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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JAEE JAPAN ASSOCIATION FOR EARTHQUAKE ENGINEERING

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With Bosai / Disaster Management Expo in Sendai

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

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17WCEE News Letter

With Bosai Expo

Bosai / Disaster Management Expo in Sendai

仙台市 City of Sendai

Program / Speakers

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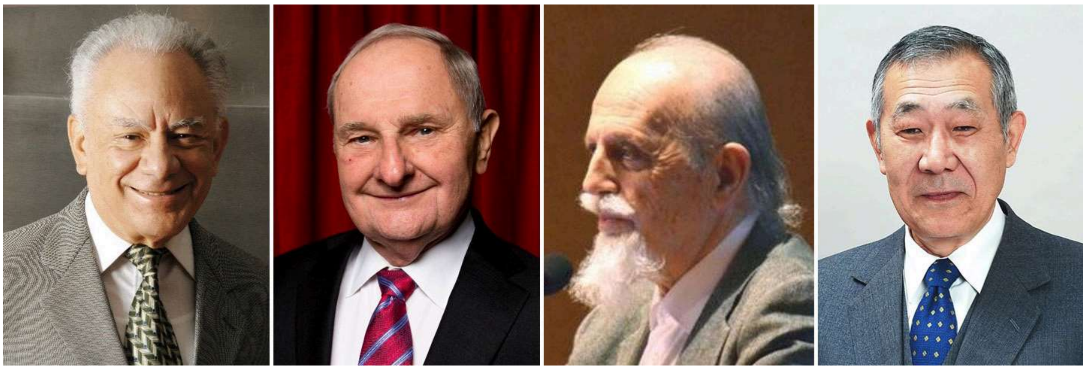
Meet the Masters



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)

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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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
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HAMOOD ALWASHALI, DEBASISH SEN, MASAKI MAEDA, MATSUTARO SEKI	ADVANTAGES AND LIMITATIONS OF RETROFITTING MASONRY INFILLED RC FRAMES BY FERRO-CEMENT BASED ON EXPERIMENTAL OBSERVATIONS
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GIOVANNI MUCIACCIA, GIUSEPPE DI NUNZIO	CYCLIC BEHAVIOR OF SCREWED HEAD ANCHOR SYSTEM FOR APPLICATIONS IN NUCLEAR POWER PLANTS
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MANISH KUMAR, SUJIT V MATALE, DURGESH C RAI	INFLUENCE OF PERIMETER SUPPORTS ON THE SEISMIC RESPONSE OF PLASTERBOARD SUSPENDED CEILING SYSTEMS
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SIAMAK SATTAR, MIKE MAHONEY, RYAN KERSTING	FUNCTIONAL RECOVERY OF THE BUILT ENVIRONMENT AND CRITICAL INFRASTRUCTURE
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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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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
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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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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
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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
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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
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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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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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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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17th World Conference on Earthquake Engineering, 17WCEE
Sendai, Japan - September 13th to 18th 2020

DEVELOPMENT OF EARTHQUAKE AND TSUNAMI DISASTER MITIGATION PLAN FOR MANDALIKA MOTOGP CIRCUIT IN LOMBOK

R. Baheramsjah[(1)], A.M. Mansoer[(2)].H. Harinto[(3)],H. N. Nurjaman[(3)]. M. Irsyam[(4)], M. Asrurifak[(4)], M. Ridwan[(4)], L. Faizal[(4)], H. Latief[(4)], B. Hariandja[(5)], Suwito[(6)], D. Dinariana[(7)]

[(1)] *Chief Executive Officer, Mandalika Grand Prix Association, Indonesia, ricky.baheramsjah@themandalikagp.com*
[(2)] *President Director, Indonesian Tourism Development Corporation, Indonesia, info@itdc.co.id*
[(3)] *Steering Committee, Indonesian Tourism Development Corporation, Indonesia, info@itdc.co.id*
[(4)] *National Centre of Earthquake Studies, Research Institute of Housing and Human Settlement, Ministry of Public Work and Housing, Indonesia, info@puskim.pu.go.id*
[(5)] *Emeritus Professor, Civil Engineering Department, Institut Teknologi Bandung, Indonesia, binsar_hariandja@ymail.com*
[(6)] *Assistant Professor, Construction Engineering and Management Department, Universitas Agung Podomoro, Indonesia, suwito@podomorouniversity.ac.id*
[(7)] *Associate Professor, Civil Engineering Department, Universitas Persada Indonesia, Indonesia, dwidinariana@gmail.com*

