20 - 22 AUGUST 2013

HOTEL BOROBUDUR JAKARTA

PROGRAM & ABSTRACTS BOOK

ASIAN CIVIL ENGINEERING COORDINATING COUNCIL

INDONESIAN SOCIETY OF CIVIL AND STRUCTURAL ENGINEERS

6 CECAR

THE 6TH CIVIL ENGINEERING CONFERENCE IN THE ASIAN REGION

and Annual HAKI Conference 2013

EMBRACING THE FUTURE THROUGH SUSTAINABILITY

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TECHNICAL SESSIONS

- Analytical and Design Methods
- Application of Information Technology
- Bridge Engineering
- Building Information Management
- Case Studies and Failure Investigation
- Climate Change and Coastal Management
- Construction Engineering and Management
- Disaster Mitigation, Adaptation, Preparedness Strategies
- Durability and Serviceability of Materials and Structures
- Environmental Impacts
- Geotechnical and Foundation Engineering
- Green Buildings
- Innovative Construction Products, Systems, and Practices and Testing Technology
- Mega Projects
- New Construction Material
- Performance Based Design and Analysis
- Prefabrication Technology
- Recycling of Resources
- Repairs, Retrofitting, and Maintenance
- River Basin Management
- Safety and Reliability
- Standards, Regulations and Codes of Practice
- Structural Health Investigations
- Sustainable Infrastructure/Construction
- Testing Technology
- Underground Construction Technologies
- Urban Problems
- Wind Engineering

SPECIAL SESSIONS

- Anti Corruption
- Long Span Bridges
- Tsunami –Lessons Learned from Past Disasters
- Building Information Management
- Precast Concrete Structures
- Disaster Mitigation, Adaptation, and Preparedness Strategies

OTHER PROGRAMS

- Symposium on Asia and Pacific Collaboration of ITS research
- Workshop on Vulnerability and Resilience of Critical Infrastructure Systems in Asia
- Forum on Concrete Model Code
- Asian Board Meeting
- Presidential Session on Infrastructures

SHORT COURSE

- A short course on Earthquake Engineering
- Structural Engineering Softwares-Next Generation

KEYNOTE SPEAKERS

Djoko Kirmanto
Ministry of Public Works
Indonesia

Djoko Kirmanto graduated from Gadjah Mada University in Yogyakarta and completed his masters in land and water development at IHE-DELFT in the Netherlands in 1977. He was appointed in 1997 as assistant to the residential development department head at the Ministry of Public Works during the Soeharto administration. Since 2001, he has held the post of director general of residential affairs at the Ministry of Settlement and Regional Infrastructure, Minister of Public Works.

Gregory E. DiLoreto
ASCE President 2013
USA

Greg DiLoreto is the Chief Executive Officer of the Tualatin (To-wal-a-tin) Valley Water District located in metropolitan Portland Oregon. He has worked in the public works field for 34 years, 17 years as a public works director/city engineer. Mr. DiLoreto holds a B.S. degree in Civil Engineering from Oregon State University and a Master degree in Public Administration from Portland State University. He is registered as a civil and environmental engineer and a professional land surveyor in Oregon. Mr. DiLoreto is a fellow in the American Society of Civil Engineers. He served on the ASCE Board of Direction 2004-06. He has received the 1986 ASCE Edmund Freidman Young Engineer Award, the 1995 ASCE Oregon Section Outstanding Civil Engineer award and the 2005 ASCE Government Engineer of the year award. In 2003 he was inducted into the Oregon State University Academy of Distinguished Engineers.

Yozo Fujino
University of Tokyo
Japan

He is a professor of civil engineering, at the University of Tokyo, since 1990. He has also served as science adviser (adjunct) to Ministry of Education, Science and Technology, in 2002-2004. Prof. Fujino was a Melchor Chair Visiting Professor, University of Notre Dame, Indiana, USA, in 1997, a Visiting Associate Professor in Asian Institute of Technology, Bangkok, Thailand, in 1987, and a Visiting Scholar, Dept. of Civil Engineering, University of Illinois, Urbana, Illinois, in 1980.
His fields of expertise inlcude bridge and structures, bridge design, bridge aerodynamics, bridge loading analysis, cable dynamics, wind effects on structures, control and monitoring of bridges and tower-like structures, bridge maintenance and management, earthquake effects on structures, nonlinear dynamics, passive control and active control of bridges and tower-like structures, and safety and security of urban environments.

