various performance levels through nonlinear pushover analysis (POA) and nonlinear time history analysis (NLTHA) under a variety of far-field and near-field with directivity effects earthquakes. The SR connections are modeled as multi-linear plastic link element with a kinematic hysteresis behavior in standard software SAP2000. POA is performed to identify the performance levels at different locations; elastic to the near collapse level. For the numerical study, 5-story steel moment frames with rigid and SR connections are designed for the Indian standard provisions to assess the seismic performances. Further, the responses obtained from the POA are compared with the benchmark NLTHA. The response quantities of interest are considered as the energy dissipation in SR connections, the peak top-floor displacement, the maximum base shear, the maximum inter-story drift and the SRSS of maximum plastic hinge rotations. From the study, it is concluded that predictions from POA are quite reliable upto the elastic and elastic-plastic performance levels. Further, the energy dissipations at the SR connections are found to be significant in NLTHA showing improved inelastic behaviour of SR frames as compared to rigid frames.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SEISMIC ENERGY DISSIPATION IN SEMI-RIGID CONNECTED STEEL FRAMES

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Keywords: *Semi-rigid; Near-Field; Far-field; Energy Dissipation*

A comparison between the losses of seismic energy between the semi-rigidly connected building frames modeled in two different ways and the corresponding rigidly connected frame is presented. For this purpose, three different types of earthquakesare considered, namely, the far-field, and the near-field with directivity and fling-step effects. Each type of earthquakeis scaled to a PGA level that ranges from 0.2g to 0.6g. The loss of seismic energy is investigatedwith respect toa number of seismic demand parameters such as the maximum inter-story drift ratio, the maximum roof displacement, the total number of plastic hinges, the SRSS of maximum plastic hinge rotations and the energy dissipation. A ten-story steel building frame designed according to the Indian standard code is taken as the illustrative example. A nonlinear time history analysis is performed using SAP 2000 to find the responses. The results of the study indicate that (i) the seismic energy dissipation in the multilinear plastic link modeling of the semi-rigid joints is considerably more as compared to the multilinear elastic link modeling of the same; the difference between the two energy dissipations decreases for reduced PGA level; (ii) the energy dissipation in rigid frames is more as compared to the semi-rigid frame modelled with multilinear elastic link model; multilinear plastic link model provides comparable seismic energy loss to the rigid frames; and (iii) the nature of energy dissipationgreatly differs with the nature of earthquake, PGA level, type of modeling of the semi-rigidity and the type of connection.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SEISMIC ENERGY DISSIPATION IN SEMI-RIGID CONNECTED STEEL FRAMES

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Keywords: *Semi-rigid, Near-Field, Far-field, Energy Dissipation*

A comparison between the losses of seismic energy between the semirigidly connected building frames modelled in two different ways and rigidly connected frames, for different types of earthquakes scaled to different PGA levels is presented. Three types of earthquakes are considered, namely, Far field earthquake, Near field with directivity effect and Near field with fling step earthquake. Scaled PGAs range from 0.2g to 0.8g. The loss of seismic energy is investigated with respect to a number of seismic demand parameters such as maximum inter story drift ratio, maximum story displacement, total number of plastic hinges, SRSS of maximum plastic hinge rotations and the nature of hysteresis loops of a ten story steel building frame. The results of the study indicate that (i) the seismic energy dissipation in multilinear plastic link modelling of semi rigid joint is considerably more as compared to multilinear elastic link modelling of the same; the difference between the two energy dissipations decrease for reduced PGA level; (ii) the energy dissipation in rigid frames is more as compared to the semi-rigid frame modelled with multilinear elastic link model; multilinear plastic link model provides comparable seismic energy loss to rigid frames; (iii) the nature and number of hysteresis loops greatly differ with the nature of earthquake, PGA level, type of modelling of semirigidity, the PGA level and the type of joint; (iv) amongst all seismic demand parameters considered, maximum inter story drift shows maximum variance.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

RECENT PROGRESS AND EXPERIENCE IN TAIWAN ON PASSIVE CONTROL TECHNOLOGY AND APPLICATIONS

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Keywords: *passive control technology, seismic isolation, energy dissipation, practical application, Pulse-like ground motion*

In Taiwan, seismic isolation and energy dissipation technology has been extensively applied in new and retrofitted buildings and infrastructures against seismic attacks after the 1999 Chi-Chi Earthquake. In the beginning, most applications involved critical structures such as emergency response facilities that are required to remain fully functional during and after earthquakes. Since 2009, the use of such technology has been greatly expanded to residential buildings for better seismic protection. To date, the numbers of building projects adopting seismic isolators and velocity-dependent dampers are more than 130 and 400, respectively. Recently, isolating equipment and facilities from damage due to earthquakes also attracts growing attention and has been implemented in practice. In this paper, several representative applications of passive control technology to buildings and critical facilities in Taiwan are illustrated first. The practical performance of some seismically isolated buildings during the 2016 Mei-nong Earthquake and 2018 Hualien Earthquake, which was observed for the pulse-like ground motions, are also reviewed. Then, several new and advanced testing facilities of the National Center for Research on Earthquake Engineering (NCREE) are briefly introduced. By applying the new testing facilities at NCREE, the research on pulse-like ground motion relevant to seismic isolation control technology is discussed.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

FRICTION DAMPER SYSTEM FOR SEISMIC RESPONSE REDUCTION

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Keywords: *Energy Dissipation; Earthquake Resistant Design; Friction Damper; Supplemental Damping; Seismic Retrofit*

A new system for enhancing energy dissipation capacity through supplemental friction dampers has been developed. The proposed system consists of a set of slider plates supported by a pair of struts and does not obstruct the access to open spaces and can be readily deployed for retrofitting works with the help of handy clamping devices. The performance of the proposed damper system was tested on shake table for maximum credible earthquake motion corresponding to the most severe seismic zone of the Indian standard IS-1893 in a simple portal frame 2.0 m × 1.7 m in plan and 2.0 m tall. The natural frequency and damping of the portal frame were estimated from free vibration as 7.0 Hz and 0.9%. Under the test conditions, a reduction of 30% in the seismic demand was observed. Further reduction is possible by suitable changes in the system parameters and material forfriction interface.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

APPLICATION OF BASE ISOLATION FOR RETROFITTING OF EDUCATIONAL BUILDING WITH MASONRY WALLS IN PERU

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Keywords: *Base Isolation, Retrofitting, Educational Building, Masonry structures*

Seismic Isolation of structures in Peru is becoming a common method of providing protection from earthquake damage. By reducing the seismic forces transmitted into the structures, seismic isolation protects the main structure and the most important the safety of occupants as well as the contents and secondary structural elements. The rehabilitation of existing structures by the implementation of seismic isolation at ground level has been carried out into hospitals, historic buildings of all around the world, but in Peru it is a new technology. In this research, the seismic behavior of an educational building with masonry walls designed according to the conventional approach is evaluated for the implementation of seismic isolation. The results show an important improvement of the behavior of the structure against the traditional approach. This improvement is considerable, achieving a level of performance of immediate occupation under a MCE. The retrofitting technique using base isolation has great potential for rehabilitation of educational structures that have been constructed without taking into account the new technologies or approaches of seismic design.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

IMPROVEMENT OF SEISMIC PERFORMANCE IN EDUCATIVE RC BUILDING USING INNOVATIVE EARTHQUAKE – RESISTANT SYSTEM

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Keywords: *Seismic Isolation, Educational Buildings, Improvement of Seismic Performance*

In last years, the use of devices that improve the seismic response of structures has increased considerably. Many structures that were designed with the latest seismic design codes and considering the conventional approach have not had an adequate behavior against earthquakes (Chile, 2010) and in some cases they lost their total capacity of resistance (Mexico, 2017). This fact endorses the implementation of antiseismic devices into the structures for improving their seismic capacity. In the first part of the present research, the seismic behavior of an educational building designed according to the conventional approach is evaluated through the Peruvian Code, E.030. Its behavior is subsequently evaluated incorporating two systems of seismic dissipation, as well as two types of seismic isolators. The results show an improvement of the behavior of the structure against the traditional approach. In some cases, this improvement is considerable, achieving a level of performance of immediate occupation under a MCE. Finally, this research will serve as a starting point for the implementation of these innovative techniques into the design regulations in a mandatory way and in general in essential buildings according to the E.030 where it is necessary to have a high level of seismic performance.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

THE EXPERIENCE OF BRIDGE SEISMIC ISOLATION IN RUSSIA

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Keywords: *highway bridges, railway bridges, seismic isolation systems, seismic load*

Positive experience of applying seismic isolation systems for seismic stability of the civil and industrial buildings and structures began to extend to the objects of transport construction about twenty years ago, as is evidenced by theoretical and experimental studies conducted in this regard, as well as by the use of seismic isolation devices in the road bridge structures in Europe, Japan and China. At the same time seismic isolation systems in the railway transport facilities (bridges, overpasses) were still not used in the world practice, that was related to a number of unsolved engineering problems, especially under high-speed running conditions. Reducing the seismic load when using seismic isolation leads to increasing of a structure main periods and consequently increases its deformability, so that above-standard significant displacements emerge, they can lead to a rail rupture under the operational loads. Nevertheless, a number of Russian engineers and scientists had carried out a number of studies and succeeded in solving this problem theoretically and practically. This solution made it possible to ensure the safe operation of the bridge tracks under operational loads, to reduce the seismic loads during minor and moderate earthquakes, to limit damages during strong impacts, and had been applied for seismic protection in new constructions for the Olympics in Sochi, Russia. The paper considers the peculiarities of seismic isolation on both highway and railway bridges. They are based on the projects that had been implemented in the seismic regions of Russia given the world scientific experience.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

DISSIPATIVE BRACING AND BASE ISOLATION DESIGN SOLUTIONS FOR NEW PREFAB R/C STRUCTURES

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Keywords: *Dissipative braces, fluid viscous devices, base isolation, curved surface sliders, new prefab structures, design*

Starting from the results of a previous research of the authors dedicated to the seismic retrofit of existing prefab R/C buildings by means of advanced protection strategies [1], a novel study aimed at extending to the field of new prefab R/C structures the application of these technologies is presented in this paper. A benchmark building was designed to the purpose, assuming the typical geometrical layout and dimensions of single-hall industrial buildings in Italy, which are also similar to the characteristics of the same class of buildings in other countries of the Mediterranean area. The design was carried out in the three following hypotheses: (a) according with a traditional ductility-based normative approach; (b) incorporating dissipative bracings, equipped with fluid viscous dampers; (c) placing a seismic isolation system at the base, composed of a set of double curved surface sliders. The earthquake and performance levels assumed, their relevant limitations, the design criteria and the technical installation of the three solutions are discussed in detail. A comparison of relevant sizes, seismic performance and costs is finally presented. [1] Sorace S, Terenzi G (2017). Existing prefab R/C industrial buildings: Seismic assessment and supplemental damping-based retrofit. Soil Dynamics and Earthquake Engineering, vol. 94, p. 193–203.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

MID-STORY SEISMIC ISOLATION DESIGN AND DYNAMIC ANALYSIS OF SOHO GINZA

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Keywords: *mid-story isolation; large podium with two towers; rubber bearing; viscous damper*

Mid-story seismic isolation design and dynamic analysis are taken for SOHO Ginza, which is located in Suqian City, Jiangsu Province, China. This building is composed of a large podium with two towers. The isolation story sits between the podium and the towers, which is composed of rubber bearing and viscous damper. The control index and the detail arrangement of the isolation story are proposed. The finite element model is established and the time-history analysis is taken. The results indicate that under precautionary intensity earthquake, the story displacements and the story shears of the isolated structure decrease compared with those of the non-isolated structure. The story displacements of the podium and towers can meet the criteria under the rare earthquake. It is concluded that the mid-story isolation technology is feasible in the structure of large podium with two towers. And the isolation effects are significant.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

SEISMICALLY ISOLATED STRUCTURE WITH LEAD RUBBER BEARING CASE STUDY: ELEVATED TOLL JAKARTA-CIKAMPEK II PROJECT

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Keywords: *seismic isolation system; isolator bearing; lead rubber bearing; nonlinear time history analysis; hysteresis curve; energy dissipation;*

As a solution to overcome extreme traffic demand in one of the busiest Indonesia's toll roads, a project called The Elevated Toll Jakarta-Cikampek II was initiated by the Government. The 40 KM elevated structure is designed as seismically isolated structure using lead rubber bearings as the isolators. This solution is projected to answer challenges of high seismicity issue, constructability, high initial cost of construction and extreme project loss in the case of any interruption in bridge operation due to repairs after earthquake events. Lead rubber bearing is chosen because of the ability of the device to provide large damping capacity and high flexibility at the same time, and also because of its unique re-crystallization property that could be beneficial to sustain repeated earthquakes without any bearing replacements. The process of designing seismically isolated structure is presented, initially from a simplified Single Degree of Freedom method to get the basic parameters of the isolator bearings. Furthermore, a Dynamic Response Spectrum Analysis on a three-dimensional modeling is used to get the final seismic response demands. As the final assessment, a nonlinear time history analysis is performed on the final three-dimensional modeling to see the compliance of the inputted nonlinear parameters of the bearings and the resulted nonlinear behavior of the isolators which is expressed by its hysteresis curve. A total of seven sets three-directional compatible-spectrum accelerograms are artificially generated for the nonlinear time history analysis.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

SHAKING TABLE TEST TO VERIFY A NEW SEISMIC RESPONSE CONTROL SYSTEM USING BLOCK & TACKLE

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Keywords: *Response control, High-rise building, Block and tackle, Earthquake, Damper*

This paper proposes a new seismic response control system using a block and tackle (hereinafter, referred to as a movable pulley damper system) developed especially for high-rise buildings. The proposed system has a configuration where a damper is installed on the track of the cable-stayed wire, amplifying the amount of movement of the wire by using a movable pulley that increases the damping effect to reduce the vibration of a building. Since the wire can be stretched across distant parts of a building, this system is able to exert an effect on a large relative displacement. To control the shear and bending deformation of a high-rise building during earthquake shaking, we examine a method to connect the core structure (parking tower) and the sur-rounding frame (housing part) of a high-rise building using the movable pulley damper system. This system aims to reduce the earthquake response of the building by the force of the damper attached to the core structure. By enlarging the relative displacement between the core structure and the peripheral frame by the moving pulley, it is possible to move the damper in considerable extent to dissipate large vibration energy. To verify the effectiveness of this response control system, a small shaking table test was conducted for a specimen simulating the core structure and the peripheral frame of a high-rise building.