Abstract

Indonesia has begun the construction of new Moto GP circuit in Mandalika region, Lombok, West Nusa Tenggara. The Mandalika circuit will be the only street circuit of Moto GP and will start hosting Moto GP races in 2021. The circuit is located in a scenic Indian Ocean beach resort area in Lombok. Considering that Lombok is situated near earthquake sources in the form of the sub-duction due to convergence of two major tectonic plates of Indo-Australia and Eurosia, and several active faults in the island and ocean, the earthquake and tsunami mitigation plan of circuit infrastructures and facilities needs to be handled. Even though racing event is not a daily activity, the management wants the circuit arena to be also used as pilot project for natural disaster mitigation that is combined with educational tourism. As part of mitigation plan, seismic micro-zonation was specially conducted for the site so as to get more accurate earthquake load to be used in the design of buildings and infrastructures in and around the circuit. In addition, the latest earthquake resistant building technologies were incorporated into the design. Tsunami simulation was conducted based on earthquake sources potential of subduction in Indian Ocean that was propagated to Mandalika beach and then employed to develop mitigation plan in Mandalika circuit area. Mitigation plan in the forms of evacuation area plan, evacuation route plan, and evacuation protocol plan was designed as tourist attraction. The overall earthquake and tsunami mitigation plan will be packaged as educational tourism so that it can change the people's view on that natural phenomenon from threat to business potential.

Keywords: earthquake; tsunami; sub-duction; Mandalika; Moto GP

1. Introduction

Mandalika, located in a scenic Indian Ocean beach resort area in Lombok Island, West Nusa Tenggara Province, is one of new tourist destinations in Indonesia. As such, Indonesian Government wants to maximize Mandalika's potential as a tourist attraction. One of the efforts by government is to build Mandalika MotoGP circuit and host the event of MotoGP race starting on 2021. Mandalika MotoGP circuit will be the only street circuit in MotoGP series. Figs 1(a) and 1(b) show map and construction progress of Mandalika MotoGP circuit. The event is expected to boost tourism industry in the surrounding areas. The economy, employment opportunities and the utilization of natural resources are expected to improve.

(a) (b)

Fig. 1– (a) Map of Mandalika MotoGP circuit, Lombok, (b) Construction progress of Mandalika Moto GP circuit, Lombok

In developing Mandalika tourism area, a sustainable development strategy taking into account the environment and natural disaster risk, is employed. This strategy is carried out so that the buildings and infrastructures constructed in the area do not impact the environment negatively and are able to withstand any anticipated natural disaster. This study mainly focuses on the disaster mitigation plan against earthquake and tsunami.

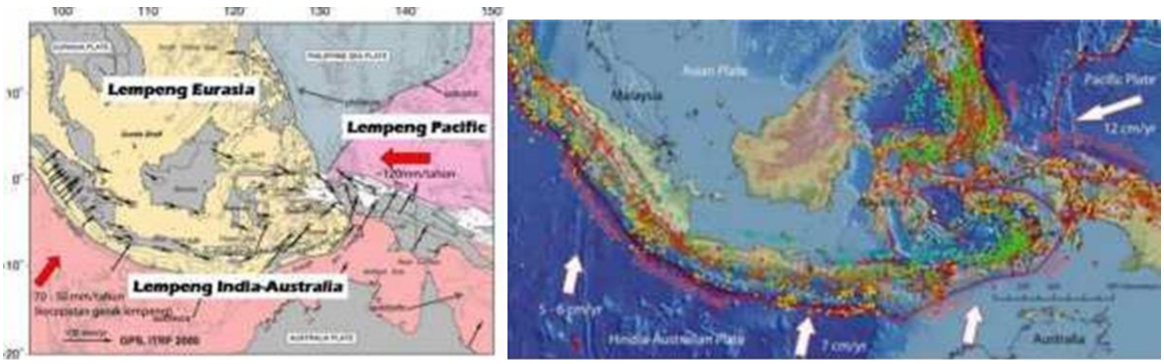
Geographically, Mandalika is located near the coastline and at the sub-duction zones due to convergence of two major tectonic plates of Indo-Australian and Eurasia plates and resulted in the formation of the Sunda and Banda island arcs. Thus, the region is prone to earthquake and tsunami threats. Any buildings and infrastructures built in the region must be designed against earthquake and tsunami. In addition, for the safety of population in the region, tsunami disaster management plan must be prepared and implemented.