Mete A. Sözen
Purdue University
USA

Mete A. Sözen is the Kettelhut distinguished professor of structural engineering at Purdue University, West Lafayette, Indiana, USA. His research interests include development of professional design codes for reinforced and pre-stressed concrete structures, and for earthquake-resistant design of reinforced concrete structures.
He has received several honors and awards: Honorary Doctorate, Bogazici University, Turkey, 2004; John Parmer Award, Structural Engineers Association of Illinois, 2003; Distinguished Lecturer, Earthquake Engineering Research Institute, 2002; Noel Nathan Memorial Lecturer, University of British Columbia, 2002; Outstanding Paper Award, ASCE Council on Forensic Engineering , 1998; Honorary Doctorate, Johann Pannonius University, Hungary, 1998; Honorary Doctorate, Georgian Technical University, Tbilisi, 1998; and Illinois Section Structural Group Lifetime Achievement Award, 1998.

KEYNOTE SPEAKERS

Masyhur Irsyam
Bandung Institute of Technology
Indonesia

Currently, Masyhur Irsyam is a professor at the Faculty of Civil and Environmental Engineering, Bandung Institute of Technology, Indonesia. His research interests include Soil Behavior, Ground Improvement, Foundation Engineering, Geotechnical Earthquake Engineering, Stability of Slope and Excavation, Soft Ground Tunneling, Offshore Geotechnics, Computational Geotechnics, Instrumentation and Testing in Geotechnical Engineering.

Bambang Susantono
Vice Minister of Transportation
Indonesia

Bambang Susantono is the Vice Minister for Ministry of Transportation, Republic of Indonesia. He is the President of Intelligent Transportation System (ITS) Indonesia and a Board Member of Intelligent Transportation System (ITS) Asia-Pacific. He serves as the President of Civil Engineering Alumni Association of Bandung Institute of Technology (ALSI-ITB) and a Board of Trustee of the South South North Foundation in Johannesburg, South Africa.
Bambang Susantono holds a Bachelor in Civil Engineering from the Bandung Institute of Technology, a Master of Science in Civil Engineering (MSCE) in Transportation Engineering, a Master of City and Regional Planning (MCP), and a Doctor of Philosophy (Ph.D.), all from the University of California at Berkeley. He teaches at the Graduate Program and is the program coordinator of Master's program in Infrastructure Management in Civil Engineering at the University of Indonesia.

Sang-Ho Lee
Yonsei University
South Korea

Sang-Ho Lee is a professor in the Department of Civil and Environmental Engineering at Yonsei University, Seoul, Korea. He is the Head of the Civil and Environmental Engineering Department, and Director of the Research Center for Asset Management of Civil Infrastructure and Small and Medium Business Promotion Center of Yonsei University.
He has received B.S. and M.S. degrees in the Civil Engineering from Yonsei University (Korea), and Ph.D. degree from Northwestern University (USA). His former area of expertise was Computational Mechanics such as Meshfree Method and eXtended Finite Element Method (XFEM), and current research interests are Building Information Modeling (BIM) of Infrastructure and BIM-based Asset Management of Infrastructure. He serves and has served as the committee chair or key member in the areas of Construction CALS-EC, Construction-IT convergence, BIM, International Standards, etc.

Gwo-Fong Lin
National Taiwan University
Taiwan

Gwo-Fong Lin is currently a Distinguished Professor in the Department of Civil Engineering at the National Taiwan University. He was the Chairman of the Civil Engineering Department and Director of the Hydrotech Research Institute at National Taiwan University. He has received various honors and awards.

