17WCEE 17th WORLD CONFERENCE ON EARTHQUAKE ENGINEERING

With Bosai / Disaster Management Expo in Sendai

At Sendai International Center, Sendai, Japan (Hybrid Conference)

Links

International Association for Earthquake Engineering

Japan Association for Earthquake Engineering

Proceedings

As the spread of the COVID-19 has become a problem around the world, many countries are facing health and economic issues. In addition, many of you are also being subjected to various restrictions in your daily life, as movements inside and outside of the country, and visits and meetings with other people are restricted. First of all, I would like to sincerely wish for the health of you, your family and colleagues, and for an early resolution of the COVID-19 problem.

As mentioned in previous communications, the 17th World Conference on Earthquake Engineering (17WCEE) was originally planned to be held from September 13 to 18, 2020, but due to the COVID-19 problem, we, the 17WCEE Organizing Committee, decided to postpone the 17WCEE by one year, to be held from September 27 to October 2, 2021, the 10th anniversary year of the 2011 Great East-Japan Earthquake and Tsunami Disaster in the same venue, in Sendai City, Miyagi Prefecture, Japan. At the same time, we promised that the full papers submitted by the end of March 2020 will be published as 2020 17WCEE Proceedings in September 2020.

I am very happy to inform you that delivering on this promise, the Proceedings has been successfully published this month with the support of all 17WCEE related people. The 17WCEE Organizing Committee would like to express sincere appreciation to those involved. The Proceedings contains over 2,500 full papers submitted by the end of March 2020 after completing all registration procedures by the deadline. Although the 17WCEE will be held in 2021, the papers published in the Proceedings become the author's research achievements in 2020 and can be widely referred to and utilized in the world.

Also, based on the one-year postponement of the conference, we will accept additional papers and combine them with the 2020 17WCEE Proceedings, and publish them in September 2021 as 2021 17WCEE Proceedings.

The 17WCEE Organizing Committee will do its best to successfully hold the 17WCEE in 2021.

Kimiro MEGURO
Chair, 17WCEE Organizing Committee
Professor, The University of Tokyo

Official Announce Letter is here.

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JAPAN ASSOCIATION FOR EARTHQUAKE ENGINEERING

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17WCEE News Letter

With Bosai Expo

Bosai / Disaster Management Expo in Sendai

仙台市 City of Sendai

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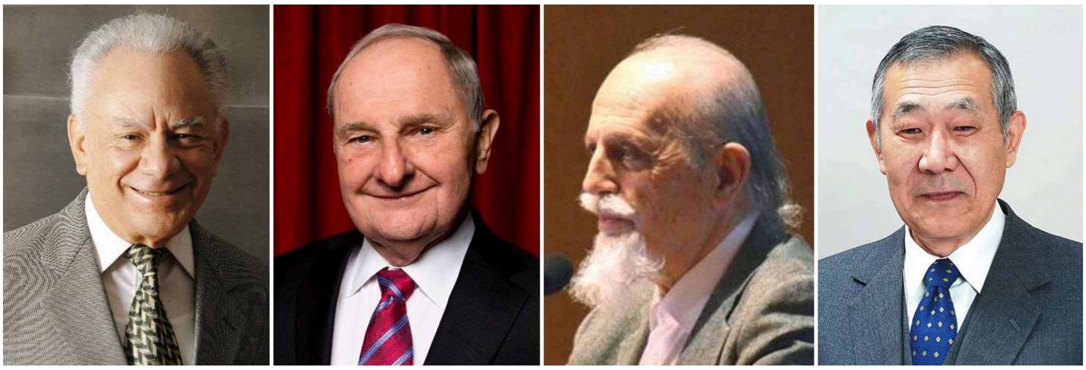
Meet the Masters



In "Meet the Masters"organized by IAEE (International Association for Earthquake Engineering), we invite great names of earthquake engineering to WCEE. The four masters listed below are invited to 17WCEE. For each master, a special session related to the master's expertise is organized during WCEE, in which the master offers a keynote lecture. To make the session run most smoothly, a person who has been close to the master is asked to serve as a moderator.

The Masters at the 17WCEE are:

*Prof. James Jirsa (USA)
*Prof. Tsuneo Katayama (Japan)
*Prof. Luis Esteva (Mexico)
*Prof. Theo Tassios (Greece)

To encourage young researchers/practitioners and students particularly from developing countries

Keynote Lectures

*The speakers and the lecture materials may change without prior notice.

Professor Kojiro Irikura

Professor

Aichi Institute of Technology, Japan

For more details

Professor Satoshi Fujita

Professor

Tokyo Denki University, Japan

For more details

Mr. Niels B. Holm-Nielsen

Practice Manager

Global Facility for Disaster Reduction and Recovery (GFDRR)

For more details

Dr. Robert J. Budnitz

Staff Scientist (retired)

Lawrence Berkeley National Laboratory, University of California, USA

For more details

Dr. Amod Mani Dixit

General Secretary

National Society for Earthquake Technology (NSET), Nepal

For more details

Professor Tracy Kijewski-Correa

Professor

The University of Notre Dame, USA

For more details

Invited Lectures

*The speakers and the lecture materials may change without prior notice.

Professor Xilin LU

Professor

Research Institute of Structural Engineering and Disaster Reduction, College of Civil Engineering, Tongji University, China

For more details

Professor Gregory G. Deierlein

John A Blume Professor of Engineering,

Stanford University, USA

For more details

Dr. Jun-ichi Hoshikuma

Center for Advanced Engineering Structural Assessment and Research, Public Works Research Institute, Japan

For more details

Professor Muneo Hori

Director General

Center for Mathematical Science and Advanced Technology, JAMSTEC, Japan

For more details

Professor Mustafa Erdik

Professor

Kandilli Observatory and Earthquake Research Institute, Bogazici University, Turkey

For more details

Professor Misko Cubrinovski

Professor

University of Canterbury, New Zealand

For more details

Professor Satoshi Yamada

Professor

The University of Tokyo, Japan

For more details

Professor Fabrizio Paolacci

Professor of Structural Engineering,

Roma Tre University, Italy

For more details

Conference Style

There have been some changes to the Presentation Style as follows.

1. Oral presenters who cannot attend the conference on-site can also make their presentation in real time by on-line.
2. For Poster Presentations, 17WCEE will not conduct an SOP (Short Oral Presentation) on-site, but instead, we are planning to hold SOP on-line (Flash Talk) in few minutes for each presentation. Additional information will be given