2. Earthquake and Tsunami Hazard

Earthquake and tsunami have been identified as two forms of natural disasters that threat Mandalika resort area. As such, they both will be described herein.

2.1 Earthquake

Indonesian archipelago is located on subduction zones of three main active tectonic plates, namely the Eurasian Plate, Pacific Plate, and Indo-Australian Plate as shown in Fig. 2(a). Indo-Australian plate moves to the north direction with the rate of 50-70 mm per year and slides down below deep sea bed of Sumatra, Java and Timor (at East Nusa Tenggara) islands. As a result, and due active movement of the plates, the country is frequently struck by major earthquakes. The major earthquakes normally occur at the areas near the boundaries among the 3 plates and along the lines of active faults formed at the plate interior part of Indonesian archipelago as shown in Fig. 2(b). Sub-duction zones located in south of Lombok island as well as active faults located in Lombok and Bali islands contribute to the level of earthquake hazard in Mandalika resort area, Lombok.



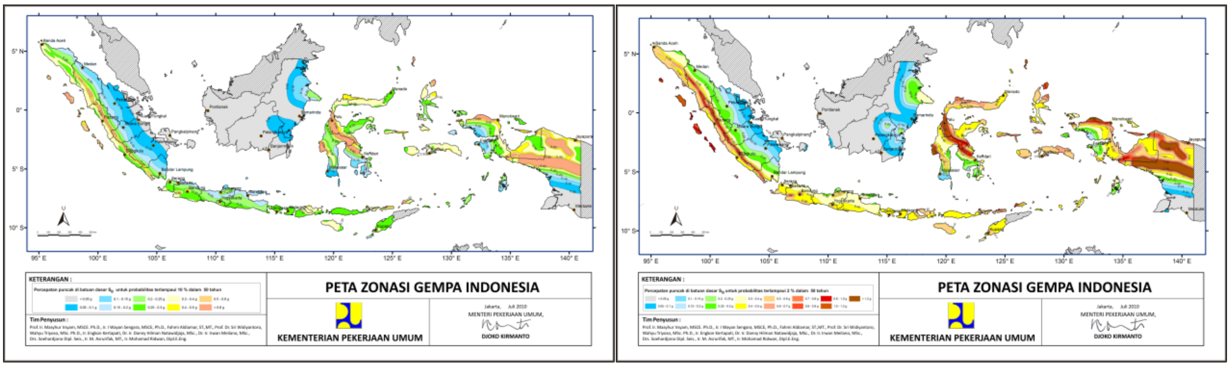
(a) (b)

Fig. 2 – (a) Map of Indonesia active tectonic plates and (b) Map of Indonesia active tectonic plates and earthquake records since 1973 [7]

Since the Mandalika area is located in a high-risk seismic zone, the impact of earthquake needs to be taken into consideration when designing buildings and infrastructures in the area. In general, earthquake can result in disaster due to soil deformation along seismic fault and, depending the magnitude of the earthquake, the seismic ground motion can spread to the surrounding areas with radius up to hundred kilometers. In addition, seismic shock wave can cause further disaster in the forms of soil sliding and settlement. And if the earthquake source is located beneath the ocean, the seabed movement can trigger tsunami.

To determine the level of seismic hazard of a region in relation to structural design of building, a parameter, named Peak Ground Acceleration (PGA) is normally used. Seismic ground motion analysis is carried out using method called Probabilistic Seismic Hazard Assessment (PSHA). In this study, the required parameters for earthquake hazard analysis are adopted from Indonesian Seismic Hazard Map 2010 (published by Ministry of Public Work and Housing), a part of design code used for designing earthquake resistant structures.

For designing a structure in a region, designed lateral base shear force due to seismic ground motion must be determined based on requirements set by government body in Indonesian National Standards (SNI). The design standard provides guidelines to design earthquake resistant structures that are able to prevent loss of life and global collapse. According to SNI 1726:2002, seismic design load is determined based on the return period of 475 years, or has 10% probability of exceedance in 50 years. Maps of PGA developed by Ministry of Public Work and Housing using either probabilistic or deterministic method are presented both in 10% and 2% of probability of exceedance in 50 years as shown in Figs 3(a) and 3(b), respectively.