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FINITE ELEMENT ANALYSIS OF LAMINATED RUBBER BEARING COMPRESSED BY STEEL COLUMN WITH SMALLER CROSS SECTION AREA THAN RUBBER BEARING

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Keywords: *Seismic Isolation, Finite Element Method, Rubber Bearing, Steel Column*

Generally, the laminated rubber bearing used for seismically isolated structure is installed between a substructure and a superstructure made of the reinforced concrete. The compressive force is transmitted by a member having a larger cross-sectional area than the rubber bearing. Therefore, in experiments of rubber bearing, the force loading method that compresses the entire cross section is adopted. The application of seismically isolated structure has been expanding in Japan, and examples of installing the rubber bearing on steel columns are increasing. In that case, the steel column is often smaller than the size of the rubber bearing. Therefore, the influence of the compressive force on the properties of the rubber bearing when it is transmitted by the steel column smaller than the sectional size of the rubber bearing is clarified by finite element analysis. In the analysis, we assumed solid cross sectional columns and hollow cross sectional columns with a smaller cross section than rubber bearing. The analysis results revealed that when an extremely smaller columns is attached, the compression deformation of the rubber bearing becomes non uniform and adversely affects the horizontal deformation performance.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

APPLICATION OF AN ENERGY-BASED DESIGN PROCEDURE TO THE DESIGN OF FLUID VISCOUS DEVICES IN A DISSIPATIVE BRACING-BASED SEISMIC RETROFIT INTERVENTION

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Keywords: *Supplemental damping technologies, seismic retrofit, frame structures, dissipative braces, fluid viscous devices, energy-based design procedures*

Supplemental damping techniques are increasingly applied in the field of seismic retrofit of frame buildings. Among these techniques, «mainly dissipative» (MD) ones, i.e. capable of supplying a high damping action without significant stiffening effects of the structural system, are preferred when rather stiff structures are dealt with in current conditions. A retrofit intervention designed with a MD-type technology for a school built in Florence in 1980s is presented in this paper. The building is irregular in plan, as it is composed by two frame reinforced concrete and two steel frame blocks, without mutual separation gaps. A careful reconstruction of the characteristics of the constituting members, based on the original design documentation and on-site testing campaigns, highlighted a series of drawbacks in current state, related to a remarkable degradation of the materials, and insufficient strength of several members. The MD-type system adopted as retrofit solution consists in a set of dissipative braces incorporating fluid viscous dampers. The latter are sized by a recently proposed energy-based design procedure (Terenzi 201ABSTRACT The recent earthquake revealed that the main source of both casualty and economic loss is due to high vulnerable building stock in Turkey. In order to reduce the seismic risk around the country, Turkey has released a regulation for «urban renewal». Based on this regulation huge number of vulnerable buildings have been replaced with the new once in recent years. Since the seismic design performance objective is «life safety» in current Turkish Seismic Code the new buildings has the same seismic safety level. In order to minimize both the structural and non-structural damage in earthquakes, seismic isolation can be a rational solution to be used not only in the urban renewal applications but also the new designed residential buildings in Turkey. In order to investigate the feasibility of this application, a set of real buildings has been selected from the building available building database that reflects the basic structural system and geometric properties of the building stock in Turkey. The representative buildings that have been used in the analysis phase is grouped based on number of stories as 5,10 and 15 story that covers almost 75% of the building stock in Turkey. The seismic isolation system using high damping rubber bearing type isolation units has been designed based on Chapter 14 of new Turkish Seismic Code that involves the analysis and design procedure of seismically isolated buildings. Additionally, alternative isolation systems have been designed using LRB and curved surface friction isolator type isolation units for comparison. The

superstructure members have been optimized in terms of member dimensions and reinforcement considering the criteria given in Chapter 14 of new Turkish Seismic Code. As the result of this study, a set of isolation units properties has been determined for representative buildings (5, 10 and 15 story) and different seismic risk levels (moderate and high). The results of the study involve the isolation unit properties, approximate cost of the isolation system and BOQ of superstructure members are determined for each building class. An economical evaluation has also been performed to compare the overall building cost with the proposed isolation system. It has also been emphasized that the seismic performance target for residential buildings should be upgraded to «minimum damage» or «continuous functionality» in next generation seismic design codes. Once this approach has been accepted in seismic design procedure, next generation residential buildings will suffer minimum damage and provide a seismically resilient building stock. KEYWORDS: residential building, seismic isolation, minimum damage, resilient building stock

OBSERVATION AND MONITORING OF BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

PERFORMANCE VERIFICATION OF SEISMIC ISOLATION DEVICES USED IN A BASE-ISOLATED BUILDING FOR 30 YEARS

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Keywords: *base-isolated building, natural rubber bearing, aged deterioration, free vibration test, static loading test*

The authors have been carried out a series of experiments on the aging effects of laminated rubber bearings for 30 years using an actual building which was first completed in Japan. This building is a four story RC structure with 25 rubber bearings and 12 sets of steel dampers as isolation devices. In these experiments, static loading tests and free vibration tests have been conducted using hydraulic jack at compression of this building in 1986, then in 1987, 2005 and 2016. The maximum deformation of 10cm, corresponding to the 100% shear strain of the rubber bearings, were adopted in every tests. From these test results, the increase of horizontal stiffness of 25 bearings were estimated as almost 7% after 30 year usage under actual circumstances. In order to evaluate the large deformation capacities of the bearings, two bearings were removed from the building and the element tests were carried out in 2017. The bearing used for 30 years performed not lower than 350% strain before its rupture. Through this research, it is confirmed that the natural rubber bearings use for 30 years maintain their characteristics of horizontal stiffness and deformation capacities sufficiently as were expected.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

RETROFIT OF A 100 METER TALL STACK USING TUNED MASS SUPPORTED ON SEISMIC ISOLATORS

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Keywords: *Tuned Mass Damper, Reinforced Concrete stack, Vibration Test, Seismic Isolators*

Recent upgrade in the performance objectives of the facility owner, required the structural assessment of the 90-meter reinforced concrete stack in an Oil Refinery Located in a high seismic zone. Designed in 1979, the 90-meter exhaust stack fails to meet the performance objectives. Due to high importance of the operation, retrofit with minimal downtime was essential, thus a tuned mass damper alternative was opted. In this study, in addition to material and geotechnical tests, forced vibration and ambient vibration studies were executed as well. Based on the obtained data, analytical model was created with matching dynamic properties. Various TMD alternatives were evaluated prior to selection of tuned mass supported on high damping rubber seismic isolators alternative for this specific structure. This paper summarizes the design process including development of the analyses model, determination of actions on the structure and optimization of the selected retrofit configuration

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SLOW-CYCLIC TEST OF STEEL PLATE SHEAR WALL WITH FLOOR SLAB

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Keywords: *Steel plate shear wall; Slow cyclic experiment; Connection ductile detailing; Effect of slab; Lateral loading*

This study presents a large-scale slow-cyclic experimental study of a single-story steel plate shear wall (SPSW) with a composite slab casted over the top horizontal boundary element (HBE). The bottom-HBE had no slab casted over it. The objectives of the study were to investigate the effect of the floor slab on the forces developed in the HBEs, and to check the efficacy of the proposed connection detailing in shifting the location of the plastic hinge away from the beam-column joints. The comparison of the response of the two HBEs is utilized to achieve this objective. The main emphases of the study were the yielding behaviour of the infill plate and the boundary elements, the behaviour of the plastic hinges, the crack propagation in the slab, and the failure modes of the SPSW components. Due to the presence of the slab, the top HBE exhibited a reduction in the axial forces but an increase in the vertical tension forces in the web region. The proposed connection detailing facilitated the axial-flexural plastic hinges in the HBEs to be formed away from the connections, which enhanced the ductility of the system in comparison to the past experimental studies. The specimen demonstrated a stable hysteretic response up to 6% story drift.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SEISMIC EVALUATION OF A REINFORCED CONCRETE SCHOOL BUILDING RETROFITTED WITH STEEL BRACING SYSTEM

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Keywords: *seismic assessment, pushover analysis, performance-based design, collapse mechanism, strengthening techniques, steel elements*

An accurate seismic design is based on a combination of linear seismic analysis, followed by a non-linear analysis procedure. A common tool for the estimation of earthquake demands at multiple performance levels is pushover analysis. This paper aims to evaluate the inelastic behaviour of an existing reinforced concrete school building constructed in 1973 in the city of Kavala, Greece. It examines the subjection of a monotonic load which increases iteratively, through an ultimate condition, and then investigates the need of implementation of retrofitting techniques. The assessment of the building is based on the National Interventions Code (KAN.EPE., 2013) and performance levels, namely Immediate Occupancy, Life Safety and Collapse Prevention, are specified in compliance with ATC-40. According to six different analyses, including triangular and uniform distribution of horizontal forces, it is concluded that structure can´t reach the target level of safety, as defined by importance levels criteria that ensure continued functionality of the building. For the variety of structures, several retrofitting techniques can be considered. In this study, the utilization of diagonal bracing arrangements in order to increase the seismic capacity is examined. The main conclusion is that, steel bracing system could provide an efficient approach for strengthening of existing buildings.

5.MEASURES AGAINST SEISMIC EVENTS BEYOND EXPECTATIONS SUCH AS MEGA-EARTHQUAKES, LONG PERIOD EARTHQUAKES AND VERTICAL MOTIONS

NEW EVALUATION FORMULAE FOR SHEAR STRENGTH OF LEAD-RUBBER BEARINGS

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Keywords: *Lead rubber bearings; Heat-mechanics interaction behavior analysis; Dynamic and cyclic loading tests; Yielding stress of lead core; Strain rate dependency*

The strength of lead rubber bearings (LRBs) can be reduced by «lead core heating» caused by their absorption of seismic energy. The purpose of this study is to clarify strength degradation in LRB in the event of a long-duration earthquake such as the 2011 Tohoku Earthquake in Japan. In this paper, the yielding force of the LRB is defined as the sum of the intercept force of the RB and the yielding force of the lead core. Various dependency tests and cyclic loading tests with temperature measurement of lead were conducted for the RB and LRB specimens with diameters of 250 and 500 mm. From the tests, the evaluation formula for the yielding stress of the lead could be described by the temperature of the lead and shear strain rate of LRB with high accuracy. Dynamic loading tests were conducted for LRBs of real size in order to confirm the validity of the proposed formulae. Two kinds of analysis methods were used to consider the heat diffusion, namely the Constant Flux Solution and the Finite Difference Method. From the examination above, it was confirmed that the proposed formulae could accurately predict the mechanical behavior of LRB under cyclic loading.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SIMPLIFIED MODEL FOR THE SEISMIC ANALYSIS OF A SOIL- LONG PILE GROUP-STRUCTURE SYSTEM

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Keywords: *Soil-structure interaction; Pile group; Impedance function; Lumped-parameter model; Chebyshev polynomials*

A simplified semi-analytical approach based on Thin Layered Method (TLM) and Chebyshev nested lumped-parameter model (LPM) is presented for the seismic analysis of a soil-long pile group-structure system subjected to earthquake waves. The force-displacement relationship between the unbounded soil and the long pile group is described by dynamic impedances which are obtained by the TLM. A nested lumped-parameter model based on the complex Chebyshev model is proposed to incorporate the frequency-dependent impedances with conventional governing equations for time history analysis of superstructure. The formulations and corresponding computer programs are verified by comparison examples. The time history analysis of a 15-story superstructure supported by a 3*3 long pile group under seismic excitation is presented to show the stability and advantages of the present model.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

A HYBRID SIMULATION ON A STEEL PANEL DAMPER SUBSTRUCTURE WITH ONLINE MODEL UPDATING

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Keywords: *hybrid simulation, model updating, steel panel damper, experiment, multi-axial, geographically distributed*

This paper describes the preparation and execution of a series of quasi-static hybrid tests conducted on a specimen of a steel panel damper (SPD). The prototype building is a three-dimensional six-story moment resisting frame with four SPDs incorporated in each story as the main seismic resisting system. The prototype building was subjected to bi-directional earthquake excitation, during which each SPD element exhibited seismic responses of 12 degrees of freedom (DOF). Therefore the hybrid tests were required to be conducted by using a multi-axial testing system (MATS) which can simultaneously imply deformation of multiple DOFs on the specimen. The finite element analysis program «Platform of Inelastic Structural Analysis for 3D Systems» (PISA3D) was chosen as the analysis engine. To this end, PISA3D was augmented to support geographically distributed hybrid simulation in a general-purpose manner. An external displacement control (EDC) method was proposed to increase the MATS control accuracy. An online model updating (OMU) technique was developed and employed in this series of hybrid tests such that the actual material properties identified from the SPD specimen during the tests could be immediately used to update those of the other SPD numerical elements. The flexibility of the testing platform was well demonstrated since this highly complex series of hybrid tests could be completely defined and smoothly executed without any hardcoding in the underlying software programs. The effectiveness of EDC method and the OMU technique was also confirmed by the test results.