PROCEEDINGS OF THE SEVENTEENTH WORLD CONFERENCE ON EARTHQUAKE ENGINEERING JAPAN 2021

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DEYUAN TIAN, RUSHAN LIU, ZHI ZHU	A STYDY ON FAST CALCULATION METHOD OF SEISMIC VULNERABILITY OF BUILDING STRUCTURE
JIARUI WU, DAIKI SATO	DYNAMIC CHARACTERISTICS OF SEISMICALLY ISOLATED HIGH-RISE BUILDING BASED ON SEISMIC RESPONSE RECORDS
HAN SEON LEE, HUILING PIAO, RUTH ALI ABEGAZ	EVALUATION OF ACCIDENTAL TORSION OF TORSIONALLY-BALANCED BUILDINGS USING THE RESISTANCE ECCENTRICITY
MASATO SAKURAI, TETSUYA NISHIDA	POST PEAK SIMULATION OF RC SHEAR WALLS WITH OPENINGS BASED ON NON-LINEAR FE ANALYSIS
JYOTI LAMSAL, KOICHI KUSUNOKI, MATSUTARO SEKI, TATSUYA AZUHATA	SEISMIC RETROFIT OF AN EXISTING RESIDENTIAL BUILDING IN NEPAL TO FUNCTIONALIZE AS A HOSPITAL USING FERROCEMENT
RYO INOUE, TAKURO MORI, KOTARO SUMIDA, HIROSHI ISODA, KEI TANAKA, TOSHIAKI SATO	STATUS OF WOODEN HOUSES IN MASHIKI TOWN TWO YEARS AFTER THE 2016 KUMAMOTO EARTHQUAKES
HOLGER LOVON, VITOR SILVA, ROMEU VICENTE, TIAGO FERREIRA	INCORPORATING EPISTEMIC AND ALEATORY UNCERTAINTIES IN FRAGILITY MODELLING OF MASONRY STRUCTURES
JOSEPH KUBIN, DANYAL KUBIN, UGURCAN OZCAMUR, ILKER ALI ILIS, GOKSENIN FEROGLU, BENGU ELCIK EROL, SELCAN KAAN ACAREL, MERVE YALCIN, OZGE YILDIRIM	SEISMIC ISOLATION OF A DATA CENTER BUILDING: HYBRID SYSTEM WITH CSS, LRB AND FVD
TED CROSS, FLAVIA DE LUCA, RAFFAELE DE RISI	VALIDATION OF MACRO-MODELLING AND EQUIVALENT FRAME METHODOLOGY WITH EXPERIMENTAL DATA
JOSEPH KUBIN, DANYAL KUBIN, GOKSENIN FEROGLU, HALUK SUCUOGLU, ILKER ALI ILIS, UGURCAN OZCAMUR, ILKER HAKKI OZDEM, SINEM YALCIN	RETROFITTING OF A BRIDGE FORM HISTORICAL STATION USING SEISMIC ISOLATION
GIUSEPPE ABBIATI, STEFANO MARELLI	SEQUENTIAL EXPERIMENTAL DESIGN OF HYBRID SIMULATIONS FOR BAYESIAN CALIBRATION OF COMPUTATIONAL SIMULATORS
AHSANA PARAMMAL VATTERI, DINA D'AYALA, PIERRE GEHL	BAYESIAN NETWORKS FOR SEISMIC VULNERABILITY ASSESSMENT OF CONFINED MASONRY SCHOOL SYSTEMS
LIDIJA KRSTEVSKA	SEISMIC TESTING OF NON-STRUCTURAL SYSTEMS
HAMOOD ALWASHALI, DEBASISH SEN, MASAKI MAEDA, MATSUTARO SEKI	ADVANTAGES AND LIMITATIONS OF RETROFITTING MASONRY INFILLED RC FRAMES BY FERRO-CEMENT BASED ON EXPERIMENTAL OBSERVATIONS
HAMOOD ALWASHALI, JINGYUE SUN, AHMED GHAZI ALJUHMANI, ALEKSEY SHEGAY, MASAKI	EXPERIMENTAL STUDY ON RESIDUAL SEISMIC CAPACITY OF RC SQUAT WALLS

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GIOVANNI MUCIACCIA, GIUSEPPE DI NUNZIO	CYCLIC BEHAVIOR OF SCREWED HEAD ANCHOR SYSTEM FOR APPLICATIONS IN NUCLEAR POWER PLANTS
YESIM BIRO, BILGE SIYAHI, BULENT AKBAS	THE SPECTRAL DECAY PARAMETER *K* (KAPPA) FOR HARD ROCK STRONG GROUND MOTION STATIONS IN TURKEY
MANISH KUMAR, SUJIT V MATALE, DURGESH C RAI	INFLUENCE OF PERIMETER SUPPORTS ON THE SEISMIC RESPONSE OF PLASTERBOARD SUSPENDED CEILING SYSTEMS
MARIA CAMILA HOYOS, ANDRÉS FELIPE HERNÁNDEZ	HOW UNCERTAINTIES AND ASSUMPTIONS IN SEISMIC RISK ANALYSIS AFFECT THE DECISION-MAKER'S RISK PERCEPTION
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DIMITRIS PITILAKIS, CHRISTOS PETRIDIS, AIKATERINI KOLITSIDAKI, APOSTOLIA BADRALEXI	CITY-SCALE EARTHQUAKE VULNERABILITY ASSESSMENT INCLUDING NONLINEAR SOIL-STRUCTURE INTERACTION
SIAMAK SATTAR, MIKE MAHONEY, RYAN KERSTING	FUNCTIONAL RECOVERY OF THE BUILT ENVIRONMENT AND CRITICAL INFRASTRUCTURE
ROHIT KUMAR ADHIKARI, DINA D'AYALA, ALASTAIR NORRIS	SEISMIC PERFORMANCE EVALUATION OF THE EXISTING AND RETROFITTED STONE MASONRY HOUSES IN NEPAL
DURGESH C RAI, PARUL SRIVASTAVA	SEISMIC FRAGILITY ANALYSIS OF C-BENT PIERS IN METRO VIADUCTS
FELIPE RIVERA, TIZIANA ROSSETTO, JOHN TWIGG	ASSESSING EARTHQUAKE RISK EVOLUTION FROM A PROCEDURAL JUSTICE PERSPECTIVE
AGUSTIN BERTERO, RAUL BERTERO, FILIP FILIPPOU	DEMAND-ORIENTED GROUND MOTION SELECTION USING NONLINEAR PREDICTORS OF RESPONSE
SERGIO LAGOMARSINO, STEFANIA DEGLI ABBATI, SERENA CATTARI	EFFECTS OF THE VERTICAL COMPONENT ON THE SEISMIC RESPONSE OF URM BUILDINGS
RICKY BAHERAMSJAH, ABDULBAR MANSOER, H HARINTO, HARI NURJAMAN, MASYHUR IRSYAM, M RIDWAN, L FAIZAL, H LATIEF, BINSAR HARIANDJA, SUWITO SUWITO, DWI DINARIANA	DEVELOPMENT OF EARTHQUAKE AND TSUNAMI DISASTER MITIGATION PLAN FOR MANDALIKA MOTOGP CIRCUIT IN LOMBOK
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SEBASTIAN CASTRO, FELIPE ARROSPIDE, ALAN POULOS, YOLANDA ALBERTO, JUAN CARLOS DE LA LLERA	CONSTRUCTION AND RISK EVALUATION OF A WATER SYSTEM NETWORK UNDER SEISMIC HAZARD IN CENTRAL CHILE
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VALENTINA PUTRINO, DINA D'AYALA	A MECHANICS-BASED PROCEDURE TO DETERMINE THE DAMAGE MECHANISM OF MASONRY WALLS SUBJECTED TO OUT-OF-PLANE HORIZONTAL LOADINGS
SERENA CATTARI, STEFANIA DEGLI ABBATI, SERGIO LAGOMARSINO	FLOOR SPECTRA VALIDATION THROUGH ACTUAL DATA FROM THE 2016/2017 EARTHQUAKE IN CENTRAL ITALY
SERENA CATTARI, DARIA OTTONELLI, FULVIO FRANCO, TOMMASO BUSCHIAZZO, ANDREA GUARDIANI	TOWARDS AN IMPROVED URBAN SEISMIC RESILIENCE: THE PILOT CASE STUDY OF SANREMO MUNICIPALITY
JUAN MANUEL MAYORAL, GILBERTO MOSQUEDA	SEISMIC INTERACTION AMONG ON-GROUND AND UNDERGROUND STRUCTURES
JUAN MANUEL MAYORAL, GILBERTO MOSQUEDA	SEISMIC INTERACTION OF INTERDEPENDENT SYSTEMS IN URBAN AREAS