SCHEDULE
Day 2

21 AUG 2013 — **WEDNESDAY**

15:40 - 17:20	6A	**Intelligent Transportation System**
		Chair: **HIROSHI MAKINO** (JSCE), Co-Chair: **SANG-HYUP LEE** (Korea Institute of Technology)
	076	*ITS-Based Solutions for Urban Traffic Problems in Asia Pacific Countries* H. MAKINO, S. KAMIJYO, and T. OSARA
	100	*A Study on the Characteristics and Operational Limitations of the Portable Reference Equipment Used for ITS Systems Performance Evalution* S. H. LEE, K. C JANG, and C. Y. MA
BANDA A	163	*Applications Strategy of Information Technology for Smart Transportation in Korea* N. C. BAIK, Y. M. KIM, J. H. KIM, and D. W. CHOI
	279	*A Study on the Traffic Flow Characteristics at Signalized Intersections during Snowfall* S. LEE, Y. SON, J. IM, and S. JUN
	280	*A Study on the Travel Time and Capacity Changes on Expressway by Snowfall* S. LEE, Y. SON, J. IM, H. YOO, and S. JUN
15:40 - 17:20	6B	**Analytical and Design Methods**
		Chair: **EDIANSJAH ZULKIFLI** (Institut Teknologi Bandung)
	124	*Effect of 3-D Welding Imperfection on Ultimate Strength of Welded Structural Member (1) -Introduction of Welding Imperfection for FEM Analysis-* D. H. PARK
	269	*Bending Capacity of Glulam Timber Beam* A. P. USMAN, A. NASUTION, and S. SUGIRI
FLORES B	241	*Flexural Strength of Glued Laminated Timber from Selected Malaysian Tropical Hardwood* N. M. BHKARI, A. A. BAKAR, P. M. TAHIR, and Z. AHMAD
	221	*An Experimental Study of Bamboo as a House Retrofitting Material for Developing Countries* E. SUHELMIDAWATI, W. BOY, R. ADRIADI, and R. ZAMZARENA
	155	*Friction Damper in Traditional Building in Indonesia* B. LUMANTARNA and P. PUDJISURYADI
15:40 - 17:20	6C	**Repairs, Retrofitting, and Maintenance**
		Chair: **D. H. CHOI** (Hanyang University)
	338	*Strengthening of Steel I-Girder Bridge with Deteriorated RC Slab by Pultruded GFRP I-Girders* B. ABDULLAH
	190	*Seismic Retrofit of Existing RC members with CFRP Grid by Polymer Cement Mortar for Shotcrete* K. YAMAGUCHI, S. HINO, K. TANIGUCHI, and S. NAKAMURA
FLORES A	206	*A Study on the Engineering Properties on Concrete with the Application of Pozzolanic Material and Waste Tire Rubber Powder* C. J. CHEN, Y. M. TANG, S. S. TSENG, and H. Y. WANG
	219	*Investigation and Proposed Structural Repair for Conduit Tunnel of Pacal Dam* S. ASAD and M. SUPRAPTO
	331	*Retrofitting of Bumiminang Hotel Building in Padang* F. A. ISMAIL, T. BOEN, FAUZAN, A. HAKAM, and ZAIDIR
15:40 - 17:20	6D	**Sustainable Infrastructure/Construction**
		Chair: **B. J. CHRISTENSEN** (BASF Construction Chemicals)
	351	*Developing Report Card to Identify Key Infrastructure Needs and Funding –Korean Case* T. S. LEE and S. R. SWAIN
SUMBA A	336	*Sustainable Urban Development in Energy Planning and Implementation: A Perspective for India among Developing Nations with Respect to Developed Nations* J. K. VYAS and A. D. J. VYAS
	025	*A New Special Economic Zone (SEZ) Belt -Synchronized Development for Embracing Asia-* R. KATSUMATA

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SIMPLIFIED ANALYSIS METHOD FOR TOWERS OF FOUR-SPAN SUSPENSION BRIDGES
Dong-Ho Choi and Sun Gil Gwon, Hanyang University, Korea.