(a) (b)

Fig. 3 – Peak Ground Acceleration (PGA) seismic hazard map at bedrock (S_B) for (a) 10% probability of exceedance in 50 years, (b) 2% probability of exceedance in 50 years

Based on the result of PSHA above, it is found that Mandalika resort region has a quite high PGA at bedrock of 0.250 g for 10% probability of exceedance in 50 years (return period of 475 years) and of 0.375 g for 2% probability of exceedance in 50 years (return period of 475 years) as summarized in Table 1.

Table 1 – Hazard level of coast line towns against earthquake

Location			Order	Coordinate		PGA		Hazard Level
Name	District	Province		Latitude	Longitude	10% PE50	2% PE50	
Selong	Lombok Timur	NTB	2	116.538	-8.652	0.150	0.225	HIGH
Mataram	Mataram Town	NTB	1	116.139	-8.583	0.250	0.375	HIGH

2.2 Tsunami

The word tsunami has the origin from Japanese language and consists of two syllables, “tsu” meaning wave and “nami” meaning harbour, and thus has the overall meaning of harbor wave. Tsunami is normally triggered by sudden change of large volume of water in the ocean or lake caused by natural disasters. One of natural disasters that often causes tsunami is an earthquake.

The two recent large tsunamis that are caused by the earthquake are 2011 Tohoku Tsunami, Japan and 2004 Aceh Tsunami, Indonesia. These two tsunamis and also other large tsunamis in the past had a very devastating impact to man-made environment and lives. The destruction caused by tsunami’s massive flooding to the coastal area include:

i. Destroy wooden houses except their foundations.
ii. Destroy non-structural elements of houses and buildings made of reinforced concrete and steel structures. The structural elements are normally still intact.
iii. The destruction force of tsunami increases with the increased amount of rubbles (from destroyed buildings, vehicles, ships, etc.) floating in tsunami wave
iv. Broken-down of reinforced concrete wall due huge horizontal force coming from tsunami current, lifted building floor due buoyancy force of water or trapped water
v. Rolled building because lifted pile foundation due to loss of friction resistance of sandy soil because of liquefaction.
vi. Secondary effects such as fire and explosion of power plants

Distribution of wave height along the coastal line at Mandalika Moto GP circuit region and its surrounding area (KMPL), as shown in Fig. 4, are between 5 meters and 10 meters for return period of 500 years while energy distribution and Estimated Tsunami Arrival (ETA) of 38 minutes at KMPL is shown in Fig. 5.

Based on the result from DTHA, the city of Denpasar has maximum tsunami amplitude of 9.3 m with ETA of 38 minutes, while the city of Mataram of 6.3 m and ETA of 28 minutes as summarized in Table 2. Considering that position of city of Denpasar is relatively the same to Mandalika Moto GP circuit region in term of position from sub-duction zones in the south of Bali and Lombok Islands, thus the maximum tsunami amplitude of about 10 m with ETA of 38 min. can be taken.

Table 2 – Tsunami hazard level for coastal line cities in Bali and Lombok

Location			Order	Coodinate		H MAX (m)	T MAX (min.)	Hazard Level
Name	District	Province		Latitude	Longitude			
Selong	East Lombok	NTB	2	116.538	-8.652	6.6	20	HIGH
Mataram	City of Mataram	NTB	1	116.139	-8.583	6.3	27	HIGH