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RICARDO ANTONIO HERRERA, NICOLAS LEIVA, LEONARDO MASSONE, JUAN FELIPE BELTRAN	NUMERICAL MODELLING OF THE PLASTIC HINGE OF GIRDERS IN STEEL MOMENT RESISTING FRAMES
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CARLOS A ARTETA, ANDRES TORREGROZA, DANIEL GASPAR, NORMAN A ABRAHAMSON	HOW MANY CMS' ARE ENOUGH FOR SEISMIC RESPONSE ASSESSMENT?
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ROBERT TREMBLAY, PAUL MOTTIER	A SIMPLE SELF-CENTERING BASE SHEAR FUSE FOR COST-EFFECTIVE CONTROLLED ROCKING STEEL BRACED FRAMES
AHMED ELGAMAL, ABDULLAH ALMUTAIRI, JINCHI LU	IMPLEMENTATION OF A MULTI-SPAN BRIDGE-GROUND PBEE FRAMEWORK FOR SEISMIC AND LIQUEFACTION SCENARIOS
MARIO LOPES, CARLOS SOUSA OLIVEIRA	EARTHQUAKE EARLY WARNING SYSTEM FOR PORTUGAL: FEASIBILITY AND PERSPECTIVE OF THE STAKEHOLDERS
KAZUMA INOUE, KEITA SAITOH, YUTA UMEYAMA, AKIRA IGARASHI, TAKAAKI IKEDA	ANALYSIS OF DIRECTIONALITY CONSIDERING PERIODIC CHARACTERISTICS FOR OVSERVED STRONG GROUND MOTIONS
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KHIN MYAT KYAW, KIMIRO MEGURO	NUMERICAL MODELING OF MID-RISE REINFORCED CONCRETE BUILDING INCORPORATION OF SOIL-STRUCTURE-INTERACTION FOR DIFFERENT SOIL CONDITIONS WITH AEM
HISASHI NAKAO, KOHEI EGUCHI, TOMOYA YONO, MICHIO OHSUMI	DAMAGE MECHANISM OF OKIRIHATA BRIDGE DUE TO KUMAMOTO EARTHQUAKE
MUNKHUNUR TOGTOKHBUYAN, TAGAWA HIROSHI, CHEN XINGCHEN	EXPERIMENTAL STUDY ON STEEL BEAM-TO-COLUMN JOINT STRENGTHENED BY BUCKLING-RESTRAINED KNEE BRACE USING STEEL BAR CORE
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MIGUEL MEDALLA, DIEGO LOPEZ-GARCIA, FARZIN ZAREIAN	SEISMIC CHARACTERIZATION OF STEEL BUILDINGS SUBJECTED TO MEGATHRUST EARTHQUAKES
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MASAKATSU MIYAJIMA, RYOSUKE NOGUCHI	INFLUENCE ON DAMAGE TO LIFELINE ON PERFORMANCE OF HOSPITALS IN THE 2018 HOKKAIDO IBURI-TOBU EARTHQUAKE IN JAPAN
KENJIRO YAMAMOTO, SHANTHANU RAJASEKHARAN, KIMIRO MEGURO	STUDY ON MOISTURE EFFECTS ON MASONRY RETROFITTED WITH FIBER REINFORCED PAINT
RUIFU ZHANG, LI ZHANG, LIYU XIE, SONGTAO XUE	DYNAMIC EXPERIMENT AND ANALYTICAL RESEARCH OF A CRANK INERTER SYSTEM
YU BAO, DIMITRIOS KONSTANTINIDIS	EFFECT OF AN ADJACENT WALL ON THE OVERTURNING OF A SLIDING-ROCKING BLOCK SUBJECTED TO PULSE EXCITATION
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SABINE LOOS, DAVID LALLEMANT, JAMIE MCCAUGHEY, NAMA BUDHATHOKI, FEROZ KHAN, RITIKA SINGH, JACK BAKER	BEYOND BUILDING DAMAGE: MODELING POST-DISASTER NEED
TAKAO NISHIZAWA, RYOTA SUEKUNI	OUTLINE OF STRUCTURAL DESIGN FOR KYOTO CITY HALL
GUIXIN ZHANG, BAITAO SUN	SEISMIC CAPABILITY OF BUILDING AND RISK ANALYSIS OF EARTHQUAKE DISASTER OF CHINESE MAINLAND
TIZIANO PEREA, JOSÉ ANTONIO SIFUENTES, GELACIO JUÁREZ-LUNA	STRUCTURAL ASSESSMENT OF STEEL BEAM-TO-COLUMN CONNECTIONS SUBJECTED TO CYCLIC LOADING BY NONLINEAR FINITE ELEMENT ANALYSIS
HAOWEN ZHENG, SHOICHI KISHIKI, NOBUHIKO TATSUMI, TAKANORI ISHIDA, YOSHINAO KONISHI	QUICK INSPECTION METHOD OF U-SHAPED STEEL DAMPERS BASED ON RESIDUAL DEFORMATION

KEN-ICHI FUJITA, HARUMI YASHIRO	EVALUATION OF HUMAN DAMAGE IN EVACUATION FROM TSUNAMI FOR A COMMON SCENARIO EARTHQUAKE
SATOSHI YAMAGAMI, HIDETAKA FUNAKI, YOSHIKI KOYAMA, HAJIME YAMAGIWA	DYNAMIC CHARACTERISTICS OF SEISMICALLY ISOLATED STRUCTURES IN MICROTREMOR
HARI NURJAMAN, AGUS WANTORO, YUDHI DHARMAWAN, JOSE RESTREPO, SUGENG WIJANTO, BINSAR HARIANDJA, LUTFI FAIZAL, SUWITO SUWITO, DWI DINARIANA	USE OF VERTICALLY UNBONDED POST TENSIONED ON PRECAST CONCRETE WALL TO COUNTERACT VERTICAL EARTHQUAKE
RICHARD CHRISTENSON, MUAMMER AVCI	BASE ISOLATION STUDIES USING REAL-TIME HYBRID SIMULATION AND FIXED BASED BUILDING SHAKE TABLE TESTS
KAZUHIRO KANEDA	INVESTIGATION OF LATERAL VISCOUS BOUNDARY IN TWO PHASE DYNAMIC ANALYSIS OF 3D IRREGULAR LAYER SYSTEM GROUND
LUIS MARTIN LAVADO DURAND, JORGE LUIS GALLARDO TAPIA, CLAUDIA MITIE HONMA	EXPERIMENTAL AND NUMERICAL ANALYSIS OF BEHAVIOUR IN COMPRESSION AND SHEAR OF HANDMADE CLAY BRICK MASONRY
MEGAN BOSTON, SHERRY BANEZ, TARA FERNANDEZ-RITCHIE, NICOLE FRUEAN, NATASHA PAIRIS, MARK LAY	TOWARDS CREATING RESILIENT CITIES: A CASE STUDY OF HAMILTON, NEW ZEALAND
YOSHIMASA SHIGENO, KIYOSHI YAMASHITA, JUNJI HAMADA	SEISMIC PERFORMANCE OF A PILED RAFT FOUNDATION WITH GRID-FORM DMWS CONSIDERING SOFTENING OF STABILIZED SOIL
FUMINO SUZUKI, KENICHI KATO, TETSUSHI WATANABE, YUSUKE TOMOZAWA	STRONG GROUND MOTION SIMULATION OF THE GREAT 1923 KANTO EARTHQUAKE IN THE TOKYO METROPOLITAN AREA BASED ON STRONG MOTION GENERATION AREA
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TREVOR ALLEN, JONATHAN D GRIFFIN, DAN J CLARK, HADI GHASEMI	REFLECTIONS ON THE NSHA18: WHAT WAS DONE WELL? WHAT COULD BE DONE BETTER?
KENTARO NAKAI, TOSHIHIRO NODA, SHINYA FUKUDA, HIDEHIKO MURAO, AKIRA ASAOKA	LOCALIZED/ENORMOUS SEISMIC DAMAGE OF SUBSURFACE GROUND INDUCED BY THE STRATUM IRREGULARITY
TOSHIHIRO NODA, KENTARO NAKAI	SEISMIC DAMAGE OF SOFT CLAY LAYER DIRECTLY UNDER THE RIVER LEVEE THAT BECOMES PROMINENT BY L2 EARTHQUAKE
GANESH KUMAR JIMEE, K. MEGURO, A. M. DIXIT, ADITYA TAMANG	DISASTER RISK REDUCTION AND MANAGEMENT AT LOCAL GOVERNMENTS IN NEPAL: POLICIES, CHALLENGES & ROAD AHEAD
PAOLA PANNUZZO, TAK-MING CHAN	NUMERICAL ASSESSMENT OF THE FLEXURAL BEHAVIOR OF HOT-FINISHED STEEL BEAMS UNDER MONOTONIC AND CYCLIC LOADING
GEOFFREY W RODGERS, VISHNUPRIYA VISHNUPRIYA, JAMES GEOFFREY CHASE, CONG ZHOU	UPPER AND LOWER BOUNDS OF DEVICE FORCE CAPACITY IN HIGH FORCE TO VOLUME (HF2V) DEVICE DESIGN
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ANNA MATSUKAWA, AYA TAUSJIOKA, FUMINORI KAWAMI, JUNKO MURANO, SHIGEO TATSUKI	INCLUSIVE DISASTER RISK REDUCTION WITH BEPPU MODEL: ASSESSMENT BY COMPARISON OF 37 MUNICIPALITIES IN HYOGO PREFECTURE