SEISMIC ISOLATION DESIGN OF THE MAIN BRIDGE OF SONGPU BRIDGE

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Keywords: *Songpu Bridge; friction pendulum bearing; seismic isolation design; seismic response*

The main bridge of Songpu Bridge was a long-span steel truss girder bridge. Due to the increased traffic pressure, the upper deck needs to be widened to six lanes, and the lower deck needs to be changed into non-motor lanes and sidewalks. However, the load capacity of the old pile foundations cannot be retrofitted due to real situation. Therefore, it is necessary to carry out the seismic analysis for the bridge. The friction pendulum bearings are used in the seismic isolation design and the analysis results show that the friction pendulum bearings applied in both schemes, i.e. the whole bridge isolated, or only continuous pier isolated, can achieve great seismic isolation effects, while the latter is more economical than the former. Meantime, the seismic responses of the main bridge with different parameters of the friction pendulum bearings are compared to come up with the reasonable seismic isolation design for the main bridge.

ECCENTRICITY INFLUENCE ON COUPLING RESPONSE AND DAMAGE AMPLIFICATION OF CURVED BRIDGES IN EARTHQUAKES

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Keywords: *curved bridge; irregularity; eccentricity; unfavorable direction; spacial effects*

Deformations and forces of curved bridges are not in proportion to the intensity and direction of loads. Plane irregularity is the direct reason for the complicated seismic responses and failures for curved bridges. This paper is to study the plane irregularity index -- eccentricity, i.e., the offset of the center of mass (COM) from the center of stiffness (COS), and the COM from load input directions, on the seismic responses and pounding of curved bridges. First, geometric eccentricity, which is determined by the curve's shapes, is studied by examining the bridge responses with respect to the bridge rise-span ratios; second, physical eccentricity, i.e., the offset of COS from COM, is studied by rearranging the locations of bearings and restraints; Last, load eccentricity, i.e., the deviation of excitation directions from the axis of symmetry of bridges, is studied to figure out the favourable or unfavourable excitation directions. Studies show that, bridges with smaller rise-span ratios are more close to straight bridges and thus have smaller coupling effects; bridges with symmetric arrangement of bearings and restraints have one-direction eccentricity, while those with asymmetric arrangement result in two-directional eccentricity, which could either strengthen or counteract the coupling effects; unbalanced capacity in transverse and longitudinal directions would produce more weak points, failure modes and uncertainty, and thus decrease the entire structure's performance and reliability; Pounding intensity is directly related to the end responses and induces larger stress on fixed piers than on isolated piers. Therefore, an important principle to design curved bridges is to fully consider and balancing the irregular factors to avoid producing unwanted weak points.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SHAKING TABLE TEST OF PSEUDO-NEGATIVE-STIFFNESS CONTROL OF A BASE ISOLATED BUILDING EMPLOYING MR DAMPER

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Keywords: *Smart isolation; Magneto-rheological fluid damper; Pseudo-negative-stiffness control; Shaking table test*

This study presents experimental studies on the effectiveness and adaptability of pseudo-negative-stiffness control of a base isolated structure employing magneto-rheological damper (MRD). Shaking table tests on conventional base-isolated structure, passive controlled structure with input current of 0 A, passive controlled structure with input current of 1 A and smart controlled structure with displacement-based pseudo-negative-stiffness (DPNS) control algorithm were conducted. Each type of the control system was subjected to four representative seismic ground motions with peak ground accelerations (PGAs) varying from 0.1 g to 0.6 g. Through comparative analysis of structural response and damper response, the control effect of DPNS control algorithm and energy dissipation characteristics of the control force of the magneto-rheological damper were studied. The experimental results indicate that the DPNS control can reduce the base isolation displacement and the superstructure responses simultaneously under low-to-median and even extreme seismic excitations, and it can adapt to both far-field and near-field seismic excitations. Because of the time-delay effect of the control system, the DPNS control force shows a small value under low-to-median seismic excitations and a large energy dissipation capacity under extreme seismic excitations.

2. DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

RECENT DEVELOPMENTS IN NEW ZEALAND IN SEISMIC ISOLATION, ENERGY DISSIPATION AND VIBRATION CONTROL OF STRUCTURES (2019)

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Keywords: *seismic isolation energy dissipation New Zealand*

Recent activity in the implementation of seismic isolation, energy dissipation and vibration control of structures in New Zealand is summarised. Recent severely damaging earthquakes in New Zealand have left many buildings and infrastructure systems inoperable and not repairable, leading to their demolition. Owners and engineers are now seeking systems that will provide more resilient seismic behaviour. Resilient structures will be able to recover operation and function quickly after a major earthquake compared with conventional structural systems. Earthquake protection technologies now being developed and used to make more seismically resilient structures include seismic isolation and energy dissipation systems. These systems can provide better damage control and repairability of structures. The paper summarises recent projects in New Zealand that have incorporated seismic isolation and energy dissipation and other earthquake protection systems such as dissipative brace systems. A draft New Zealand Guideline for the design of seismic isolation systems for buildings was recently published. The Guideline makes recommendations for how engineers should design isolated buildings to meet the performance requirements that will be well in excess of the minimum requirements of the national Building Code. The Guideline encourages the use performance-based and displacement-based design methods to explicitly design for damage control and repairability targets in addition to life safety. Details of the design Guideline are described in the paper.

TOPIC 5: «MEASURES AGAINST SEISMIC EVENTS BEYOND EXPECTATIONS SUCH AS MEGA-EARTHQUAKES, LONG PERIOD EARTHQUAKES AND VERTICAL MOTIONS»

THE MW 7.4 PALU EARTHQUAKE OF SEPTEMBER 28, 2018

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Keywords: *earthquake, tsunami, liquefaction, strike-slip*

A moment magnitude (M_w) 7.4 earthquake has rocked the Indonesian island of Sulawesi on September 28, 2018. The earthquake triggered, not only, a devastating tsunami but also a lateral soil movement due to liquefaction, destroying more than 3095 houses and causing thousands of fatalities in several large neighborhoods. This paper aims to provide detailed discussion regarding the characteristics of the earthquake's strike-slip type ground movement and to help provide recommendations based on lessons learned in this earthquake.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

COMPARISION OF MODELING APPROACHES FOR HIGH DAMPING RUBBER BEARINGS

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Keywords: *High damping rubber isolators, Multi linear model, High Damping Model, Seismic isolation*

Two approaches were employed to model the High Damping Rubber isolators used in buildings. The first approach is the commonly used multi linear plastic link (MLP) force deformation relationship employed in SAP2000. The second alternative was the use of high damping rubber isolator link (HDR) developed by Bridgestone. A 9-story seismically isolated reinforced concrete building was employed where high damping rubber bearings were used as isolators. In order to investigate the influence of force-deformation models on the response, isolators were modeled using the two-models that are described in SAP2000. The building was analyzed under a set of 7 earthquake records scaled to a target spectrum obtained from seismic hazard analysis. Base shear force transferred to the superstructure as well as the isolator displacements that are obtained from nonlinear time history analyses of the building were compared for the two modeling approaches. It has been observed that both base shear and isolator displacements obtained from the HDR model are larger compared to MLP model the difference being approximately 5–30 percent. This shows that there is a significant influence of isolator modeling on the response.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

THE CHARACTERISTICS OF THE RUBBER BEARING WITH TIN PLUG

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Keywords: *tin plug, rubber bearing, repeating durability*

Rubber bearing with an energy dissipating lead core has been used as one of seismic devices conventionally. However, while the rubber bearing with lead core has the advantage of having a damping function, the use of lead in the damping material may cause environmental problems. Non-lead has already advanced in the field of each industry, and practical use of non-lead work is necessary. We developed rubber bearing with tin plug (core) which we used tin for as damping materials from such a background. In this paper, we report on the product structure, characteristics, repeating durability of rubber bearing with tin plug. As a result of the repeated test, although the yield load slightly decreased, the supporting capacity and the restoring capacity were sufficiently retained. After the cyclic loading tests, the specimen was cut and the state of the tin plug was confirmed, but damage such as cracks was not observed. In conclusion, the repeating durability of the rubber bearing with tin plug under the cyclic loading tests was verified by the test results.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

APPLYING HYBRID TEST METHOD IN STUDYING SEISMIC RESPONSE OF FRAME STRUCTURE WITH SELF-CENTERING ENERGY DISSIPATION DEVICE

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Keywords: *Hybrid test method, seismic test, frame structure, energy dissipation device*

Hybrid test method, an innovative dynamic test method originating from pseudo-dynamic test method and substructure analysis technique, is believed to be a promising seismic test solution. When applying hybrid test, the interested part of the structure or the part supposed to have significant nonlinear response is taken as experimental sub-structure; while the rest of the structure becomes numerical sub-structure. Benefiting from its sub-structure nature, hybrid test method can be applicable to test dynamic performance of seismic isolation or energy dissipation device without physically testing whole structure. The application of hybrid test on a frame structure with self-centering energy dissipation device was reported in this paper. The prototype is a 3-story steel frame armed with self-centering energy dissipation device. Before carrying out real test, a simulation of hybrid test flow by running 2 OpenSees processes was performed. The main structure is modeled in Master program while the self-centering energy dissipation device is modeled in Slave program, connected by Simulation Finite Element Adapter experimental control in OpenFresco. The pretest simulation study was conducted to determine suitable loading protocol and input ground motion, as well as check control flow and study the feasibility of this innovative test method.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

ON SOME ISSUES OF TAKING ACCOUNT OF THE INTERACTION OF SEISMICALLY ISOLATING PILE FOUNDATIONS WITH FOUNDATION SOIL UNDER SEISMIC EFFECTS

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Keywords: *seismic isolation, accelerograms, piles*

Operation of dynamic system consisting of buildings with rigid structural scheme (large-panel, stone, etc.) on pile foundations with a high grillage pin-connected with piles and various damping (seismically isolating) elements affecting the value of calculated loads on supporting structures under seismic effects has been studied. At the same time, the structural components of seismic isolation in practical execution can be quite simple and technologically accessible for construction companies. The peculiarities of installation of pile foundations consist in the selection of the free length of piles and the ways to connect piles with a grillage (rigid, hinged), which allows for systems with sufficient ductility, on the one hand, as well as the use of elastic-plastic interaction of the soils surrounding the piles at the joint horizontal work, on the other hand. Optimal combinations of the characteristics of pile foundations, foundation soils and parameters of damping (seismically isolating) elements of the system that minimize seismic loads on the supra-foundation parts of the building structure were set up for certain types of seismic effects, the characteristics of which are determined and may be dependent on regional (local) seismological conditions, the area of earthquake occurrence. In the studies, accelerations of known real earthquakes recorded in various earthquake-prone regions of the world were taken as seismic effects. Particularly valuable are the instrumental data of the engineering seismometric service of the city of Almaty, through the use of which practical recommendations were given based on the study results for the application of seismic isolation design in earthquake engineering of the city of Almaty.