In this study, a simplified analysis method for towers of four-span suspension bridges under static live loads is proposed using an equivalent model. The model is composed of towers and equivalent springs replacing the suspended parts. The stiffness of the equivalent springs is derived based on the parabolic configuration of the cable. Dead and live loads acting on the girders of each span are replaced with horizontal and vertical forces acting on the top of each tower. Then, the equations of the load-displacement relationships of the towers are derived for structural analysis of the equivalent model. Finally, an example bridge model with main span length of 3,000m is used for verification and the resultant values such as horizontal displacements of the towers are compared by using the proposed method and finite element analysis.

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LARGE-AMPLITUDE VORTEX-INDUCED VIBRATION OBSERVED AT LONG-SPAN CABLE-STAYED BRIDGE AND ITS AERODYNAMIC COUNTERMEASURE
Hiroshi Katsuchi, Yokohama National University, Japan.
Masatsugu Nagai, Nagaoka University of Technology, Japan.
Taishi Yamamoto, Fushiki-toyama Port Office, Ministry of Land, Infrastructure, Transport and Tourism, Japan.

Vortex-induced vibration with large amplitude in the vertical direction often took place at a long-span cable-stayed bridge with the center span of 360 m after the center-span deck closure. The maximum amplitude up to 35cm was observed. A typical wind condition was a 10-min. average wind speed of 10-14 m/s with an almost normal direction to the bridge axis. After the report of vortex-induced vibration, field measurement of the vibration was carried out. In addition, a vibration test was also conducted to identify natural frequency and structural damping. As a result, it was suspected that structural damping (0.014 in log. decrement) lower than the design value (0.02) and a very smooth wind flow might increase the amplitude of vortex-induced vibration. A wind-tunnel test investigation for its countermeasure was carried out. Since aerodynamic countermeasures were preferred to mechanical dampers such as a tuned mass damper, optimum shape and location of flaps was investigated. After trial and error tests, a final solution of flaps was identified to suppress the vibration completely. Field measurement conducted before and after the flap installation proved the efficiency of flaps.

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RETROFITTING OF BUMIMINANG HOTEL BUILDING IN PADANG
Febrin Anas Ismail, Teddy Boen, Fauzan, Abdul Hakam, and Zaidir.
Disaster Study Center of Andalas University

During the September 30, 2009 West Sumatera earthquake, many engineered-buildings in Padang were damaged and some even collapsed. According to USGS, the epicenter of this earthquake is at 0.789S, 99.960E with 80 km depth and the magnitude is 7.6 Mw. The epicenter is 47 km WNW (292) of Padang, West Sumatera. Many of the damaged buildings were demolished to be subsequently built new ones, while in fact many of them could be retrofitted.
Bumiminang Hotel, an 8-stories r.c. building with r.c. walls as core and masonry walls as partition, is one of the engineered buildings that was damaged and the owners decided to retrofit instead of demolishing. For the purpose, a numerical 3D model was created implementing of the details geometry of the structures. The main analysis was performed by linear-elastic approach and the result is good enough to explain the damages that occured in Bumiminang Hotel.
This paper discusses the structural retrofitting of Bumiminang Hotel which was completed within April 2011 - February 2012.

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DISASTER MANAGEMENT FOR RIVER FLOODS
G.L. Asawa
IIT Roorkee, Roorkee, INDIA
GLA University, Mathura, INDIA

There is no nation in the world which may have never experienced a disaster. Any disaster, in its wake, leaves behind colossal tragedy in terms of loss of life and property. One cannot prevent occurrence of natural disasters. Man-made disasters can, however, be prevented or, at least, the losses minimized. Objectives of any nation or people in this regard should be to be able to forecast (if possible) the occurrence of disaster sufficiently in advance and take all measures to minimize the loss of life and property and restore normalcy, post-disaster, at the earliest. Flood disasters, like other disasters, occur frequently in many parts of the world because of erratic distribution (both spatially and temporally) of rainfall and human beings settling down in flood plains or in the vicinity of river because of their water needs and non-availability of space at higher elevations due to huge population. For river flood disaster management, both structural as well as non-structural measures need to be adopted. This paper gives recommendations with regard to these measures for short-term as well as long-term. These recommendations should help in mitigating the losses following the river floods.