CHIN-LONG LEE	PROPORTIONAL VISCOUS DAMPING MODEL FOR MATCHING FREQUENCY-DEPENDENT DAMPING RATIO
MASARU OKUTSU, AKIRA ITO, KOUJI ITASAKA, MINORU TANAKA	DAMAGES OF TELECOMMUNICATION FACILITIES DUE TO THE 2016 KUMAMOTO EARTHQUAKE
JUNJI KIYONO, KENJI FUKUNAGA, RYOTARO MABUCH, MASATSUGU SHINOHARA, TAKAFUMI ITO	SEISMIC BEHAVIOUR OF VEHICLES ON HIGHWAY
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YOSHINOBU MIZUI, HIROYUKI FUJIWARA	DEVELOPMENT AND UTILIZATION OF NANKAI TROUGH EARTHQUAKE DISASTER INFORMATION PLATFORM
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DEVELOPMENT SEISMIC DESIGN STANDARDS FOR REHABILITATION OF BUILDINGS AFFECTED BY EARTHQUAKE USING DAMPER TECHNOLOGY

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Abstract

Since strong earthquake and tsunami took place in Aceh 2004, the frequency of strong earthquakes has increased significantly in several regions in Indonesia. Researches on seismicity and earthquake engineering conducted since 2004 generally result in higher design seismic load in several region in Indonesia and stringent requirements of design standard. This condition means that many buildings that were built before the latest seismic design standard would fail to meet its performance requirements. These buildings, especially important public buildings such as government buildings, schools, hospitals and shopping centers, need technology to improve their structural performances against earthquake with minimal changing to their existing structures. Damper technology is one of such technologies that can dissipate additional earthquake load due to standard design revision. Moreover, in 2019, Indonesia Government planned to begin including damper technology in its seismic design code by adopting ASCE7-16. This study will present part of results from research related to implementation of damper technology in building that will be conducted in 3 year span. In the first year (2019), research focused on the selection of damper technology that is effective in improving seismic performance and has the potential economically to be manufactured in Indonesia. To determine the effectiveness of a damper technology in improving structural performance against earthquake load, a case study illustrating the process and decision regarding rehabilitation of a government office building in city of Palu that was recently struck by earthquake of magnitude M = 7.4 on September 28, 2018, will be conducted. A series of response history analyses will be carried out on rehabilitated structure of building used as the case study. In the second year (2020), the selected damper technology will be installed in model structure and will be tested on shaking table to verify its seismic structural performance and to establish Indonesian National Standard for the product. And in the final year (2021), production of damper product in Indonesia will be started and finalization of seismic design standard of building using damper technology will be conducted. The developed seismic design standard can then be used for designing either new building or retrofitting of existing building to achieve latest requirements or restoration of seismic performance of building impacted by earthquake.

Keywords: damper technology; seismic design standard; response history analysis; high performance-based design; shaking table testing

1. Introduction

Since strong earthquake and tsunami took place in Aceh 2004, the frequency of strong earthquakes has increased significantly in several regions in Indonesia. Researches on seismicity and earthquake engineering conducted since 2004 generally result in higher design seismic load in several region in Indonesia and stringent requirements of design standard. This condition means that many buildings that were built before the latest seismic design standard would fail to meet its performance requirements. These buildings, especially important public buildings such as government buildings, schools, hospitals and shopping centers, need technology to improve their structural performances against earthquake with minimal changing to their existing structures. Damper technology is one of such technologies that can dissipate additional earthquake load due to standard design revision.

To determine the effectiveness of a damper technology in improving structural performance against earthquake load, a case study illustrating the process and decision regarding rehabilitation of a government office building in city of Palu that was recently struck by earthquake of magnitude M = 7.4 on September 28, 2018, will be conducted. A series of response history analyses will be carried out on rehabilitated structure of building used as the case study.

2. Conditions after the Earthquake

The 2018 earthquake in Sulawesi was a 7.4 Mw earthquake followed by a tsunami that struck the western coast of Sulawesi Island, northern part on September 28, 2018, at 18.02 WITA. The epicenter was 26 km north of Donggala and 80 km northwest of Palu City with a depth of 10 km. Earthquake shocks were felt in Donggala, Palu, Parigi Moutong, Sigi, Poso, Tolitoli, Mamuju and even Samarinda, Balikpapan in Borneo, and Makassar in Celebes, as shown in Fig 1. The earthquake triggered a tsunami to a height of 5 meters in the city of Palu.

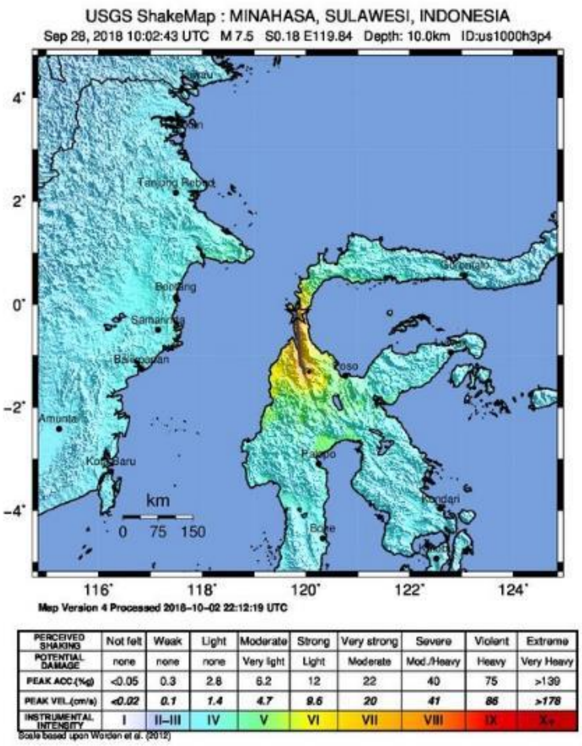


Fig. 1 – USGS Map of the Sulawesi Earthquake

In general, many buildings in Central Sulawesi Province were severely damaged by the earthquake, categorized as moderately to severely damage, including the Cipta Karya and Water Resources Office Buildings in Central Sulawesi Province (Fig 2 and Fig 3). Directorate General Cipta Karya and Water Resources Office building consists of 4 main buildings separated by dilatation. Before the earthquake occurred, these building were functioned as centers for office activities that had 2 parts of activities; Cipta Karya and Water Resources.