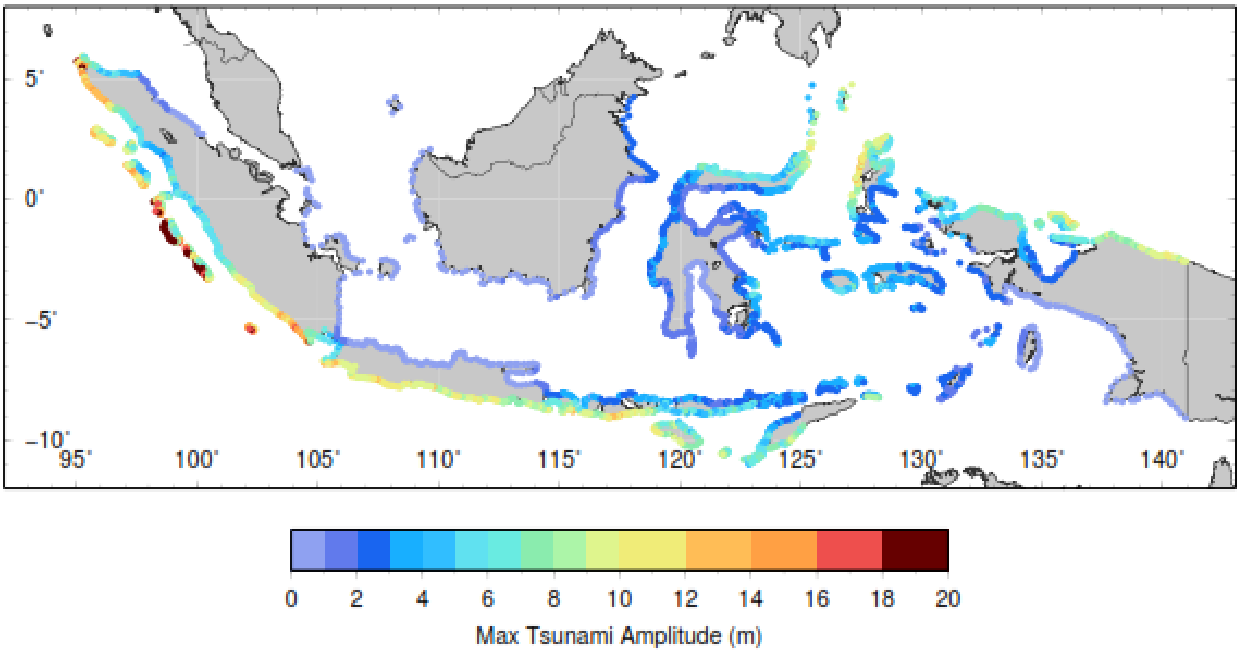


Fig. 4 – Tsunami hazard map of máximum tsunami amplitude (m) at Coastal line with return period of 500 years [7]

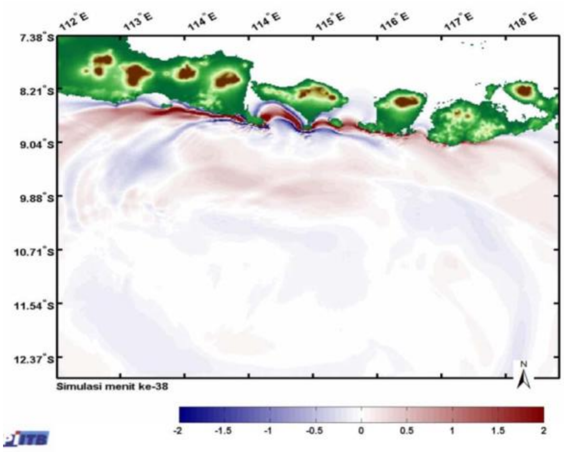


Fig. 5 – Distribution of tsunami amplitude and ETA at KMPL [7]

Based on the history of Banyuwangi Tsunami 1994 run-up with maximum tsunami amplitude of 13.9 and average amplitude of 5-8 m at Pancer bay, and of Pangandaran Tsunami 2006 with maximum tsunami amplitude of 17 meter and average amplitude of 5-8 m at Nusa Kambangan Island, the maximum tsunami amplitude at Mandalika Moto GP circuit can reach 15 m inside the bay with average amplitude of 5-10 m along KMPL with ETA of 38 minutes.

3. Implementation of Tsunami Mitigation System

Based on assessment of tsunami hazard and risk and several guidance [1-3] and previous studies [4-8], several tsunami mitigation measures have been implemented in the forms of structural and non-structural measures. The physical measures that have been implemented include:

a) Constructions of coastline protection system (breakwater, seawall, river gate),
b) Plantation of mangrove forest, and
c) Taking care of sand dune and coral reefs.