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RETROFITTING OF BUMIMINANG HOTEL BUILDING IN PADANG

Febrin Anas Ismail[1], Teddy Boen[1], Fauzan[1], Abdul Hakam[1], Zaidir[1]
[1] *Disaster Study Center of Andalas University*

ABSTRACT

During the September 30, 2009 West Sumatera earthquake, many engineered-buildings in Padang were damaged and some even collapsed. According to USGS, the epicenter of this earthquake is at 0.789°S, 99.960°E with 80 km depth and the magnitude is 7.6 Mw. The epicenter is 47 km WNW (292°) of Padang, West Sumatera. Many of the damaged buildings were demolished to be subsequently built new ones, while in fact many of them could be retrofitted.

Bumiminang Hotel, an 8-stories r.c. building with r.c. walls as core and masonry walls as partition, is one of the engineered buildings that was damaged and the owners decided to retrofit instead of demolishing. For the purpose, a numerical 3D model was created implementing of the details geometry of the structures. The main analysis was performed by linear-elastic approach and the result is good enough to explain the damages that occured in Bumiminang Hotel.

This paper discusses the structural retrofitting of Bumiminang Hotel which was completed within April 2011 - February 2012.

Keywords: *Earthquake, damage, retrofitting*

INTRODUCTION

On September 30, 2009 at 17.16 local time, a strong earthquake shook Padang and its surroundings. According to USGS (United States Geological Survey), the epicenter of this earthquake is at 0.789°S, 99.960°E with 80 km depth and the magnitude is 7.6 Mw. The epicenter is 47 km WNW (292°) of Padang, West Sumatera. Many engineered buildings suffered damage or even collapsed. Bumiminang Hotel is one of the engineered buildings that was heavily damaged. The building consists of 7 floors plus a presidential suite in the middle part of the building with a typical "Gonjong" roof. The structure is r.c. frame with masonry infill walls. The "core" area consists of r.c. thin columns resembling shear walls. The roof consists of traditional Minangkabau "Gonjong" steel construction.

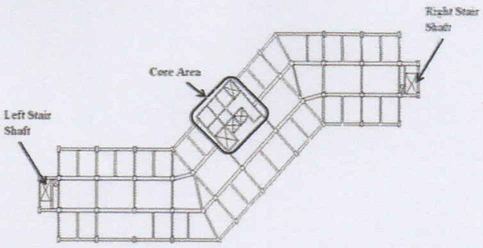


Fig. 1: Typical plan of Bumiminang Hotel

RETROFITTING OF BUILDINGS

After that earthquake, many damaged engineered buildings were demolished based on advices from consultants, government officers, foreign "experts", while in fact those buildings could be retrofitted (Fauzan 2010, Zaidir 2012). Advising to demolish buildings is a relatively easy decision, however, in reality many such decisions are not supported by sufficient data. In Indonesia the sophistication required for undertaking retrofitting has not been adequately articulated. Therefore, it is very clear that these individuals / firms / "experts" have no expertise for such undertaking. Retrofitting requires considerable expertise and technical knowhow where the objective is to achieve a better life safety performance (Arya

& Boen 1986, Boen 1992, 1995, 2000, 2003, 2005, 2006, 2008, 2009, 2012). In Indonesia, it is very urgent to develop consensus document on seismic assessment of existing buildings, buildings damaged after an earthquake and criteria for seismic retrofitting. The main advantage of retrofitting, particularly for developing countries, is that it can save cost and shorten the interuption time.

DAMAGE DUE TO THE SEPTEMBER 30, 2009 EARTHQUAKE

Assessment of Bumiminang Hotel building damage was conducted right after the earthquake in October 2009 and was published in 2011 (Febrin, et al 2011).