Fig. 2 – Damage in the Front of the Building

Fig. 3 – Damage in the Back of the Building

The design of earthquake resistant buildings aims to maintain every vital service of the building's function, limit the inconvenience of occupancy and damage to the building so that it can still be repaired at low cost when a mild to moderate earthquake occurs and avoid fatalities due to the collapse of the building in a strong earthquake event. Performance-based earthquake resistant building design is a process that can be used to design new buildings and strengthen existing buildings with an understanding of the aspects of safety risk (life), readiness for use (occupancy), and the risk of financial losses arising from earthquakes (economic loss). FEMA 356 (2000) sets the level of performance for designing earthquake resistant structures as seen in Fig 4 and Fig 5.

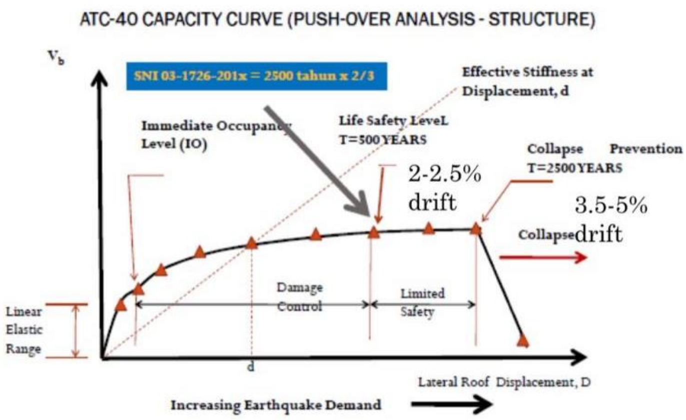


Fig. 4 – Performance Based Planning Graph

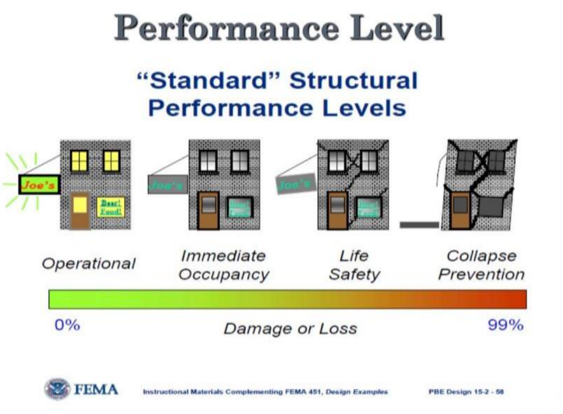


Fig. 5 – Structure Performance Level

From visual investigation, this building Performance Level does not fall in Collapse Prevention (CP) category, where the building Performance Level should be Life Safety (LS). To repair this building, 2 alternative designs were carried out. The first alternative was to use conventional retrofitting with concrete jacketing, and the second alternative using seismic damping resistant.

The data required for evaluating the structure of the Cipta Karya and Water Resources Building of Central Sulawesi Province were obtained as follows:

1. Soil investigation data conducted by the Soil Mechanics Laboratory Team of the Faculty of Engineering, Tadulako University who conducted 2 points of Boring Log. Boring log results show the type of sandy clay soil at the top and sand in the hard soil, with an NSPT value > 50 located at a depth of 12 meters.
2. As-built Drawing Building Cipta Karya and Water Resources of Central Sulawesi Province.
3. Data from the Hammer Test and UVP test results.
4. Direct survey of damaged buildings.

3. Conventional Retrofitting Evaluation

Conventional retrofitting design based on Earthquake Code SNI 1726:2012 which refers to ASCE 374.1-05[1], and Concrete Code SNI 2847:2013 which refers to ACI 318-11[2]. The designed Performance Level of the building is Life Safety (LS). The design will result in the cost required to retrofit the building.

3.1 Material

The specifications of the materials used are:

1. Concrete Jacketing : fc' = 45 MPa
2. Rebar : D ≥ 10 BJTD 40, fy = 400 MPa
   : D ≤ 10 BJTD 24, fy = 240 MPa

3.2 Description of Building Structure System

The building consists of 4 buildings separated by dilatation. In general, the structure may be categorized as a Special Moment Resistant Frame (SMRF) system. The structure was designed using the conventional concrete jacketing.

3.3 Structural Design Method

Analysis was generally carried out in 3 dimensions to obtain optimal results. The analysis was carried out in 2 parts. First, eigen-value analysis was performed to determine the dominant vibration mode and period. Vibration period data from this analysis was used to determine the static earthquake force based on the appropriate spectral response. Structural analysis was divided into two stages, namely the first stage of upper structure analysis which consists of eight layers of structure and was considered to be trapped laterally at the top level of the basement floor. As well as the second stage of the analysis of the basement structure, which is burdened by a combination of earthquake loads originating from the upper structure, the load from the inertia force of the basement floor itself and the load originating from the ground pressure around the basement.

The basement design was made stronger than the upper structure or should not fail earlier than the upper structure, so that the design was still behaving elastic to the planned earthquake load. Analysis of the 3-dimensional structure by paying attention to the torque effect is performed to obtain internal forces. Structural analysis was carried out with the help of the ETABS package program. 3D model can be seen in Fig 6.

3.4 Basic Loading and Load Reduction Parameters

1. Basic Loading
   - Concrete γ : 24 kN/m^3
   - Live Load w_{ll} : 2.5 kN/m^2
   - Super Dead load (SDL) : 1.2 kN/m^2
   - Wall : 2.5 kN/m^2
2. Parameter Coefficient Factors Reduction of life load design used in structural planning *(according to SNI 1726:2012)* are :
   - Earthquake review (Dynamic analysis) : 0.25
   - Live Load Parking floor : 1.00

3. Design parameters (reduction factor Ø) that are used in structural planning (*according to SNI 2847: 2013*) are:
   - Flexural reduction factor : 0.9
   - Axial reduction factor : 0.65
   - Shear reduction factor : 0.75
4. The effectiveness parameter of moment inertia (cross section of crack) *(according to SNI 2847:2013)* :
   - Beam Components : 0.35 Ig
   - Column Components : 0.7 Ig
   - Wall Components : 0.7 Ig

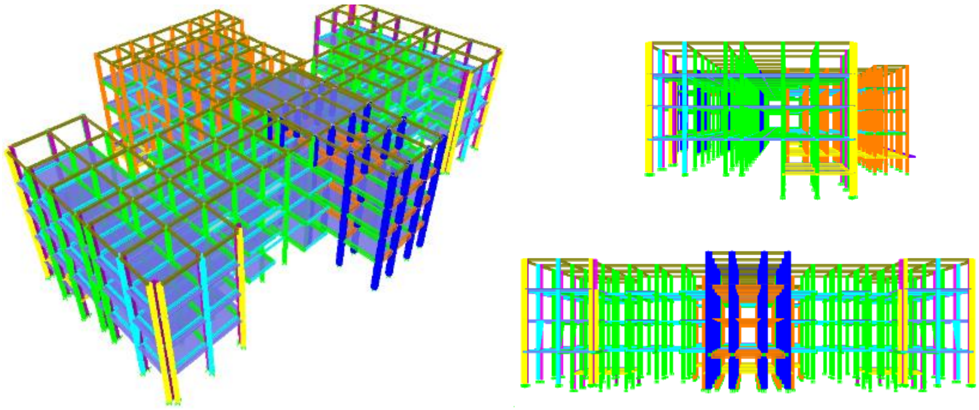


Fig. 6 – 3D View, Front View and Side View of Buildings

3.5 Determination of the Force - Earthquake Structure of the Upper Structure
For a review of earthquake forces the data used are as follows:

3.5.1 Bedrock Acceleration Map (according to SNI 1726:2012)

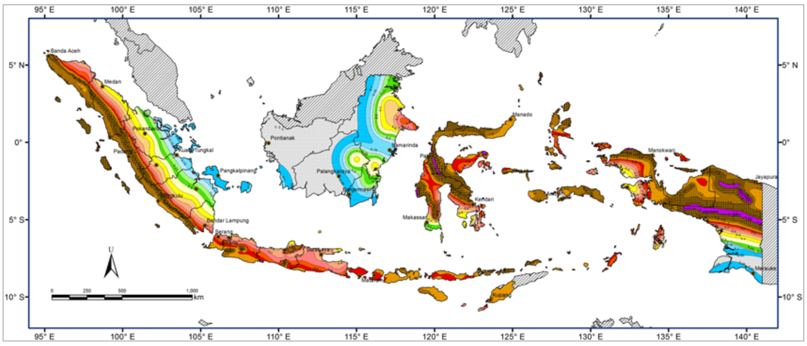


Fig. 7 – Earthquake Acceleration Earthquake Map in Short Period

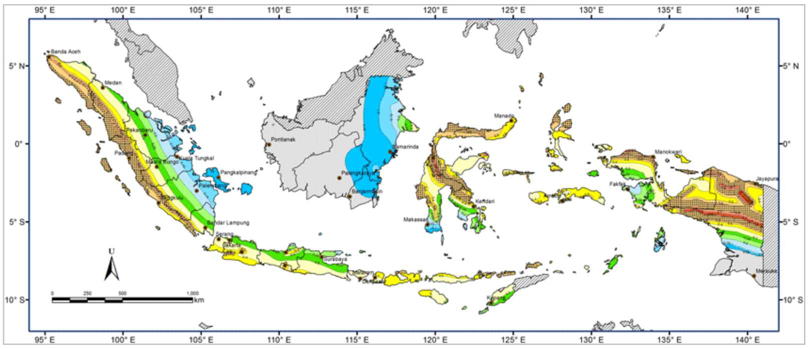


Fig. 8 – Earthquake Acceleration Earthquake Map in 1 second period

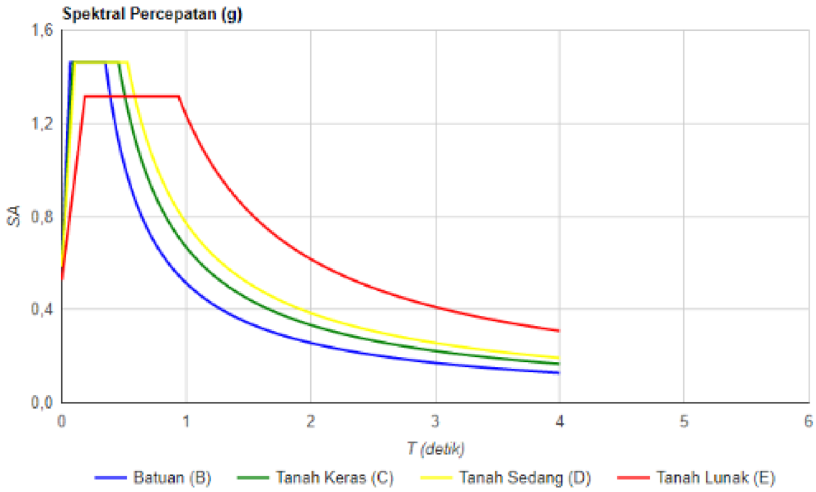


Fig. 9 – Graph of Earthquake Response Spectrum in Palu Region

3.5.2 Building Risk Category

This building is included in the risk category II with the earthquake priority factor value used Ie = 1 (Based on Table 1 and Table 2 in SNI 1726: 2012).

3.5.3 Reduction Factor, R = 8

The results of the determination of earthquake parameters from the bedrock acceleration map, soil conditions, and the above primacy factors were obtained that the building is included in the seismic design category E so that the structural system used was a reinforced concrete frame structural system for special moment bearers. (Based on point C.5, Table 9 SNI 1726: 2012).

3.6 Eccentricity of Upper Structure Plan

Distance between the center of mass and the center of rotation of the floor level e must be reviewed an eccentricity of the plan ex for the direction of the earthquake X and ey for the direction of the earthquake Y. If the largest horizontal size of the floor plan of the building structure on that level floor, measured perpendicular to the direction of earthquake loading, expressed as B and L, then the eccentricity of plan e must be determined as follows:

$$e_x = e_{ox} + (0.05\ B\ Ax) \text{ and } e_y = e_{oy} + (0.05\ L\ Ay)$$
$$Ax/Ay = (\delta_{max} / 1.2\delta_{avg})^2$$

e_{ox} and e_{oy} is innate eccentricity
0.05 B Ax and 0.05 L Ay is an unexpected eccentricity
Ax and Ay is an unexpected torque magnification factor. Ax and Ay must be ≥ 1.0

Table 1 – Determination of the value of Ax and Ay

LANTAI	δ_A (maks)	δ_B (Min)	δ_{avg}	Ax	Ax < 1
LTRB	0.049	0.038	0.043	0.883	...ok
LT4	0.039	0.029	0.034	0.916	...ok
LT3	0.028	0.020	0.024	0.950	...ok
LT2	0.013	0.008	0.011	1.051	...cek
LT1	0.002	0.000	0.001	2.778	...cek

LANTAI	δ_A (maks)	δ_B (Min)	δ_{avg}	Ay	Ay < 1
LTRB	0.051	0.050	0.05050	0.700	...ok
LT4	0.041	0.041	0.04050	0.694	...ok
LT3	0.028	0.028	0.02800	0.694	...ok
LT2	0.012	0.012	0.01220	0.694	...ok
LT1	0.002	0.000	0.00095	2.778	...cek

3.7 Building Mass and Modal Participation of Structure Above

The mass of the building per floor as shown in Table 2 below:

Table 2 – Mass per Floor Diaphragm Unit

Story	Diaphragm	MassX	MassY	MMI	XM	YM
LTRB	D5	112.51	112.51	3385.3	31.20	16.54
LT4	D4	2586.22	2586.22	1093631.2	31.22	21.64
LT3	D3	2627.90	2627.90	1105179.8	31.24	21.60
LT2	D2	2595.24	2595.24	1099637.5	31.23	21.55
LT1	D1	967.67	967.67	300559.1	31.25	34.15

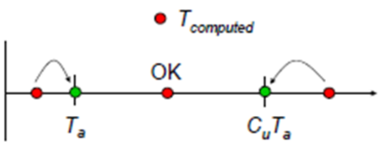
3.8 Determination of the Structural Vibration Period

Based on Article 7.8.2 SNI 1726: 2012, the fundamental period of the T structure may not exceed the coefficient results for the upper limit of the period calculated C_u from table 14 and the fundamental period of the T_a approach is calculated in accordance with Article 7.8.2.1 SNI 1726: 2012.

if $T_{computed}$ is > $C_u T_a$ use $C_u T_a$

if $T_a < T_{computed} < C_u T_a$ use $T_{computed}$

if $T_{computed} < T_a$ use T_a



The natural vibrating period of the building is as follows:

Table 3 – Vibration Period

MODAL PERIODS AND FREQUENCIES

MODE NUMBER	PERIOD (TIME)	FREQUENCY (CYCLES/TIME)	CIRCULAR FREQ (RADIANS/TIME)
Mode 1	0.78259	1.27781	8.02869
Mode 2	0.73442	1.36162	8.55531
Mode 3	0.65237	1.53287	9.63130
Mode 4	0.22190	4.50661	28.31586
Mode 5	0.21345	4.68504	29.43695
Mode 6	0.18725	5.34056	33.55572
Mode 7	0.14309	6.98865	43.91101
Mode 8	0.12801	7.81203	49.08442
Mode 9	0.12714	7.86508	49.41778
Mode 10	0.12368	8.08556	50.80305
Mode 11	0.11849	8.43956	53.02732
Mode 12	0.11815	8.46352	53.17785