MEASURES AGAINST SEISMIC EVENTS BEYOND EXPECTATIONS SUCH AS MEGA-EARTHQUAKES, LONG PERIOD EARTHQUAKES AND VERTICAL MOTIONS

DESIGN METHOD FOR BASE-ISOLATION STRUCTURE COMBINED WITH ACTIVE CONTROL BASED ON THE LIMITATION CONDITIONS OF THE RESPONSES AND CONTROL FORCE

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Keywords: *Active structure control, base-isolation structure, Linear quadratic regulator (LQR), Equivalent model, Controller design method*

The linear quadratic regulator (LQR) is widely used in active structural controls (ASCs). However, at the present stage, the influence of the design parameters (LQR weighing matrices) on the vibration characteristics of the control system has not been explicitly expressed. In particular, the estimation of the required control force has not been conducted. Therefore, the LQR weighting matrices are mainly selected by trial and error approach, making it very difficult to design a control system that achieves the desired performance. To solve this problem, an equivalent model of the single-degree-of-freedom active model (structure with active control) is constructed, using which, a calculation method for the weighing matrices that does not require a trial and error approach to satisfy the desired control performance is proposed. Thereafter, the concept of the transitional response spectrum, which is widely used in structural design, is promoted as a control force spectrum that can be used to estimate the maximum control force. Finally, the design of a passive base isolation (PBI) reactor is discussed as an example, and the performance-oriented design method for the PBI structure combined with ASC is proposed that simultaneously satisfies the limitation conditions of the responses and control force.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

BEYOND DESIGN PERFORMANCE OF VISCOELASTIC DAMPER

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Keywords: *Viscoelastic Damper, Beyond Design Performance, Dynamic Test, Fraction Differential Model*

The actual performance and damage of viscoelastic dampers under maximum considered shaking or greater earthquakes as well as their residual performance under aftershocks was rarely discussed before. In this study, four coefficients of the fraction differential model considering ambient temperature, temperature rising, cyclic soften, and strain hardening effects were firstly characterized from performance test with shear strain levels less than 300%. Secondly, VE dampers were tested with larger shear strain levels, until 1000%, to realize their ultimate performances. In between each large shear strain level, the performance test under 300% shear strain was performed to further understand their residual performance after damage. The fraction differential model was also adopted for characterizing their post-damage behavior. The result shows that the stiffness and damping coefficient of VE dampers decrease proportionally with varying shear strain levels from 600% to 840%, and can still remain half of the original values after 840%. Thirdly, VE dampers were tested subjected to seismic response histories which can be numerically analyzed in an off-line manner. Either before or after damage, the predictions by the fraction differential model have a very good agreement with the test results.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

BASE-ISOLATION FOR RESPONSE CONTROL OF BUILDINGS UNDER MULTI-HAZARD CONDITION

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Keywords: *base isolation, blast-induced ground motion, earthquake, multi-hazard, near-fault, far-fault*

The behavior and performance of base-isolated buildings subjected to multi-hazard condition, namely earthquake and blast-induced ground motions, are investigated. The efficacy of various base isolation systems in protecting multi-degree of freedom structures against: (a) near-fault earthquake ground motions, (b) far-fault earthquake ground motions, and (c) blast-induced ground motions is assessed. Five base isolation systems: (a) laminated rubber bearing (LRB), (b) lead-rubber bearing (N-Z system), (c) pure friction (PF) system, (d) friction pendulum system (FPS), and (e) resilient-friction base isolator (R-FBI) are considered in the investigation. The effects of the different parameters of the isolation systems on the building response reduction under bi-directional earthquake and blast-induced ground motions are studied. Further, suitable parameters of each isolation system for effective control of the response quantities, such as the superstructure acceleration, the isolator displacement, base shear, and storey drift, are evaluated for each ground motion type. The performances of the five isolation systems in protecting the multi-degree of freedom building structure for each excitation type are presented and compared. The various response quantities of the fixed-base building under the earthquake as well as the blast-induced ground motions are also shown for comparison.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

DEVELOPMENT AND APPLICATION OF A VARIABLE STIFFNESS ISOLATION SYSTEM CONSIDERING GROUND MOTION CHARACTERISTIC

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Keywords: *Potential energy, Semi-active control, near-fault earthquake, Minimum energy weighting, velocity energy*

In recent years, the research of isolation and mitigation system has become more and more important. In the traditional isolation and mitigation system, the control effect may be reduced because of unknown earthquake types. To have the best effect of response reduction, the systems have to be adaptive with the earthquake type. To achieve that, an upgraded algorithm, Feed-forward Predictive Earthquake Energy Analysis (FPEEA), is proposed by considering the energy of earthquake velocity to have the optimal response. The new algorithm quickly evaluates the velocity energy to have the optimal weighting of minimum energy weighting (MEW). With the optimal weighting of the potential energy and the kinetic energy, the PFEEA can reduce the structural responses efficiently. In order to demonstrate the performance of the proposed algorithm, a single-degree-of-freedom structure is used as a benchmark in both numerical simulation and experimental verification. With predicting the optimal weighting in advance, the type of earthquake can be defined before the main shock of earthquake comes. The results have shown that the dynamic response of the structure can be effectively alleviated. Comparing to the structural responses of the MEW method, the performance of the proposed algorithm is similar to MEW or even better. The shaking table test also demonstrates the feasibility of applying the proposed algorithm in practical application.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

NUMERICAL EVALUATION OF THE SEISMIC RESPONSE OF STEEL STORAGE RACK BEAM-TO-COLUMN CONNECTIONS BY FINITE ELEMENT ANALYSIS

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Keywords: *Stiffness Deterioration, Dynamic Behavior, Finite Element Modeling Cyclic Load, Beam-to-Column Connections*

Steel pallet racks (SPR) are characterized by boltless beam-column connections (BCC). The role of BCCs becomes more significant during hazardous conditions such as earthquakes. Due to the great number of beam-end connector types and member geometries, the accurate evaluation of their structural behavior, especially under seismic loads, seems to be very difficult to perform so far. In this paper, the authors present results of simulation based on cyclic tests on different types of industrial rack joints by the finite element (FE) modeling of connections. This paper mainly investigates the BCC geometrical factors affecting the dynamic behavior of braced racks. Design indications are consequently provided in order to guarantee a globally homogenous ductility among different BCC configurations under seismic actions.

OBSERVATION AND MONITORING OF BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

THE EFFECT OF LONG PERIOD GROUND MOTIONS ON HIGH-RISE BUILDINGS AND USE OF DAMPING DEVICES

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Keywords: *High-rise buildings, far-distance earthquakes, long-period ground motions, damping devices*

The response of the high-rise buildings under far-distant long-period seismic ground motions have been studied. Although most of the severe seismic damages on the building structures occur within the 50km distance from an earthquake epicenter, long-period waves can also cause damages at much greater distances. The long-period component of seismic ground motions attenuates more slowly with distance than higher frequencies. Large-scale structures such as tall buildings and big tanks can resonate with the long-period ground motion because of their own natural periods. The severity of shaking in high-rise buildings can be in a level causing panic for residents and non-structural damage even though located several hundred kilometers away from earthquake epicenter. The 2011 Tohoku Earthquake Mw9.0 caused damages in non-structural elements and equipments in high-rise buildings in Tokyo area with a distance of approximately 400km from the earthquake epicenter. There were no observed damages in the low-rise buildings. Even in Osaka area with a distance of approximately 700km from the earthquake epicenter, high-rise buildings were shaken severely on higher floors by the long period ground motions. This paper investigates the effect of long-period ground motions on the high-rise buildings analytically and examines the effect of use of damping devices.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

A FEASIBILITY STUDY OF SEISMIC ISOLATION APPLICATION IN RESIDENTIAL BUILDINGS IN TURKEY

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Keywords: *residential building, seismic isolation, minimum damage, resilient building stock*

The recent earthquake revealed that the main source of both casualty and economic loss is due to high vulnerable building stock in Turkey. In order to reduce the seismic risk around the country, Turkey has released a regulation for "urban renewal". Based on this regulation huge number of vulnerable buildings have been replaced with the new once in recent years. Since the seismic design performance objective is "life safety" in current Turkish Seismic Code the new buildings has the same seismic safety level. In order to minimize both the structural and non-structural damage in earthquakes, seismic isolation can be a rational solution to be used not only in the urban renewal applications but also the new designed residential buildings in Turkey. In order to investigate the feasibility of this application, a set of real buildings has been selected from the building available building database that reflects the basic structural system and geometric properties of the building stock in Turkey. The representative buildings that have been used in the analysis phase is grouped based on number of stories as 5,10 and 15 story that covers almost 75% of the building stock in Turkey.
The seismic isolation system using high damping rubber bearing type isolation units has been designed based on Chapter 14 of new Turkish Seismic Code that involves the analysis and design procedure of seismically isolated buildings. Additionally, alternative isolation systems have been designed using LRB and curved surface friction isolator type isolation units for comparison. The superstructure members have been optimized in terms of member dimensions and reinforcement considering the criteria given in Chapter 14 of new Turkish Seismic Code.
As the result of this study, a set of isolation units properties has been determined for representative buildings (5, 10 and 15 story) and different seismic risk levels (moderate and high). The results of the study involve the isolation unit properties, approximate cost of the isolation system and BOQ of superstructure members are determined for each building class. An economical evaluation has also been performed to compare the overall building cost with the proposed isolation system. It has also been emphasized that the seismic performance target for residential buildings should be upgraded to "minimum damage" or "continuous functionality" in next generation

seismic design codes. Once this approach has been accepted in seismic design procedure, next generation residential buildings will suffer minimum damage and provide a seismically resilient building stock.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

STRUCTURAL DESIGN OF THE 430.000 SQM HOSPITAL SUPPORTED ON 1552 SEISMIC ISOLATORS

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Keywords: *Seismic Isolations, Hospital, Triple Friction Pendulum*

Turkish Ministry of Health has mandated the application of seismic isolation on all new hospitals with a capacity of 100 beds or more. With this requirement, under the health public private partnership program, Adana Integrated Health Campus was designed and constructed. The 430.000 sqm hospital structure is currently the largest base isolated hospital in operation both in terms of construction area and in terms of number of isolators.
In this presentation, structural and seismic engineering approach with emphasis to major challenges, including, nonlinear dynamic analyses, uplift issues, testing protocols of isolators and shrinkage effects in concrete slabs has been presented.

MEASURES AGAINST SEISMIC EVENTS BEYOND EXPECTATIONS SUCH AS MEGA-EARTHQUAKES, LONG PERIOD EARTHQUAKES AND VERTICAL MOTIONS

HIGH-PERFORMANCE OIL DAMPERS FOR SEISMICALLY ISOLATED STRUCTURES TO COUNTER EXTREMELY STRONG EARTHQUAKE GROUND MOTIONS

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Keywords: *Oil damper, Prolonged earthquake ground motion, Inland earthquake, Displacement suppression Seismic isolation structures Variable resistance force*

In recent years, there has been various research and development in Japan regarding seismic isolation structures for extreme earthquake motions including long-period earthquakes and inland earthquakes. Generally, it is possible to increase the number of dampers to suppress the displacement in order to counter increased displacement of the base isolation layer in the building. However, in that case, it is extremely possible that the seismic isolation effect will be reduced with reference to the standard design earthquake motion level specified in the seismic isolation design in Japan. The high-performance oil damper which is now being developed for seismically isolated structures aims at achieving a conventional seismic isolation effect in the design domain and avoiding collision with the retaining wall by suppressing displacement in the level of extreme ground motions. This is considered to be applicable not only to newly constructed base isolated buildings but also to improving performance of existing base isolated buildings. This report describes, as summarized below, the high-performance oil damper, experimental results by a prototype machine and results of examination by time history response analysis.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

AN EXTENDED EQUIVALENT-INPUT-DISTURBANCE APPROACH FOR ACTIVE STRUCTURAL CONTROL FOCUSING ON ABSOLUTE ACCELERATION AND INTER-STORY-DRIFT ANGLE

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Keywords: *Active structural control, Equivalent-input-disturbance (EID), vibration control, absolute acceleration*

This paper presents a new equivalent-input-disturbance (EID) approach for active structural control of a building with a special focus on suppressing the absolute acceleration and the inter-story-drift angle of a building.
An EID is a signal on the control input channel that has the same effect on the output of a system as disturbances do. A conventional EID approach only considers the relative displacement and the relative velocity of a building. However, the conventional EID does not consider the absolute acceleration and the inter-story-drift angle despite these are important for active structural control of a building.
A conventional EID system consists of an EID estimator, state feedback controller and a state observer. However, these parts are designed by trial-and-error method. Thus, it is difficult to design the control system if a building has high degree-of-freedom (DOF).
This paper devises an extended EID (EEID) approach that considers not only the absolute acceleration but also the inter-story-drift angle of a building, and presents a designing method for the EEID control system.
In this paper, a 11 DOFs building model that employs a base isolation and three kinds of earthquake accelerogram are used to demonstrate the validity of our method.

OBSERVATION AND MONITORING OF BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE.

INFLUENCE OF VEHICLE IMPACT LOAD ON ISOLATED BRIDGE

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Keywords: *Bridge Vibration; Signal Processing; System Identification*

In recent years, rapid urbanization, associated with large waves of urban population growth, has been imposing crucial demands on city transportation infrastructure. Therefore, an increasing number of elevated expressways, typically long-pier bridges, were erected in the city platform to ease urban transportation pressure. However, high traffic volume of such expressway bridges can cause significant vibration. To investigate the influence of the bridge-traffic-induced vibration, this study monitored the acceleration of an isolated bridge located for 24 hours in a row. The acceleration measurements were then analyzed using the fast Fourier transformation method and a system realization method, and the system parameters of both the bridge and building were thus calibrated. Furthermore, the bridge-deck-to-pier displacement and bridge deck acceleration were measured to explore how vehicle transportation affects the structural performance of the bridge deck and pier. The results may be used as a reference for future improving the bridge-traffic-caused vibration problem.