Direct damages due to earthquake shaking

From site survey and analysis results, the following was observed:

- Based on the actual condition and the analysis results, apart from the core area, there were relatively few direct columns and beams damage. The damage of columns and beams were not patterned and sporadic. The damage of columns and beams were mostly spalling of concrete at supports, however main reinforcing bars were not deformed.
- The core area was seriously damaged, thin columns failed due to flexure and shear. The use of many thin r.c. columns for the"core" area was not appropriate. That area became overly rigid compared to the surrounding areas and took a large portion of the earthquake load. Apart from that, from the ground floor up, those thin columns reinforcement used diameter 16 mm and 22 mm. While the basement wall underneath used diameter 13 mm and the thin columns were not properly anchored to the basement wall. This caused crushing failure of the thin columns at the ground floor level, and caused a settlement of approximately 70 cm.
- In general, if the quality of concrete, detailing of reinforcement were properly supervised, the main structure apart from the core area could withstand the loads including earthquake. However, the structure system could have been designed more appropriate to withstand earthquakes. There were relatively very few main columns and beams that were damaged by the shaking. The observed damage of those columns and beams was due to the lack of confinement or bad detailing of reinforcement or poor concrete quality.

Fig. 2 : Main column failure, reinforcing bars undeformed.

Fig. 3 : Thin column failure at the "core" area

Fig. 4 : Beam failure, reinforcing bars not deformed

- The masonry columns between two r.c. columns along the perimeter of the building were only esthetical and were not properly anchored to the main structure. During the shaking, almost all masonry columns were heavily damaged. The masonry walls adjacent to those columns suffered substencial damage.
- Most walls on the ground floor were seriously damaged.
- There were two emergency stair shafts at both ends of the building. Many beams were damaged due to lack of confinement and improper detailing and poor concreting. Many of the masonry walls in the emergency stair shafts were also damaged.

Fig. 5 : Beam damage at right-side stair shaft

Fig. 6 : Beam damage at left-side stair shaft due to poor detailing and poor concreting

In-direct damages (concrete beams and masonry walls) due to settlement of the thin columns

- As mentioned, the thin columns were crushed at the ground floor and caused settlement of approximately 70 cm. Beams and slabs connected to the thin columns were forced to deform causing overstress at the other end of the slabs and beams. However, only a few beam main reinforcement was yielded.
- Masonry walls between rooms suffered minor damage except the walls adjacent to the thin columns where the beams joining the core area were forced to deform.

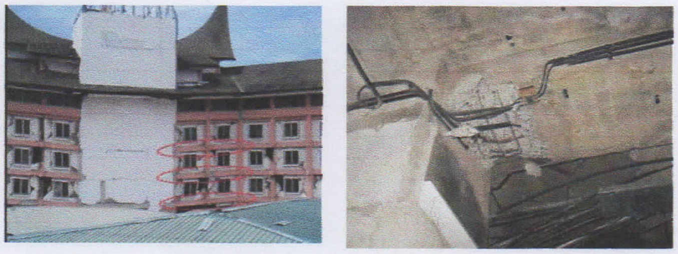


Fig. 7 : Indirect damage

METHOD AND RESULT OF ANALYSIS

To analyze this building, a numerical 3D model was created implementing all the geometry of the structures. Wall panels were also modelled. The main analysis was performed by linear elastic response spectrum approach and the result was able to predict the existing damage quite adequately. The earthquake used for the analysis was larger than the September 30, 2009 earthquake. The response spectrum was taken from the Indonesian earthquake map of 2010 with peak ground acceleration (PGA) for Padang area 0.5g and return periods of 500 and 2500 years. The estimated PGA of the September 30, 2009 earthquake was 0.3g. The importance factor was 1.25.

The purpose of the analysis is not to simulate the actual behavior, but to get reliable information that there is a correlation between the observed damages and the results of the analysis. The correlation is not perfect, but it is good enough to get a good idea to build appropriate buildings that can withstand earthquakes.