$T_a = 0.0466^{\alpha} = 0.6938$ sec (according to table 15, SNI1726:2012)

$T_{max} = 1.4 \times 0.6938 = 0.9714$ sec (according table 14, SNI1726:2012)

So the value of the period that occurs is = $T_x = 0.7825$ sec $< T_{max} = 0.9714$ sec …. Ok

$T_y = 0.7344$ sec $< T_{max} = 0.9714$ sec …. Ok

3.9 Earthquake Force Calculation at Upper Structure Design

The results of dynamic analysis for cumulative shear forces in the x and y direction can be seen in Fig. 10 below:

Determination of used earthquake force or design in X & Y direction:

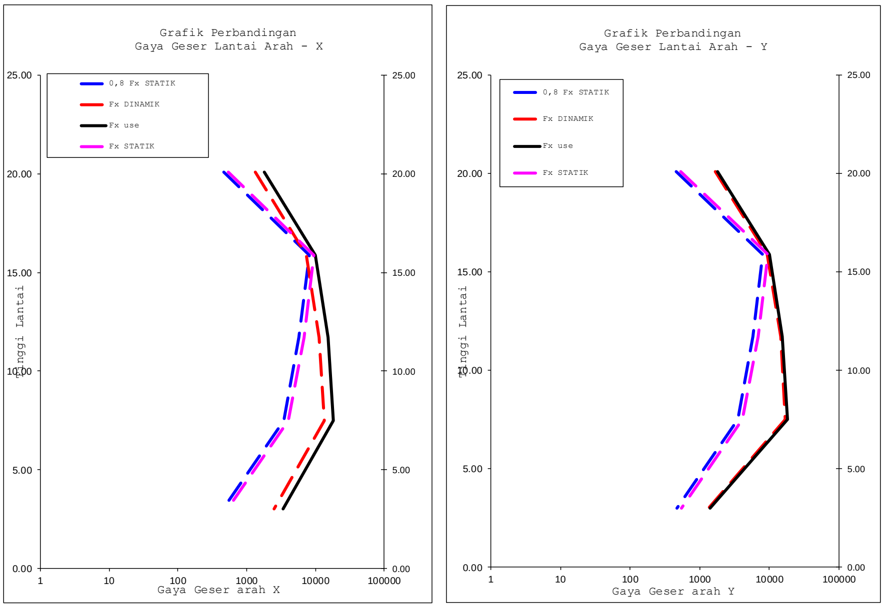


Fig. 10 – Graph of comparison of shear force in X-direction and Y-direction

3.10 Building Structure Analysis Performance

In Article 7.8.6 SNI 1726:2012, it is determined that the deviation between design floors (Δ) must be calculated as the difference in deflection of the center of mass at the top and bottom levels reviewed. The mass center deflection at the level (δ_x) must be determined according to the following equation:

$$\delta_x = C_d\, \delta_{xe} / I_e$$

C_d = deflection amplification factor (according table 9 SNI 1726:2012) = 5.5
δ_{xe} = deflection at the required location
I_e = earthquake priority factor = 1

Limitation of inter-floor deviation of Δ_a level as stipulated in Article 7.12 SNI1726: 2012 is $0.02h_{sx}$ with h_{sx} as high level below level x.

Calculation of level deviations between floors based on minimum shear forces and period values to calculate deviations between floors (in accordance with Article 7.8.6.1 and 7.8.6.2 SNI 1726: 2012). Calculation of deviation between floors also takes into account the default torque and unexpected torque.

The deviation between floors is based on the followings as shown in the following Table 4:

Table 4 - Intersection between floors in X-direction and Y-direction

Story	h_{sx} (mm)	δ_{xe} (mm)	δx=Cd.δxe/Ie	Δ	$\Delta_a=0.02h_{sx}$ (mm)	$\Delta < \Delta_a$
LTRB	4200	35.70	130.90	13.93	84.00	...ok
LT4	4200	31.90	116.97	34.83	84.00	...ok
LT3	4200	22.40	82.13	44.73	84.00	...ok
LT2	4500	10.20	37.40	28.23	90.00	...ok
LT1	3000	2.50	9.17	9.17	60.00	...ok

Story	h_{sx} (mm)	δ_{xe} (mm)	δx=Cd.δxe/Ie	Δ	$\Delta_a=0.02h_{sx}$ (mm)	$\Delta < \Delta_a$
LTRB	4200	49.30	180.77	32.27	84.00	...ok
LT4	4200	40.50	148.50	45.83	84.00	...ok
LT3	4200	28.00	102.67	57.93	84.00	...ok
LT2	4500	12.20	44.73	37.77	90.00	...ok
LT1	3000	1.90	6.97	6.97	60.00	...ok

The influence of P-delta is calculated according to Article 7.8.7 SNI 1726-2012

The effect of P-delta should not be taken into account if the stability coefficient, $\theta \leqslant 0.1$

$$\theta = \frac{P_x \Delta I_e}{V_x h_{sx} C_d}$$

P_x = total vertical design load at and above level x (kN)
Δ = deviation between floors design level (mm)
I_e = earthquake priority factor
V_x = seismic shear force between level x and x-1 (kN)
h_{sx} = story height above level x (mm)
C_d = deflection amplification factor

Table 5 - P-delta effect in X-direction

LANTAI	h_{sx} (mm)	Δ	P	V	Ie	Cd	θ	θ max	θ < 0.1
LTRB	4200	2.533	1103.68	1785.40	1.5	5.5	0.000	0.0909	...ok
LT4	4200	6.333	25370.81	9865.25	1.5	5.5	0.001	0.0909	...ok
LT3	4200	8.133	25779.69	15317.54	1.5	5.5	0.001	0.0909	...ok
LT2	4500	5.133	25459.32	18032.34	1.5	5.5	0.000	0.0909	...ok
LT1	3000	1.667	9492.87	3378.16	1.5	5.5	0.000	0.0909	...ok

Table 6 - P-delta effect in Y-direction

LANTAI	h_{sx} (mm)	Δ	P	V	Ie	Cd	θ	θ max	θ < 0.1
LTRB	4200	5.867	1103.675	1796.14	1.5	5.5	0.000	0.0909	...ok
LT4	4200	8.333	25370.811	9952.70	1.5	5.5	0.001	0.0909	...ok
LT3	4200	10.533	25779.686	15410.89	1.5	5.5	0.001	0.0909	...ok
LT2	4500	6.867	25459.315	18086.18	1.5	5.5	0.001	0.0909	...ok
LT1	3000	1.267	9492.8731	1415.14	1.5	5.5	0.001	0.0909	...ok

From the table above it can be seen that the value of $\Theta \leqslant 0.1$ in both the X and Y directions, so in planning, this structure does not take into account the effect of P-delta.

3.11 Loading Combination

In accordance with the specification in Article 7.4.2 SNI 1726:2012, the combination of loading due to the influence of earthquake loads must be taken into account to the effect of horizontal earthquake loads and the effect of vertical earthquake loads. The effect of horizontal earthquake load is determined by including the effect of the redundancy factor ρ as determined in Article 7.3.4 SNI 1726:2012. The effect of the vertical earthquake load is determined by incorporating the factor of the acceleration parameter of the design response spectrum in the short period of S_{DS} as determined in Article 6.10.4 SNI 1726:21012.

By entering the factor $\rho = 1.3$ (for the seismic design category E) and the value of $S_{DS} = 1.315$.

3.12 Estimated Cost

Estimated Concrete Jacketing method cost are around 480,000 USD.