VISCOUS DAMPER

APPLICATION OF VISCOUS DAMPERS IN SEISMIC DESIGN OF A HOSPITAL IN SICHUAN

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Keywords: *seismic, damper, additional damping ratio, energy dissipation*

The viscous dampers (setting in architecture wall) are adopted in the seismic design of a hospital frame to reduce the earthquake force. The elastic-plastic time history analysis, which is about the computational model structure under frequent and rare earthquake conditions, is carried out by SAUSAGE and SAP2000. Through the calculation, additional damping ratio and the hysteretic curve of dampers are obtained, moreover, the energy dissipation performance of the structure is compared and analyzed. The conclusion shows that the hysteretic curve of the damper is well-stacked and the energy dissipation performance is well. In addition, the use of the damper reduces the plastic damage of the main structure under rare earthquake.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

STUDY OF RC COUPLED SHEAR WALL WITH REPLACEABLE COMPONENTS

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Keywords: *RC coupled shear wall, replaceable coupling beams, replaceable corner components, design method, pushover analysis*

During past earthquakes the coupling beams and the bottom of wall piers in RC coupled shear walls easily suffered severe damage which is repaired hardly or costly. A new type of coupled shear wall with replaceable coupling beams and replaceable corner components at the bottom of wall piers is put forward. During the strong earthquake the damage is expected to mainly concentrate on the replaceable components in the wall. The function of the structural wall can be quickly restored by replacing the replaceable parts after the earthquake. The design method for the new wall is proposed. Two RC coupled shear walls, one new wall and one conventional wall, were designed. The responses and the damage process of two shear walls were analyzed and compared by numerical simulation. The results show that the lateral stiffness and load carrying capacity of the new shear wall are similar to that of the conventional shear wall. For the new wall, the replaceable coupling beams yields first, then the replaceable corner components yields. The damage concentrates on the replaceable components, and slight damage occurs in other parts. Compared with the conventional shear wall, the seismic performance of the new shear wall is improved significantly.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

SIMPLIFIED METHOD OF DESIGNING AN INNOVATIVE SEISMIC ISOLATION SYSTEM FOR HIGHWAY BRIDGES: ANALYTICAL STUDY AND EXPERIMENTAL VALIDATION

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Keywords: *innovative isolation system; highway bridges;simplified design method; design example; shake table testing validation*

Since the sliding of laminated-rubber bearings and the concrete shear key failure were mostly observed for small to medium-span highway bridges in the 1999 Chi-Chi earthquake and the 2008 Wenchuan earthquake, an innovative isolation system composed of laminated-rubber bearings and yielding steel dampers was developed, designed and implemented in these bridges to improve their seismic performance during an intense earthquake. This study investigated the seismic performance of the proposed isolation system analytically and experimentally. By idealizing the bridge system as a simple series-parallel combination of bridge components (e.g. superstructures, bearings, steel dampers, substructures), several new parameters were defined and their correlated parametric formulations were derived accordingly. Based on this, a simple yet efficient step-by-step method of designing this innovative isolation system was presented, followed by the validation through a design example and shake-table testing. The design example showed that the proposed design method was feasible and easy to perform with only a small number of iterations. Shake table tests validated the reliability and effectiveness of this design method for designing the proposed isolation system for highway bridges with satisfactory seismic performance.

SEISMIC ISOLATION

DYNAMIC RESPONSE OF LIQUID STORAGE TANK WITH BEARING ISOLATION ON ELASTIC SOIL

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Keywords: *Cylindrical liquid storage tank; Liquid-structure interaction; Base isolation; Soil-structure interaction; Lumped-parameter model; Seismic response*

The seismic response of a base-isolated liquid storage tank on the half-space soil is studied. The coupled dynamic system that accounts for the base isolation and soil-structure interaction (SSI) effect is developed to evaluate the security of the liquid storage tank. The continuous liquid in the flexible tank is lumped as convective spring-mass, impulsive spring-mass and rigid mass. The bearing isolation is described via the equivalent linear elastic-viscous damping model. The soil impedances are equivalent to the lumped-parameter system with frequency-independent coefficients. The governing equations of motion of the total system are solved using the Newmark's integration method. A comparison between the present results and the existing results is presented to show the accuracy and validation of the coupled model. The effectiveness of isolation system in reducing the response of broad/slender tanks considering the deformable soil is demonstrated by comparing the results of isolated versus non-isolated cases. Parametric studies are conducted for isolated broad/slender tanks on elastic soil to estimate the effect of isolation period, isolation damping ratio and soil stiffness on the tank responses. The study shows that the interaction of a base-isolated liquid storage tank and the flexible soil is significant.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

MID-STORY SEISMIC ISOLATION DESIGN AND DYNAMIC ANALYSIS OF SOHO GINZA

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Keywords: *mid-story isolation; large podium with two towers; rubber bearing; viscous damper*

Mid-story seismic isolation design and dynamic analysis are taken for SOHO Ginza, which is located in Suqian City, Jiangsu Province, China. This building is composed of a large podium with two towers. The isolation story sits between the podium and the towers, which is composed of rubber bearing and viscous damper. The control index and the detail arrangement of the isolation story are proposed. The finite element model is established and the time-history analysis is taken. The results indicate that under precautionary intensity earthquake, the story displacements and the story shears of the isolated structure decrease compared with those of the non-isolated structure. The story displacements of the podium and towers can meet the criteria under the rare earthquake. It is concluded that the mid-story isolation technology is feasible in the structure of large podium with two towers. And the isolation effects are significant.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

NUMERICAL EVALUATION OF THE SEISMIC RESPONSE OF STEEL STORAGE RACK BEAM-TO-COLUMN CONNECTIONS BY FINITE ELEMENT ANALYSIS

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Keywords: *Stiffness Deterioration, Dynamic Behavior, Finite Element Modeling Cyclic Load, Beam-to-Column Connections*

Steel pallet racks (SPR) are characterized by boltless beam-column connections (BCC). The role of BCCs becomes more significant during hazardous conditions such as earthquakes. Due to the great number of beam-end connector types and member geometries, the accurate evaluation of their structural behavior, especially under seismic loads, seems to be very difficult to perform so far. In this paper, the authors present results of simulation based on cyclic tests on different types of industrial rack joints by the finite element (FE) modeling of connections. This paper mainly investigates the BCC geometrical factors affecting the dynamic behavior of braced racks. Design indications are consequently provided in order to guarantee a globally homogenous ductility among different BCC configurations under seismic actions.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

RESPONSE SPECTRUM METHOD FOR THE DESIGN OF ISOLATED BUILDINGS

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Keywords:

An isolated building, composed of the superstructure and the isolation system, whose damping levels are significantly different, is typically non-classical damping system. This results in inapplicability of traditional response spectrum method for the design of isolated buildings. A multidimensional response spectrum method based on complex mode superposition is herein introduced, which properly takes into account the non-classical damping feature in the isolated structure. From the base-isolated benchmark model, as a numerical example, application of the procedure is illustrated companying with comparison study of time-history method, traditional response spectrum method and the proposed method. The results show that the proposed method is valid, while the traditional approach cannot reflect the damping characteristics of isolated buildings and may lead to insecurity of structures.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

DISCUSSION FOR KEY ISSUES OF ISOLATION TECHNOLOGY APPLIED IN LONG-SPAN COMPLEX BUILDINGS

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Keywords: *torsional control; temperature effects; wind-resistant design; boundary constraints; vertical seismic action*

High seismic precautionary intensity areas are widely distributed in China. Along with the rapid development on urbanization process, the requirements for quality and safety of buildings are constantly increasing. Long-span buildings are generally public-type buildings and characterized by dense crowds, high importance, and complex shapes. Thus these buildings have strict requirements for seismic performance and large demand for reduction of earthquake actions. At present, the development of isolation technology is relatively advanced and its application in long-span buildings can effectively reduce earthquake actions and improve seismic performance of structures, so that long-span buildings can effectively play the function of post-earthquake disaster relief. In this paper, the key issues in the application of isolation technology in long-span complex structures are discussed, including torsional control, temperature effects, wind-resistant design, boundary constraints, vertical seismic action, and the layout of the playing field on isolation layer of stadium structure, which can provide reference for related programs.

VISCOUS DAMPER

APPLICATION OF VISCOUS DAMPERS IN SEISMIC DESIGN OF A HOSPITAL IN SICHUAN

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Keywords: *seismic, damper, additional damping ratio, energy dissipation*

The viscous dampers (setting in architecture wall) are adopted in the seismic design of a hospital frame to reduce the earthquake force. The elastic-plastic time history analysis, which is about the computational model structure under frequent and rare earthquake conditions, is carried out by SAUSAGE and SAP2000. Through the calculation, additional damping ratio and the hysteretic curve of dampers are obtained, moreover, the energy dissipation performance of the structure is compared and analyzed. The conclusion shows that the hysteretic curve of the damper is well-stacked and the energy dissipation performance is well. In addition, the use of the damper reduces the plastic damage of the main structure under rare earthquake.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

AN INERTIAL-TYPE VERTICAL ISOLATION SYSTEM WITH A SMART FRICTION DAMPER FOR SEISMIC PROTECTION OF EQUIPMENT

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Keywords: *vertical isolation, inertia type, equipment protection, leverage mechanism, near-fault earthquake*

Vertical seismic excitation may have a detrimental effect on nonstructural component, such as equipment, within a building structure. Seismic isolation may be an effective solution for the protection of equipment. Nevertheless, most existing isolation systems are for mitigating horizontal excitations only. Development of a vertical isolation system (VIS) is difficult, due to a conflict between the demands of static and dynamic isolation stiffness. In other words, a VIS must have sufficient rigidity to sustain the static weight of the isolated object, while it must also have sufficient flexibility to mitigate the dynamic responses under an earthquake. To overcome this difficulty, a novel semi-active VIS that consists of an inertia-type vertical isolation system (IVIS) and an imbedded piezoelectric friction damper (PFD) is proposed in this study. The primary difference between the IVIS and a traditional VIS is that the former has an additional leverage mechanism and a counterweight. Through the leverage mechanism, the counterweight will provide a static uplifting force and an extra dynamic inertia force, such that the effective vertical stiffness of the IVIS becomes higher in its static state and lower in the dynamic state. On the other hand, the PFD will provide a controllable friction damping force for the IVIS, in order to further reduce the vertical isolator displacement without affecting isolation efficiency. In order to verify its feasibility, a prototype of the proposed system was fabricated and tested on a shaking table in this study. It is shown the experimental results agree well with the theoretical ones. To further verify the isolation efficiency, the seismic responses of the proposed system subjected to 14 different vertical ground motions, including the ones with long-period near-fault characteristics, were simulated numerically. The numerical results show that, as compared to the responses of a traditional system, the proposed system is able to reduce an average of 80% of the peak isolator displacement in the 14 selected earthquakes. As for the reduction of acceleration response, the new system is particularly effective for near-fault earthquakes or near-resonant excitations, but is less effective for far-field earthquakes of more high-frequency contents, as compared with the traditional system.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

APPLYING HYBRID TEST METHOD IN STUDYING SEISMIC RESPONSE OF FRAME STRUCTURE WITH SELF-CENTERING ENERGY DISSIPATION DEVICE

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Keywords: *Hybrid test method, seismic test, frame structure, energy dissipation device*

Hybrid test method, an innovative dynamic test method originating from pseudo-dynamic test method and substructure analysis technique, is believed to be a promising seismic test solution. When applying hybrid test, the interested part of the structure or the part supposed to have significant nonlinear response is taken as experimental sub-structure; while the rest of the structure becomes numerical sub-structure.
Benefiting from its sub-structure nature, hybrid test method can be applicable to test dynamic performance of seismic isolation or energy dissipation device without physically testing whole structure. The application of hybrid test on a frame structure with self-centering energy dissipation device was reported in this paper. The prototype is a 3-story steel frame armed with self-centering energy dissipation device. Before carrying out real test, a simulation of hybrid test flow by running 2 OpenSees processes was performed. The main structure is modeled in Master program while the self-centering energy dissipation device is modeled in Slave program, connected by Simulation Finite Element Adapter experimental control in OpenFresco. The pretest simulation study was conducted to determine suitable loading protocol and input ground motion, as well as check control flow and study the feasibility of this innovative test method.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SEISMIC PERFORMANCE OF NONLINEAR ENERGY SINK WITH NEGATIVE STIFFNESS AND SLIDING FRICTION

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Keywords: *Seismic response control, nonlinear energy sink, negative stiffness, sliding friction, transient internal resonance*

In this paper, negative stiffness and sliding friction are considered in the present nonlinear energy sink (NES), to enhance passive targeted energy transfer from the primary structure to the attached NES under seismic excitation. To this end, a one-story moment-resistant frame is considered as a primary structure, which is attached with the present NES device using sliding and bi-stable geometrical nonlinearities. After deriving the governing equations of the system, numerical optimization is carried out to select the appropriate design of the device. Based on the numerical study results, shake table tests are carried out to verify the control effect. Good agreement between simulation and experiment is derived after the structural identification and calibration. The experimental results validate the numerical predictions that a significant fraction of energy introduced directly to the primary structure by seismic excitation, can be rapidly transferred to the present NES and be dissipated. The seismic performance of the present NES is compared with those of the linear tuned mass damper (TMD) and the cubic NES. The comparison shows that the attenuation observed under the present NES control is competitive and is totally more robust in respect to variation of the primary structural stiffness. This is found to be achieved by an immediate cascade of broadband internal resonance captures especially in low frequency domain, as the essential cause of high efficiency of the present NES system.