On the other hand, the non-structural measures include:

a) Tsunami hazard assessment,
b) Real time monitoring of tsunami early warning system,
c) Tsunami friendly spatial planning,
d) Improving building code,
e) Educating local population about tsunami awareness, preparedness including tsunami drill, and
f) Building TES and evacuation signs

3. Design Tsunami Temporary Evacuation Shelter (TES)

Tsunami evacuation shelter is designed based on earthquake and tsunami probability maps. For Mandalika circuit Moto GP area, the following data are used:

- Tsunami height at coastal line is 15 meters
- Estimated Tsunami Arrival (ETA) is 40 minutes

These data are used to design some facilities as part of tsunami mitigation system.

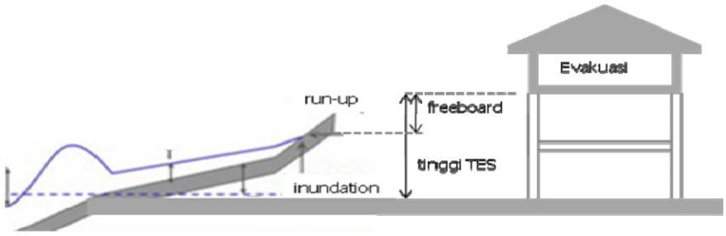


Fig. 6 – TES height

3.1 Evaluation of TES height

TES height, as illustrated in Fig. 6, can be determined using Eq. (1) below:

$$H = H_i + H_f \tag{1}$$

where

H = TES height from the ground surface (m),

H_i = Inundation height of tsunami wave (m) and

H_f = freeboad height (3 m + 30% H_i).

For example, if design parameter for the tsunami height is 10 m, then the TEST is H = 10 + (3 + 0.3 × 10) = 16 m.

3.2 Evacuation Time

Time needed by tourists and local people in Mandalika and its surrounding area to evacuate can be determined by considering the following factors:

a) Estimated Tsunami Arrival, ETA, and
b) Time for Early Warning, TEW.

The critical time to evacuate safely before tsunami arrival can then be evaluated using Eq. (2). Critical time (ETE, Evacuation Time Estimate) is time difference between ETA and TEW.

$$ETE \geq ETA - TEW \quad (2)$$

When an earthquake takes place, the estimated time to prepare tsunami early warning time, T_0, for Mandalika resort area is about 5 minutes or less (I_{na} TEWS, BMKG, 2012. Estimated time required to spread the news from local government to people in the impacted area is about 5 minutes (T_1). Reaction time for people to prepare evacuation is about 5 minutes (T_2). Thus, $T_{EW} = T_0 + T_1 + T_2 = 15$ minutes. Taken ETA = 40 minutes, then ETE = ETA - TEW = 25 minutes.

3.3 Location of TWE and TEA Tsunami

For designing the location of TES and TEA, it is necessary to consider the longest distance that can be reached by weak people with physical limitation. There are two methods that can used to determine optimum distance and location as follows:

a) Empirical calculation developed by FEMA

b) Calculation based on physical field condition

Table 2 presents calculation location distance radius of TES and TEA using field condition calculation method.

Table 3 – Calculation distance radius TES at Mandalika Moto GP circuit region

Effective Evacuation Time (ETE)	Walk Speed of people (Weak)	Travel Distance to TES	Maximum Distance between 2 TES Locations
25 minutes	2 mph (3.22 km/hour)	1.34 km	2.68 km

From radius distance calculation, the minimum numbers of TES can be determined. Eleven TES locations are selected over Mandalika Moto GP circuit region as shown in Fig. 7. Distance between TES is adjusted based on other factors to improve TES effectiveness as explained in Figs 8 (a) and 8 (b).