Fig. 11 – Concrete Retrofitting Design & Process

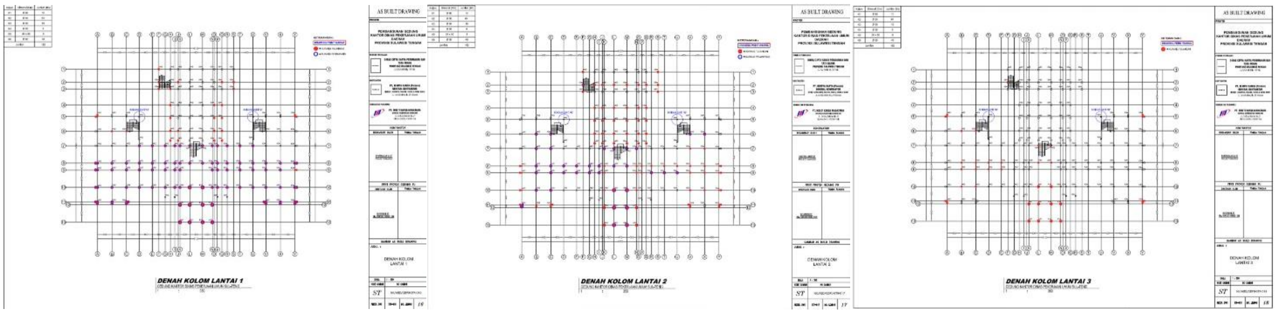


Fig. 12 – Column Retrofit Layout

4. Seismic Damping Design

Concept and mechanism of seismic with seismic isolation is shown in Fig 13. The purpose of seismic isolation is to reduce the effect of the ground motion to structure, thus avoid destruction. To achieve this, the basic cycle of structure can be extended to avoid the size of seismic energy concentration, thus reduce the seismic force of structure as shown in Fig 14. However, the reduction of seismic force by extension of structural cycle comes inevitably with the larger structural displacement, as shown in Fig 15, arising difficulties in design. In order to control the large deformation within limits, a damper can be incorporated into the structure to increase the damping and decrease the displacement of the structure. It can be seen from Fig 14 that the dynamic acceleration of structure can be decreased with increasing the damping of structure [3].

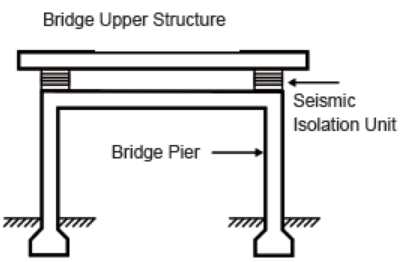


Fig. 13 – Sectional View of the Seismic Isolation

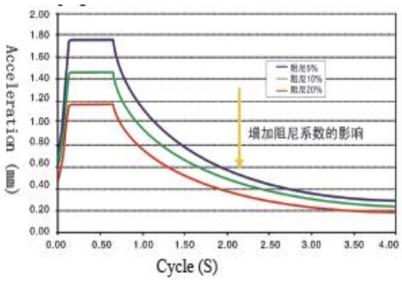


Fig. 14 – Impacts of Damping on the Acceleration of Upper Structure

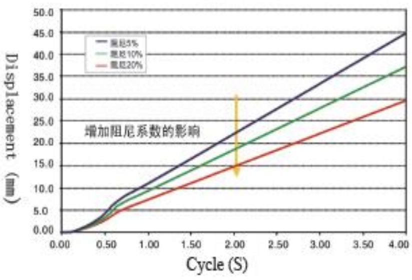


Fig. 15 – Impacts of Damping on the Displacement of Upper Structure

The structure seismic isolation technique is to extend the natural vibration cycle of structure by a seismic isolation unit, reducing the seismic displacement response at the top of pier or foundation while attenuating the acceleration response of upper structure, so as to ensure the structure safety. The principle of seismic isolation is to extend the natural vibration cycle of structure by a seismic isolation unit, increasing the damping coefficient to reduce the acceleration response of structure in the earthquake; and at the same time distributing the seismic force evenly over every pier, averting the seismic force from concentrating on one pier.

Performance of the Lead Rod Damping Seismic Bearing can be seen in Fig 16:

Horizontal Equivalent Stiffness

$$K_B = \frac{F(u) - F(-u)}{2u}$$

Equivalent Damping Ratio

$$h = \frac{\Delta W}{2\pi W}$$

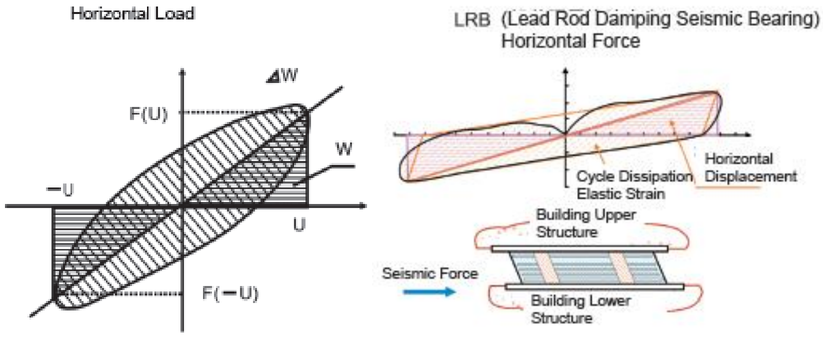


Fig. 16 – Horizontal Load and Force Performance of Lead Rod Damping Seismic Bearing

Dimensions of the Lead Rod Damping Seismic Bearing can be seen in Fig 17.

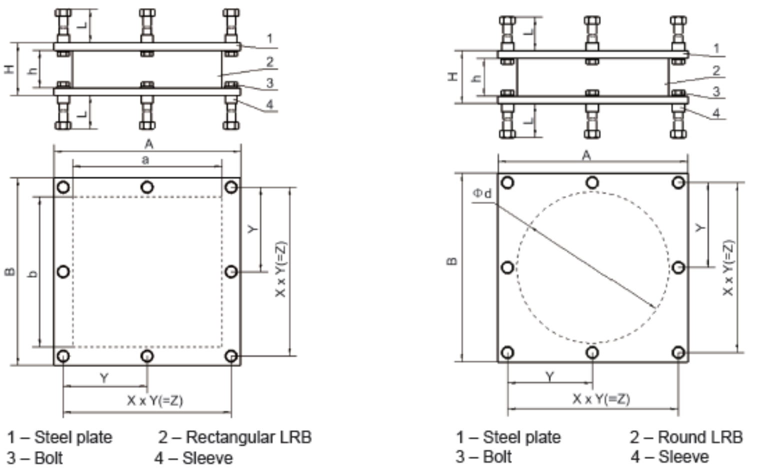


Fig. 17 – Dimensions of the Rectangular LRB and Round LRB

Fig. 18 – Seismic Bearing Installation

The estimated cost for Seismic Damping Design are around 1,100,000 USD if performance level is Immediate Occupancy (IO), or around 600,000 USD if performance level range from Immediate Occupancy (IO) to Life Safety (LS).

5. Conclusion

From the results of the structural inspection and evaluation of the Cipta Karya and Water Resources building, the following conclusions are made:

1. The main structure was found to have structural damage in the column and beams, especially the condition of the architectural components that have been tilted and broken. Such performance conditions have already exceeded Life Safety performance limits. Improvement/strengthening can still be made to bring the building performance back into Minimum Performance Requirements (Life Safety).
2. Stairs found to experiencing severely damages (cracked and tilted), thus exceeds the Near Collapse performance limits. The stairs must be demolished.
3. Estimated cost for alternative construction engineering are proposed as follow:
   a) Concrete Jacketing: 480,000 USD
   b) Seismic Damping Design
      - If performance level is Immediate Occupancy (IO): 1,100,000 USD
      - If performance level range from Immediate Occupancy (IO) to Life Safety (LS): 600,000 USD

6. References

[1] ACI 374.1-05, Acceptance Criteria for Moment Frames Based on Structural Testing and Commentary
[2] ACI 318-11, Building Code Requirements for Structural Concrete
[3] OVM 2012, Seismic Mitigation and Isolation Products for Structure