MEASURES AGAINST SEISMIC EVENTS BEYOND EXPECTATIONS SUCH AS MEGA-EARTHQUAKES, LONG PERIOD EARTHQUAKES AND VERTICAL MOTIONS

DESIGN METHOD FOR BASE-ISOLATION STRUCTURE COMBINED WITH ACTIVE CONTROL BASED ON THE LIMITATION CONDITIONS OF THE RESPONSES AND CONTROL FORCE

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Keywords: *Active structure control, base-isolation structure, Linear quadratic regulator (LQR), Equivalent model, Controller design method*

The linear quadratic regulator (LQR) is widely used in active structural controls (ASCs). However, at the present stage, the influence of the design parameters (LQR weighing matrices) on the vibration characteristics of the control system has not been explicitly expressed. In particular, the estimation of the required control force has not been conducted. Therefore, the LQR weighting matrices are mainly selected by trial and error approach, making it very difficult to design a control system that achieves the desired performance. To solve this problem, an equivalent model of the single-degree-of-freedom active model (structure with active control) is constructed, using which, a calculation method for the weighing matrices that does not require a trial and error approach to satisfy the desired control performance is proposed. Thereafter, the concept of the transitional response spectrum, which is widely used in structural design, is promoted as a control force spectrum that can be used to estimate the maximum control force. Finally, the design of a passive base isolation (PBI) reactor is discussed as an example, and the performance-oriented design method for the PBI structure combined with ASC is proposed that simultaneously satisfies the limitation conditions of the responses and control force.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

THE NEW UNIFORM VF-ENERGY DISSIPATION DEVICE: REFINED MODELLING

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Keywords: *Hysteretic response, nonlinear model, passive control, seismic isolation devices, energy dissipation devices, displacement control devices*

In the Institute of Earthquake Engineering and Engineering Seismology (IZIIS), Ss. Cyril and Methodius University in Skopje, extensive experimental and analytical research have been performed in the framework of the innovative NATO Science for Peace Project "Seismic Upgrading of Bridges in South-East Europe by Innovative Technologies (SFP: 983828)". The specific project part included development of the innovative USI-SF system representing advanced technology for seismic isolation and seismic protection of bridges. With integration of the newly developed uniform VF-energy dissipation device, highly important advances of the USI-VF system have been achieved. The response of the isolated segment of the structure becomes controlled by simultaneous effects of the present isolation system and the new advanced added damping system. This paper presents refined 3D theoretical modelling of the specific hysteretic response of the main components and the integral prototypes of the developed new uniform VF-energy dissipation devices, under simulated earthquake-like cyclic loads up to deep nonlinearity. Successful model validation was made based on original results obtained from the completed experimental tests. The innovative concept of the adaptive vertical pin-shaped multi-gap energy dissipation device, VF-MG device, has created important improvements and important advanced seismic response features. The multi-gap VF-MG devices introduces the added "adaptive" damping to the commonly isolated system which generally does not possess sufficient damping capacity.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

SEISMIC PERFORMANCE OF BASE-ISOLATED FRAME SUBJECTED TO NEAR-FIELD EARTHQUAKES

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Keywords: *Base isolation; near-field earthquakes; directivity effect; fling-step effect; lead rubber bearing*

The behavior of a base-isolated building frame is investigated with the help of a numerical study for near-field earthquakes with directivity effect and fling step effect. For the study, the nonlinear time history analysis (NTHA) is carried out for a 10-storey building frame, both for the fixed base and base-isolated conditions, subjected to near-field ground motions. Lead rubber bearing (LRB) isolator is selected for providing isolation to the building frame. Two ground motions each with directivity effect and fling step effect are considered. Two levels of earthquakes are assumed in the present study, i.e., design level (scaled to have PGA = 0.2g) and extreme level (scaled to have PGA = 0.4g). The selected response parameters for the comparative study are peak values of inter-storey drift, top floor displacement, top acceleration, number of plastic hinges, isolator displacement, and base shear. Some of the important conclusions of the study are (i) the performance of base-isolated frame is better than the fixed base frame, especially at lower level of PGA, i.e., 0.2g; (ii) at higher PGA level, i.e., 0.4g, the base-isolated frame gets into significant inelastic state; and (iii) Large isolator displacements are induced by the near-field earthquakes, especially for earthquakes with fling-step effect.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SEISMIC PERFORMANCE OF FIXED BASE AND BASE-ISOLATED BUILDING FRAME

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Keywords: *Base Isolation, Seismic Performance, LRB*

Seismic performance of three types of building frames, i.e., fixed base building frame and two base-isolated frames, are compared at the performance points consistent with specified IS earthquake spectrum. For this purpose, a reinforced concrete 6-storey fixed base building frame seismically designed following IS 1893–2016 code is base-isolated for better seismic performance. Keeping the same load conditions and configuration, the frame is also designed according to the proposed base-isolated building code (Draft, IS 1893–2018 Part-6). The lead rubber bearing isolators are used as base isolation system in the buildings. The seismic demands evaluated at the performance points include inter-storey drift, top floor displacement, base shear, and number of plastic hinges. The performance points are obtained for three different assumed PGA levels, namely, 0.2g (design level), 0.4g (medium), and 0.6g (high). The seismic demands obtained from different performances points thus achieved are compared with those obtained from nonlinear time history analysis (NTHA) performed with simulated ground motion consistent with IS 1893–2016 response spectrum. A critical evaluation of the seismic demands for various cases is carried out for identifying efficacies of three building frames under seismic excitations. For the analysis and design standard software ETAB is used. The study concludes that (i) performance of the conventionally designed building is considerably enhanced when it is base-isolated in respect of all seismic demands; (ii) seismic demands at the performance points for the base-isolated frame designed according to the proposed code are better than those of conventionally designed frame in respect to not all but a few demand parameters; and (iii) seismic performance of the conventionally designed frame, when base-isolated is significantly improved at higher PGA levels as compared to the fixed base frame and the designed base-isolated frame. Keywords: Seismic isolation; Lead rubber bearing; Performance points; Seismic demands.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SEISMIC PERFORMANCE EVALUATION BY CAPACITY SPECTRUM METHOD FOR BASE-ISOLATED FRAMES

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Keywords: *Capacity spectrum method, Seismic Performance, Lead rubber bearing*

Performance evaluation of the base-isolated buildings using Capacity Spectrum Method (CSM) at different performance points is relatively less as compared to the target displacement comparison. The present study aims to investigate the efficacy of the capacity spectrum method (CSM) in the prediction of seismic demands as compared to nonlinear time history analysis (NTHA) for base-isolated building frames at different performance points ranging from elastic to plastic state of the structure. To make the study comprehensive one, the comparison is done for a large number of response quantities. In this line, a ten-story base-isolated building frame with lead rubber bearing (LRB) isolators is considered for the analysis. Corresponding fixed base frame is also analyzed as reference for comparison purposes. Performance points are obtained by modified CSM as per FEMA 440, which are consistent with three peak ground acceleration (PGA) levels including (i) 0.2g, low PGA; (ii) 0.4g, medium PGA; and (iii) 0.8g, and also, at the collapse point. IS 1893–2016 response spectrum compatible time histories, which are artificially generated and scaled to the aforementioned PGA levels, are used for NTHA. The results of the study reveal that the CSM is good in predicting the seismic demands in base-isolated building frames up to a specific performance point consistent with the low PGA level. Beyond this level, the difference in some response quantities between CSM and NTHA increases with increase in the PGA. Keywords: Capacity spectrum method; Performance point; Nonlinear time history analysis; Lead rubber bearing; Base isolation

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

SEISMIC FRAGILITY ANALYSIS OF SPHERICAL STORAGE TANK WITH SIMPLIFIED FINITE ELEMENT MODEL

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Keywords: *spherical tank, seismic analysis, fluid-structure interaction, simplified model, fragility curves*

A three-dimensional simplified model is presented for conducting seismic fragility assessment of the spherical liquid storage tank. The proposed model consists of concentrated fluid mass assigned to the beam-column element through rigid links. Before conducting fragility analysis with the simplified model, its validation was done by comparing seismic analysis results through FSI (fluid-structure interaction) model. FSI model is characterized liquid element that can exhibit proper fluid-structure interaction and sloshing behavior. Seismic behavior of the simplified model and FSI model was studied at different filling state. Time history analysis was performed for 50% and 80% filling state to compare seismic base shear and overturning moment results for the simplified and FSI model. Once the seismic results were checked and validated, fragility analysis was carried out by the simplified model. A set of 18 different ground motions were selected from the historic earthquake database. Nonlinear time history analyses were performed to obtain strength of spherical storage system at different limit states. Finally, fragility curves were developed based on the maximum likelihood estimation approach with respect to defined strength limit states.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

RESPONSE SPECTRUM METHOD FOR THE DESIGN OF ISOLATED BUILDINGS

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An isolated building, composed of the superstructure and the isolation system, whose damping levels are significantly different, is typically non-classical damping system. This results in inapplicability of traditional response spectrum method for the design of isolated buildings. A multidimensional response spectrum method based on complex mode superposition is herein introduced, which properly takes into account the non-classical damping feature in the isolated structure. From the base-isolated benchmark model, as a numerical example, application of the procedure is illustrated companying with comparison study of time-history method, traditional response spectrum method and the proposed method. The results show that the proposed method is valid, while the traditional approach cannot reflect the damping characteristics of isolated buildings and may lead to insecurity of structures.

7 STANDARDS FOR DESIGN, CONSTRUCTION, MAINTENANCE

EVOLUTIONARY POWER SPECTRAL MODEL FOR THE FULLY NON-STATIONARY GROUND MOTIONS AND ITS ENGINEERING APPLICATION

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Keywords: *fully non-stationary; evolutionary power spectral density; generalized harmonic wavelet transform; time-varying parameters; bedrock filter; K-T spectrum*

Based on the power spectral model of filtered Gaussian white noise which is in the stationary earthquake process, the parametric model of fully non-stationary time-varying power spectrum is developed for describing time-varying spectral energy, and a model parameter with engineering significance is obtained through parameter identification. Firstly, the use of bedrock filter to modify the K-T spectrum makes the time-varying spectral parameters have a clear physical meaning and which is more consistent with the physical characteristics of the bedrock ground motion. Furthermore, the time-frequency distribution of the seismic is acquired on account of the generalized harmonic wavelet transform, and the time-varying power spectrum of the actual ground motion is estimated by the Spanos-Tratskas method. At last, genetic algorithms and second optimization technology are introduced to fit mathematical expressions of time-varying parameters, and a fully non-stationary time-varying power spectral model of ground motion is established. The Japanese KIK-net strong earthquake database is adopted to identify the model parameters, which is reclassified according to the site category in China. Finally, the validity and applicability of the model are verified by the spectral representation method. The ground motion random model proposed in this paper provides a more accurately reference for describing the earthquake, and also provides a basis for the simulation of fully non-stationary ground motion.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

TRANSVERSE VIBRATION AND BUCKLING ANALYSIS OF THIN CIRCULAR PLATE UNDER ARBITRARY IN-PLANE LOAD

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Keywords: *thin disk; in-plane load; Ritz method; transverse vibration; natural frequency; buckling*

Based on the stress distribution formulae for the plane of half infinite space under the single concentrated force and using the superposition principle of external loads, the stress distribution expressions in a circular disk are obtained when the disk is subjected to the self-balance concentrated force system in the plane. Furthermore, the stress expressions for the disk subjected to distributed force system in the plane are obtained by the use of integral calculations. Take the product of Chebyshev polynomial and boundary function as the trial function, the general eigenvalue equations for transverse free vibration and buckling are obtained by means of the Ritz method. By solving the eigenvalue equations, the natural frequencies and critical buckling load of the thin disk under the action of any surface loads are obtained. This method can not only give highly accurate results and fast convergent rate, but also guarantee small computational cost and easy programming.

EXPERIMENTAL STUDY OF SEISMIC BEHAVIOR OF PRECAST CONCRETE LAYERED SLAB AND BEAM TO COLUMN INTERIOR JONTS

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Keywords: *precast frame structure; exterior joint; low-cycle reversed loading test; seismic performance*

In order to study on the seismic performance of beam to column joints of high-rise precast concrete structure, which select the interor joints of the bottom layer, middle layer and the top layer of a 100 meters high precast concrete structures.structures, an experimental study on full-scale beam to column joint models subjected reversed cyclic loading was conducted.The study focuses on the influence of joint and beam bar anchorage on the seismic behavior of beam column joints, and that through the test comparison: Precast concrete structure and Cast concrete structure have the similar seismic performance; Steel through set or effective anchorage in beam to column joints have the same seismic performance

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

EXPERIMENTAL STUDY OF VARIABLE STIFFNESS SEISMIC ISOLATOR OF SERIES CONNECTION

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Keywords: *seismic-isolation technology, variable stiffness seismic-isolator of Series connection, elastomeric isolator.*

Laminated bearing rubber is one of the key factors of seismic-isolation technology, this paper developed a series of variable stiffness laminated bearing rubber. In the initial stages, the isolators have smaller horizontal stiffness (less than the minimum shear stiffness of the combined isolator), this variable stiffness device will play its role, when the horizontal shear deformation arrive the design target displacement, the isolators have larger horizontal stiffness. Through full scale experiment, study the properties of variable stiffness Laminated bearing rubber, including compressive properties, shear properties and hysteretic behavior properties.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

THE SEISMIC RESPONSE ANALYSIS OF KEEL ARCH ACCORDING TO VERTICAL GROUND MOTION

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Keywords: *Seismic Design, Spatial Structure, Vertical Ground Motion, Seismic Response*

Since the earthquake motion is three-dimensional, vertical ground motion can occur along with horizontal earthquakes. Especially, in the case of large spatial structure, the effect of vertical ground motion is much affected by vertical ground motion due to dynamic characteristics such as vibration mode. In this study, the seismic response of the keel arch according to horizontal and vertical ground motion is analyzed through the linear elastic time history analysis. As a result, the vertical displacement response at 1/4 point of the span occurred largely when horizontal ground motion occurred however the vertical displacement response at center point of the span occurred largely when vertical ground motion occurred. Therefore, the seismic load combination considering horizontal and vertical ground motion is analyzed.