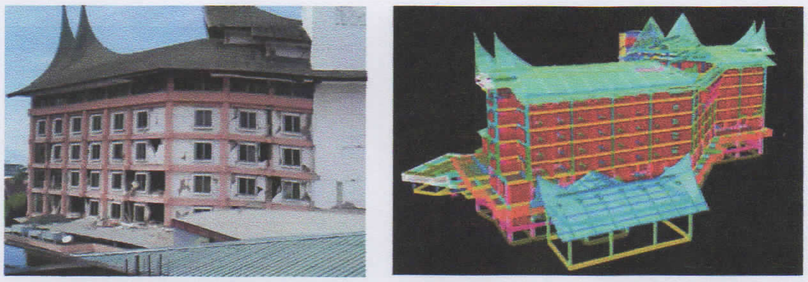
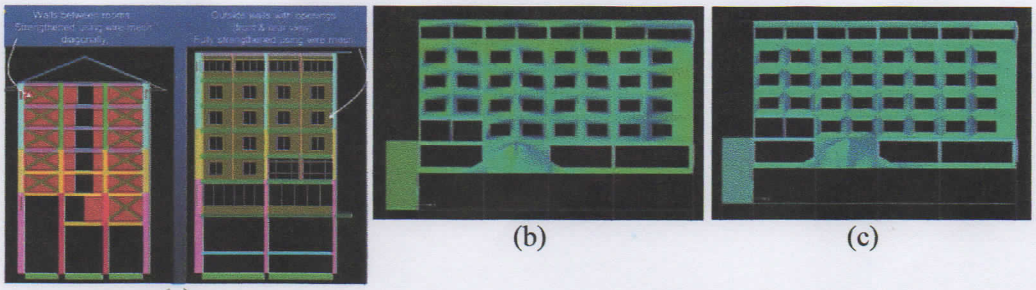


Fig. 8 : Bumiminang Hotel before retrofitting (left); 3D model analysis using ETABS NL v9.7 (right)



(b) (c)

(a)

Fig. 9 : Retrofitting of walls using wire mesh (a); retrofitted walls, stresses in bricks did not exceed the allowable stress (-0.35 ~ 0.133 N/mm^2) (b); stresses in plasters did not exceed the allowable stress(-1.3 s/d 3 N/mm^2) (c)

IMPLEMENTATION OF RETROFITTING

The implementation works include retrofitting the core area; stair shafts, both, left and right side of the building; damaged concrete columns and beams outside core area; installing practical columns replacing masonry esthetics columns and repair damaged walls using wire mesh.

The area that suffered serious damage was the middle part of the building where the thin columns were located, close to the elevators (core area). There were two alternatives for implementing the retrofitting of the core area as follows:

Alternative 1

The area surrounding the thin columns will be reinforced with steel frames and subsequently all the core area will be jacked up to the original level. To do such alternative there was a need of at least 30 jacks with capacity of 200 tons each. However, such construction equipments needed was not available in Indonesia. Therefore alternative 1 was considered not feasible and changed into alternative 2.

Alternative 2

Since alternative 1 is not feasible, the other option left is to demolish all the core area and rebuild it. For that purpose there was a need to temporarily support all the beams and the slabs connecting to the core area from the ground floor up to the machine room. H steel profiles were used for the purpose. Before demolishing the core area, all beams and slabs were separated from the core. To speed up the retrofitting, it was decided to rebuild the core area with steel frames and light weight blocks as walls.

After the steel frame construction of the core is completed, the beams and slabs connecting to the core must be re-connected. 10 ton car jacks were used to restore the levels of the deformed beams and slabs.

Fig. 10 : Temporary support using H profiles

Fig. 11 : Demolishing core area

Fig. 12 : Disconnecting concrete slab from the core area

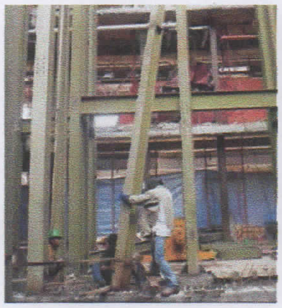


Fig. 13 : Erection of steel construction in the core area

Fig. 14 : Slab at core area

Fig. 15 : Jacking of concrete beams at the perimeter of core area to restore the original level