4.RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

STUDY ON DAMPING EFFECT OF VARIABLE FRICTION DAMPER WITH BUTTERFLY HYSTERETIC CURVE

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Keywords: *butterfly hysteretic curve; hysteretic curve; variable friction damper; energy dissipation; passive vibration control; additional damping ratio*

The variable friction damper with «butterfly» hysteretic curve has a small sliding force. After sliding, the damping force increases with the deformation, hysteretic curve is like a butterfly with large ends and small middle. As this kind of variable friction damper does not need a large sliding force, when the damper in the initial state (accounting for the majority of its expected service life),there is no need of large pre-tightening force, thus avoiding the relaxation creep problem of the pre-tightening system. In this paper, several typical variable friction dampers with butterfly hysteretic curves are introduced, and illustrated the simulation methods of this kind of dampers. Then the theoretical method of its additional damping ratio is given and the energy dissipation effect of variable friction dampers with different parameters is investigated in practical project.By the contrast analysis, the influence of the parameters of the «butterfly» hysteretic curve variable friction damper on its energy dissipation effect is studied.Finally, the points needing attention in structural design of variable friction damper are given.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

STUDY ON SEISMIC RESPONSE OF ISOLATED LNG STORAGE TANK CONSIDERING INSULATION

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Keywords: *LNG storage tank; insulation; isolation; simplified mechanical model; numerical simulation method*

Insulation can transfer load between inner and outer tank walls in LNG(Liquefied Natural Gas) storage tank. To study the effect of insulation on LNG storage tank, a 5-particles simplified mechanical model of LNG storage tank with insulation is proposed and used to calculate the base shear, bending moment and sloshing wave height under the anti-seismic and isolated conditions. Meanwhile, the finite element platform ADINA is used to calculate the seismic responses and compare with the simplified mechanical model results. The results show that: the seismic responses between the two methods are similar, the 5-particles model is more reasonable and has larger responses than numerical simulation method. Besides, the insulation has a certain damping effect on anti-seismic LNG storage tank, but has a rare damping effect on isolated LNG storage tank.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

RESEARCH ON VARIABLE CURVATURE ROLLING ISOLATION OF HORIZONTAL STORAGE TANKS

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Keywords: *Horizontal storage tanks; Rolling isolation; Simplified mechanical model; Ground motion response*

In order to reduce the seismic response of horizontal tank equipment in the petrochemical industry, according to the structural characteristics of horizontal storage tank, it can be considered to install variable stiffness rolling isolation devices at the base of storage tank. The isolation layer stiffness increases with the increase of isolation layer displacement, which can effectively reduce the seismic response and displacement of structure. Based on potential fluid theory, this paper deduced the simplified mechanical model of horizontal storage tank variable stiffness rolling isolation considering liquid sloshing effect. The numerical analysis method was used to study the horizontal tank seismic response. The results showed that variable stiffness rolling isolation can effectively reduce the seismic response of horizontal storage tank, especially the base shear force, overturning moments, and also have a certain control over the sloshing wave height of liquid storage. The variable stiffness rolling isolation device can effectively reduce hydrodynamic pressure, especially the rigid hydrodynamic pressure. It is recommended that the seismic design of horizontal storage tanks can adopt variable stiffness rolling isolation.

STANDARDS FOR DESIGN, CONSTRUCTION, MAINTENANCE

PROPOSAL FOR THE DESIGN DISPLACEMENT ESTIMATING OF SEISMIC ISOLATION SYSTEMS IN PERU

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Keywords: *insulation system, time history analysis, design spectrum of pseudo acceleration, target risk*

A proposal for the design displacements of seismic isolation systems (DD) are presented. DD were obtained as a function of the pseudo-spectral acceleration defined in the Peruvian code E.030 (2016), amplified by a factor that relates the spectral acceleration in the direction of the Maximum response (MD), and the geometric mean (Geoman), calculated using a set of 28 Peruvian seismic records grouped into two types of soil (firm soil and soft soil). Also, displacements for the probable maximum earthquake (DM) was calculated amplifying DD with a factor calculated as the ratio between the spectral acceleration with a 1% risk target in 50 years and geoman of the set of Peruvian records. The study concludes that design displacements can be obtained by amplifying the spectral displacements calculated using the E.030 code by factors of 1.20 for periods shorter than 1.0 sec and 1.3 sec for longer periods. In addition, displacements for the probable maximum earthquake with a uniform risk target of 1% in 50 years can be obtained by amplifying DD by a factor of 1.25

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

INVESTIGATION ON THE EFFECTIVENESS OF DAMPERS FOR RETROFITTING THROUGH SEISMIC RESPONSE ANALYSES UNDER REAL AND SIMULATED MOTIONS

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Keywords: *Dampers, Reinforced Concrete Frame Structure, Real Records, Stochastic Finite-Fault Ground Motion Simulation Technique, The 1999 Duzce (Turkey) Earthquake (Mw=7.1)*

Earthquakes are among the most destructive natural hazards to the built environment resulting in economic losses as well as fatalities. Recently, many studies are focused on reducing the potential loss induced by ground shaking to the built environment. A recent and reliable tool to mitigate the potential risk is the implementation of dampers. The effect of dampers varies depending on the building seismic hazard, dynamic properties, and damper parameters. In this study, the effect of dampers is investigated for the case of a mid-rise building under a selected set of earthquake ground motions. The selected building is a 7-story 3-bay reinforced concrete frame structure where the dampers are installed for retrofitting purposes. The set of ground motion records includes both real and simulated records of the 1999 Duzce (Turkey) earthquake with Mw=7.1. The simulated ground motion records are generated with stochastic finite-fault technique with dynamic corner frequency approach. The structure's numerical model is built in OpenSees finite-element analysis software and its response to earthquakes is simulated through nonlinear time history analysis. The analysis results are investigated in terms of the maximum drift ratio of the frames to observe the effectiveness of dampers. The responses under simulated records are also compared against the real responses in order to comment on the future use of simulated motions in damped buildings.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

THE NEW UNIFORM VF-ENERGY DISSIPATION DEVICE: PROTOTYPE TESTING

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Keywords: *Hysteretic response, nonlinear model, passive control, seismic isolation devices, energy dissipation devices, displacement control devices, seismic vulnerability*

In the Institute of Earthquake Engineering and Engineering Seismology (IZIIS), Ss. Cyril and Methodius University in Skopje, extensive experimental and analytical research have been performed in the framework of the innovative NATO Science for Peace Project «Seismic Upgrading of Bridges in South-East Europe by Innovative Technologies (SFP: 98382In order to research the reinforcement effects on masonry structure strengthened with external prefabricated reinforced concrete wall and investigate the possibility of adding-story isolation in the top of reinforced masonry structure, the shaking table tests of three 1/4 scaled models are conducted. These three models are reinforced masonry structure model, reinforced masonry structure with adding-story model and reinforced masonry structure with adding-story isolation model. The dynamic characteristics and seismic response of models are evaluated under different levels of earthquake. And then, the models experienced under a lot of rare seismic cases are tested again to analysis the dynamic responses of damaged structures. The results indicate that adding-story isolation structure could prolong the structural vibration periods efficiently and increase the damping ratio. Whiplash effect of superstructure of adding-story non-isolation structure is very obvious. Adding-story isolation structure can not only reduce seismic response of the substructure effectively, but also reduce the seismic response of the superstructure; therefore, reinforcement effect and seismic performance of adding-story isolation structure are significant. On the other hand, the isolating effect of seismic damaged structure will decreased obviously. Accelerations of lower masonry may be larger than the other two models. The negative impact must be taken into account in the design.

EXPERIMENTAL AND ANALYTICAL STUDY ON BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES APPLYING SEISMIC RESPONSE CONTROL TECHNIQUE

RESPONSE CONTROL OF BASE ISOLATED LIQUID STORAGE TANK UNDER BI-DIRECTIONAL EARTHQUAKE

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Keywords: *FEM; NTHA; Base Isolations; Angle of incident*

Failures of liquid storage tanks are observed during earthquakes. Thus, their protection has drawn the attention of researchers. In the present study, the behavior of the liquid storage tank is investigated under the action of a bi-directionalearthquake and base isolation devices are implemented to control the responses of liquid storage tanks. A nonlinear timehistory analysis of the liquid storage tank under bi-directional ground motions is carried out using ABAQUS which usesArbitrary Lagrangian-Eulerian (ALE) FEM for solving Fluid-structure interaction problem. Five base Isolators, four at the four corners of the tank and one in the middle, are provided to control the responses of the liquid storage tank. The parameters varied are the different ground motions and the angle of incidence of the earthquake with respect to the principal axis of the tank. The response parameters considered for investigation include the sloshing height, the base shear, the overturning moment and the Von-Mises stress in the tank wall. The study shows that base isolation can adequately control the stresses developed in the tank but amplifies the sloshing wave greatly.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

A HEURISTIC APPROACH FOR OPTIMAL DESIGN OF BRACE-TYPE HYSTERETIC DISSIPATORS FOR SEISMIC PROTECTION OF FRAMED BUILDINGS

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Keywords: *Buckling restrained braces, seismic retrofitting, passive control, optimization*

A number of brace-type hysteretic dissipators have been proposed for seismic protection of framed building structures; among them, the so-called buckling-restrained braces have experienced wide development, with extensive research and many actual implementations. As in any supplementary damping system, at least two devices per floor and per direction are installed, preferably in the building façades. Then, a major design issue is the selection of the values of the parameters that characterize the structural behavior of each device; although a number of criteria have been provided, this is still basically an open question. This paper presents a heuristic optimization approach to select such design parameters; the proposed strategy is based on a Particle Swarm Optimizer. In this formulation, the objective function is the minimization of the maximum drift and the base shear force under a representative set of earthquake ground motions; the constraints refer to functional and architectonic requirements. The aforementioned design parameters are the initial (elastic stiffness), the yielding force, and the final (post-yield or plastic) stiffness. An application example on five steel frames is presented. The ensuing nonlinear dynamic analyses are carried out using the software Opensees.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

COMPARISON OF STRUCTURAL RESPONSES FOR A BASE ISOLATED BUILDING UNDER REAL AND SIMULATED RECORDS

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Keywords: *Base Isolation, Steel Moment-Resisting Frame, Real Ground Motions, Simulated Ground motions, Structural Response Parameters*

In recent decades, base isolation systems for buildings have been commonly used as retrofitting strategy in earthquake-prone areas. Evaluation of structural responses for such base-isolated systems subjected to severe earthquakes is challenging since some regions have very few and scattered ground motion data set. Simulated ground motions can be an alternative to overcome this issue. There are several ground motion simulation methods available that provide varying levels of goodness fit between observed and synthetic data; therefore, simulated motions need to be investigated in terms of their efficiency in the prediction of alternative structural demands corresponding to base-isolated buildings. In this study, a six-story steel moment-resisting frame is selected from the SAC Steel Project and retrofitted with lead rubber bearings in accordance with ASCE 7-10. Then, nonlinear inelastic time-history analysis of the structure is carried out using the real and simulated records of the 6 April 2009 L'Aquila (Italy) earthquake (Mw=6.3). For this purpose, simulated records of the 2009 L'Aquila earthquake generated based on the Hybrid Integral-Composite method are employed. The results of analyses from the observed and simulated sets of this event are compared in terms of alternative response parameters such as inter-story drifts, base displacements, base shear and accelerations at each story level. Overall, the results show that the difference in terms of the real and estimated demand parameters from the ground motion simulation technique is negligible.

RESEARCH AND DEVELOPMENT OF SEISMIC RESPONSE CONTROL DEVICES, WHICH ARE INNOVATIVE, OR RELIABLE AND LOW-COST

EXPERIMENTAL STUDY ON OUT-OF-PLANE STABILITY OF BUCKLING-RESTRAINED BRACES

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Keywords: *buckling restrained brace, out-of-plane buckling, cyclic loading test, gusset rotation, out-of-frame plane drift, seismic design*

Buckling-restrained braces (BRBs) can efficiently absorb seismic input energy through fully yielding of steel core in both tension and compression. Thus, they have been widely adopted as structural fuses for seismic buildings. Buckling limit states in buckling-restrained braced frames (BRBFs) are commonly evaluated using simplified procedures. These procedures are based on three independent stability assessments for the BRB steel casing, end region and gusset. However, BRB out-of-plane instability has been observed in several brace and sub-assemblage tests. It appears that these three individual stability limit states are over-simplified without considering their coupling effects on the overall stability. Takeuchi et al. proposed an advanced method to evaluate the global BRB out-of-plane stability, incorporating the coupling effects of the aforementioned three limit states. However, their buckling models exclude the failure mode of plastic hinges formed at gussets with severe flexural deformation along the restrainer. In this study, Takeuchi's procedures are adopted and extended to assess the strength capacity of this buckling mode considering the flexural stiffness of the restrainer. An evaluation method using ABAQUS model analysis developed to quantify the gusset's rotational stiffness and strength. In order to verify the effectiveness of these extended procedures, cyclically increased axial deformation loading tests on four full-scale BRBs are conducted up to the compressive buckling or tensile fracture. These specimens, each of 5.8 m long with a 1670 kN yield capacity, are fabricated and tested with different restrainer sizes, gusset thicknesses, with and without gusset edge stiffeners or out-of-plane drift. The proposed procedure predicts an increase of over 80% in the overall stability with a 24% enlargement in the steel casing diameter, indicating the critical effects of the restrainer flexural stiffness. Test results show only a 13% increase in the buckling strength by adding gusset stiffeners, and a 10% decrease in the buckling strength due to 0.014 radian of out-of-plane story drift. It is confirmed that the predicted stability limit strengths agree well with the experimental results. These highlight the sensitivity of the overall BRB out-of-plane stability to the restrainer flexural stiffness, gusset stiffener, and out-of-plane drift. This paper concludes with the stability evaluation procedures considering the flexural deformational effects of the restrainer for practical BRBF design.

DESIGN AND APPLICATION OF SEISMIC RESPONSE CONTROL TECHNIQUE TO BUILDINGS, BRIDGES AND OTHER CIVIL STRUCTURES

RESEARCH ON VARIABLE CURVATURE ROLLING ISOLATION OF HORIZONTAL STORAGE TANKS

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Keywords: *Horizontal storage tanks; Rolling isolation; Simplified mechanical model; Ground motion response*

In order to reduce the seismic response of horizontal tank equipment in the petrochemical industry, according to the structural characteristics of horizontal storage tank, it can be considered to install variable stiffness rolling isolation devices at the base of storage tank. The isolation layer stiffness increases with the increase of isolation layer displacement, which can effectively reduce the seismic response and displacement of structure. Based on potential fluid theory, this paper deduced the simplified mechanical model of horizontal storage tank variable stiffness rolling isolation considering liquid sloshing effect. The numerical analysis method was used to study the horizontal tank seismic response. The results showed that variable stiffness rolling isolation can effectively reduce the seismic response of horizontal storage tank, especially the base shear force, overturning moments, and also have a certain control over the sloshing wave height of liquid storage. The variable stiffness rolling isolation device can effectively reduce hydrodynamic pressure, especially the rigid hydrodynamic pressure. It is recommended that the seismic design of horizontal storage tanks can adopt variable stiffness rolling isolation.

EXHIBITORS

HENGSHUI ZHENTAI SEISMIC ISOLATION INSTRMENT CO.,LTD

CHINA

Introduction: Hengshui Zhentai Seismic Isolation Instrment CO.,Ltd was founded in 1997. It is a professional manufacturer of rubber bearings for building isolation, rubber bearings for equipment isolation, bridge bearings, bridge expansion devices and energy dissipation dampers. After years of development and growth, the company has become the leading enterprise in the field of seismic absorption and isolation in China.
The registered capital of the company is RMB 100 million, covering an area of 150,000 square meters and a building area of more than 55,000 square meters. Zhentai company adopts a modern management model and implements the general manager responsibility system under the leadership of the chairman. There are the chief engineer, deputy general manager of production and deputy general manager of business in charge of technology, quality inspection, production and sales.

Jiangsu ROAD Damping Technology CO., Ltd (ROAD) is incorporated in China in 2008 and specialized in the shock and vibration control, and supplied more than 20,000 sets of dampers for more than 500 civil and industrial projects for the protection against earthquakes and wind effects in China and abroad.
ROAD is one of the few manufacturers equipped with the 3500kN dynamic load testing machine for viscous fluid dampers, and able to develop and test it's the state-of-the-art products independently.
ROAD, working with its partner, can offer the customized solution as a turnkey Damper contractor for seismically upgrading project by installation of dampers, including the structural design, manufacture, test, supply and installation of dampers.

OOO «DSHR»

RUSSIA

OOO “DSHR” performs all types of the reconstruction and repair works on the bridge constructions, produces and supplies state-of-the-art-type expansion joints and anti-seismic devices, manufactures elastomeric bridge bearings of any dimensions, spherical bridge bearings. Specialists of the company execute individual client-oriented approach at every stage of the project: design, manufacture, installation and technical maintenance.

HIRUN INTERNATIONAL CO LTD

CHINA

Hirun International Co.Ltd. Is a specialized company that operates In the field of civil engineering structures to identify the best technical solution supporting structural and architectural designers.
The main topics of Hirun International Co.Ltd. are the design, supply and technical assistance referred to several technologies like:
- Structural bearings
- Seismic devices
- Post tensioning systems
- Expansion joint

TİS TEKNOLOJİK İZOLATÖR SİSTEMLERİ SAN. VE TİC. A.Ş.

TURKEY

TİS Teknolojik İzolatör Sistemleri (Technological Isolation Systems), founded in 2014 in Ankara, Turkey, is the first and only Turkish company that makes design, production and domestic and overseas sale of Friction Pendulum type seismic isolator devices and structural bearings, complying with proper certificates.
In addition to CE Certificate, TİS has the Integrated Management System (IMS), which is formed by combination of ISO 9001, ISO 14001 and OHSAS 18001 procedures. Using this know-how and background, TİS provides reliable and high-quality service.
Operating in a production facility with 50,000 m2 closed and 200,000 m2 open space, TİS also has its own isolator test laboratory that can perform different static and dynamic test procedures.
By being capable of not only producing creative and reliable solutions to diverse earthquake and structural engineering problems, but also conducting R&D projects that are supported by various institutions, TİS aims to be one of the leading companies in the seismic devices and structural bearings field, by expanding its export network to the whole world.

MAURER

GERMANY, RUSSIA

Today, the strength of MAURER is largely founded on the long tradition of the company. Its history started back in 1876 with Friedrich Maurer in Munich – whose business expanded quickly in this early stage of the most rapid period of industrialization in Germany. At the outset, his craft manufacture focused on the forming of sheet metal, but by the late 19th century, it had transformed into a full-grown metal factory. In 1925, MAURER moved to the North of Munich – where it still remains today. At the time, MAURER had already attracted attention with the first steel and bridge constructions.

When Johannes Beutler acquired the company in the 1930s, it became well known for the construction of airport hangars and gates. By the end of the Second World War, a major part of the manufacturing plants had been destroyed or dismantled. However, in the 1960s, the company restored its former strength: it's specialization in bridge construction proved to be the right path for further growth. In 1993, MAURER started to develop and manufacture roller coasters. The next coup followed three years later: after intense research work, MAURER established the business unit Seismic Devices. After factories were founded in Turkey and China in 1999, additional branches in Russia, France and China were set up until 2004.

THE GERB GROUP

GERMANY, RUSSIA

More than 100 years ago, the history of GERB began when its founder, William Gerb, became fascinated with an idea that others thought could never be successful. He accepted the challenge of using steel springs to protect work areas and surrounding neighbourhoods from machinery vibrations. Since then, the GERB Group of companies has continued to develop this idea, solving dynamic problems in many new fields of application.

Machinery and equipment in power generation and metal forming plants now employ an active vibration isolation system (source isolation), to reduce foundation size and cost. Sensitive measurement and test equipment, and even entire buildings, employ a passive isolation system (receiver isolation) to protect against disturbing vibrations from nearby machines and traffic, or from earthquakes. Both active and passive isolation systems permit easy realignment of the foundation when poor soil conditions cause the foundation to settle.

Tuned mass dampers are a special type of vibration protection, used to stabilize and reduce vibrations on bridges, buildings, stadiums and ships.

FREYSSINET

ITALY

Founded over 70 years ago by Eugène Freyssinet, the inventor of prestressing, Freyssinet brings together an unrivalled range of skills in the specialist civil engineering sector, offering integrated technical solutions in the fields of construction and structural repair.
Freyssinet is involved in numerous projects across five continents, making it the world leader in its specialist areas of:
- prestressing,
- cable-stayed structures,
- construction methods,
- structural accessories,
- structural repair and strengthening,
- structural maintenance.

These activities are performed on a wide range of structures, including civil engineering structures, buildings, skyscrapers, industrial installations, power production plants, offshore platforms, transport and sporting infrastructure, and more.
Freyssinet is a subsidiary of the Soletanche Freyssinet Group, a world leader in the soils, structures and nuclear sectors.
Freyssinet's ambition is to be the reference in the field of specialist construction.
Driven by a strong culture of safety, excellence and performance, our vision is to be the partner of choice in the construction, repair and maintenance of structures.
Through responsible leadership of our men and women, we will strive to be at the forefront of innovation and to anticipate the future needs of our Clients.
Responding to evolving markets, we will pursue our international development combining our global competence with our local networks to further enhance our range of services.

Тульский МеталлоПрокатный Завод
«Стальные решения ваших идей»

LLC "METAL ROLLING PLANT"

RUSSIA

LLC "Metal Rolling Plant" has been operating since 2013. The basis of the plant is a modern small-grade rolling mill 300 with a capacity of 10 thousand tons per month of hot-rolled products. Our enterprise offers the wide range of high-quality fittings of both classical, and a screw profile, soil anchors, mine support and accessories to them. Production of our plant finds application in such areas as mining, geotechnics, civil, industrial and road construction. For building purposes, the enterprise has developed and produces a unique a screw profile and connecting couplings to it significantly reducing metal content of reinforced concrete structures.

LLC "INTELTEST"

RUSSIA

LLC "Inteltest" is Russian representative of Bangalore Integrated System Solutions (P) Ltd., (BiSS http//biss.in) -leading Indian developer and manufacture of different servo-controlled test systems including shake tables for seismic applications. The experience of over twenty years of innovation allows us to design and produce sophisticated solutions for most exacting customers requirements. High-end control electronics and the software using for seismic applications are allowed us to offer complex solution for controlling up to 3-axis 6 degrees-of-freedom systems to provide most common seismic applications. BiSS is offering wide range of testing solutions for seismic application starting from basic one or two axis testing system up to unique all-in-one design 3 axis 6 DOF system with reaction frame.
LLC "Inteltest" is providing full technical and sales support of BiSS testing systems in Russia and CIS. We'll be glad to provide you any possible assistance in case of interest in any BiSS testing solution.

THE JAPAN SOCIETY OF SEISMIC ISOLATION

JAPAN

The Japan Society of Seismic Isolation promotes seismic isolation (SI), thereby contributes to the construction of safer and higher quality buildings.
*Disseminating the proper usage of SI and improve SI technology
*Contribution to the development and improvement of reliable seismic-resistant technology based on standards for safe and quality buildings.

THE RUSSIAN ASSOCIATION FOR EARTHQUAKE ENGINEERING

RUSSIA

The activity of RAEE is aimed at:
- development of preventive measures to protect the population and territories from natural and manmade impacts, analysis and elimination of their consequences;
- development and implementation of legal and economic norms and standards to ensure the protection of the population and territories from natural and manmade impacts;
- introduction of new technologies in construction to ensure seismic safety of buildings and structures;
- participation in the preparation and implementation of measures to improve the skills of specialists related to the safety and reliability of buildings and structures in seismic regions;
- protecting the property and copyright of the members of the Association;
- organization of information support (conferences, seminars);
- publication of scientific and methodical literature and scientific and technical journal "Earthquake Engineering. Constructions safety".

LIRA SOFT

RUSSIA

"LIRA soft" is a team of highly qualified specialists, experts, designers, calculators, analysts and developers who possess advanced technologies and programming methods, innovative approaches to design and calculations.

The company "LIRA soft" is the acting member of SRO Alliance "SPB". Certificate: no. 573/17 from 28.03.2017.

"LIRA soft" is a Russian developer of the LIRA 10 design complex – a modern and convenient tool for the numerical study of the strength and stability of structures, buildings and structures by the finite element method. The program is designed for modeling and calculation of buildings and structures of any complexity – from simple frames to high-rise buildings and unique structures such as stadiums, airports, etc.

The calculations are made in the form of a report showing all the results: the collection of loads, deflections and displacements, forces and stresses, reinforcement isofield and the percentage of use of metal and reinforced concrete structures, the results of the calculation of stability and dynamic effects, the main conclusions and recommendations. The report on the results of calculations or scientific and technical support can be provided to the state examination and other state and non-state authorities. The calculated model is imported and exported without data loss.

LIRA 10 enables the integration of advanced BIM systems such as Autodesk Revit, Tekla Structures, Renga and others.

Ease of use in combination with a simple and intuitive single interface – the main ideas laid down in the concept of the LIRA 10 software complex.

ЦНИИСК
ИМ. В.А. КУЧЕРЕНКО

TSNIISK

RUSSIA

The Institute was founded in 1927 to create and improve the scientific and technical base of the construction complex of the country.
In our Institute were laid the foundations of Russian construction science. The activity of TSNIISK has had a decisive influence on the formation of the most important areas of the theory of strength and reliability. On the basis of the method of limit s tates, the theory of shells, plasticity, seismic resistance and evaluation of the impact of various dynamic loads modern principles of calculation of all types of building structures were developed. Today TSNIISK successfully works as a division of Joint Stock Company "Research center "Construction", established by the Federal Agency for state property management in the structure of the Ministry of regional development.
No large-scale construction project in the country is complete without the participation of TSNIISK. Recall, for example, that one of the authors of the project of Luzhniki Large sports arena was a former Director of the Institute V.N. Nasonov. Almost all the old and new sports facilities in Moscow and the capital region were built with the scientific and technical assistance of our scientists. TSNIISK actively worked at the facilities of the 2018 FIFA World Cup. The Association of the leading scientific forces of the construction complex of the Russian Federation and their joint efforts of JSC "SIC "Construction" allow TSNIISK named after V. A. Kucherenko implement the strategic partnership and fruitful cooperation with the Institute of foundations and underground structures named after N. M. Gersevanov (NIIOSP) and Research Institute of concrete and reinforced concrete named after A. A. Gvozdev (NIIZHB).