Fig. 16 : Connecting concrete beams into steel beams/columns at core area

Fig. 17 : Construction of walls at core area

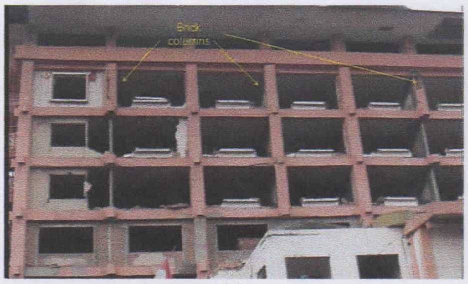
Most of the direct damage of beams and columns were due to overstress causing spalling of concrete. The damaged part was chipped and additional confinement was installed. For beams connected to the core area, where the main reinforcement was deformed, additional splices were provided apart from the additional confinement. For the reconcreting, Sikament LN was added to the concrete. The masonry walls along the perimeter of the building were reinforced with wire mesh on both sides of the wall and each r.c. window framing was installed. The masonry columns between two main r.c. columns along the perimeter of the building were replaced by r.c. columns embedded in the walls. The masonry walls between rooms were reinforced using diagonal wire mesh strips on both sides of the wall. Sikament LN was added for the mortar. To fill wide cracks, Sikagrout 215 was applied. Smaller cracks were filled with Sikadur 752 RT. The structure retrofitting was completed within 10 months.

(a) (b)

Fig. 18 : Retrofitting of damaged column outside core area - damaged column (a); additional confinement (b).

(a) (b) (c)

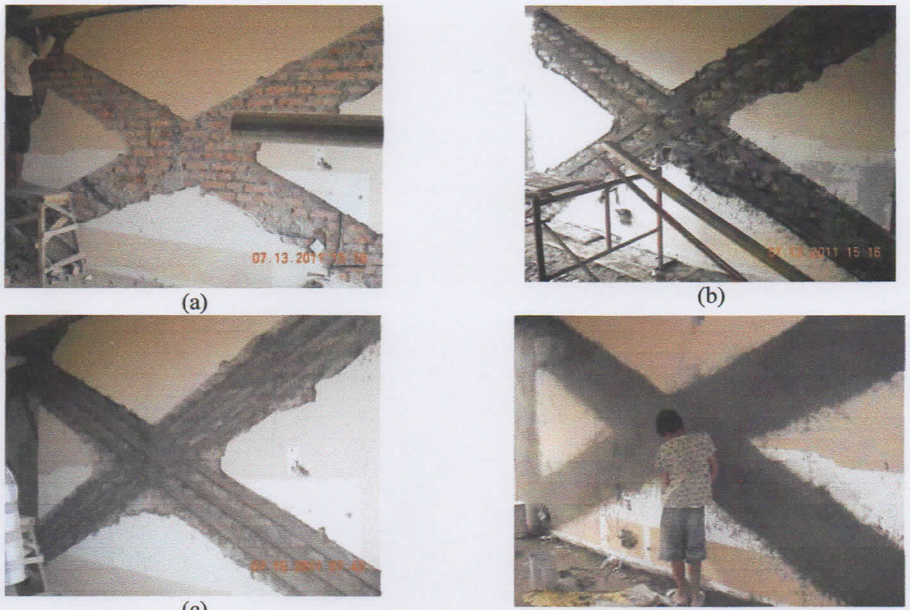
Fig. 19 : Retrofitting of damaged beam – damaged beam (a); additional confinement (b); re-concreting (c).



(a)

(b)

Fig. 20 : Replacing masonry column with practical column (a); installation of practical column (b).



(a) (b)

(c) (d)

Fig. 21 : Retrofitting of masonry walls between rooms using diagonal wire mesh strips on both sides of the wall: peeling off wall plaster (a); thin bed mortar for wire mesh (b); wire mesh installation (c); re-plastering (d).

(a) (b) (c)

Fig. 22 : Front view - before retrofitting(a); after retrofitting (b); after repainted (c).

(a) (b) (c)

Fig. 23 : Core area - before retrofitting (a); after retrofitting (b); after repainted (c).

REFERENCES

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