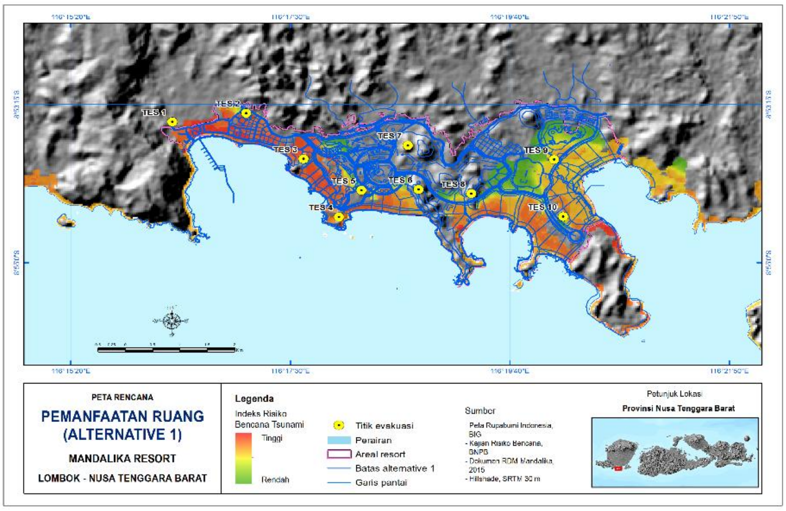
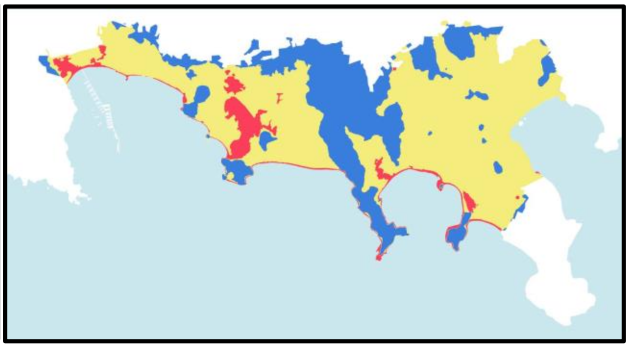


Fig. 7 – Distribution of planned TES locations in Mandalika resort region

In determining distribution of TES locations, simulation of tsunami propagation and water coverage modeling must be performed. In addition, tsunami hazard assessment takes into account vulnerability built up at Mandalika resort region. With this hazard analysis, it can be determined the evacuation route and the minimum width of footpath that can be used to evacuate mass population from danger tsunami region.

(a)



(b)

Fig. 8 – (a) Topography map of TES locations at Mandalika resort region, (b) Distribution map of tsunami flooded area and depth in Mandalika resort region [7]

From Fig. 8 (a) one can see that the land topography in Mandalika resort region has natural hills near the coastal area. It is also known that selecting evacuation place at higher ground is important aspect that must be taken into account. Therefore, higher grounds or hills are selected to be the 11 TES locations covering all areas in Mandalika resort region. Meanwhile, flooded area and depth due to tsunami wave can be seen in Fig. 8 (b) and are influenced by land topography in Mandalika Moto GP circuit region. It can be seen that area along coastal line and around downstream of Batang River will be the areas that flooded deepest.

3.4 Calculation the Area of TES

International standard for required area per person for tsunami evacuation is still not available. Therefore, in designing building capacity for TES, one can consider the requirement for comparable natural disaster such as international standard for tornado disaster evacuee (International Code Council/National Storm Shelter Association) that has almost similar requirement characteristics for short term period at the time of disaster or for long term period after disaster (FEMA P-464, 2012). Considering that tsunami is temporary building for emergency situation, and there is still no specific standard of requirement area per person for TES, then, for this study, we adopt emergency situation due to tornado published by FEMA P-646, 2012 (Table 4).

Table 4 – Recommendation space área per person inside TES facility

Temporary Evacuation Situation In Hours (Max. 24 hours)	**Room Standard per Person (m^2)**
Standing or Sitting	0.5
Wheelchairs	1
With Bed Care	2.8
Evacuation Situation Have To Stay In Days	**Room Standard per Person (m^2)**
Staying In Short Term (Couple Of Days)	2
Staying In Long Term (Couple Of Weeks)	3.7

From Table 4, standard space of TES is (0.5-1) m^2/person, in which 1 m^2/person for comfortable condition while 0.5 m^2/person for standing condition. Calculation of minimum area for each TES and TEA is carried out with consideration of the numbers of evacuee, evacuation duration and standard space requirement.

Table 4 – Proposed location and name of TES and TEA

No	Location	Name	Minimum Area of TES (m²)	Notes
TES 1 / F	West Zone	The Breeze Kuta	3962	
TES 2 / D	West Zone	The Breeze Seger	3453	
TES 3 / B	West Zone	The Lagoon	6421	
TES 4 / A	West Zone	The Serenity	1793	
TES 5 / C	West Zone	The Scenery	1560	
TES 6 / H	Middle Zone	The Hills 1	1840	
TES 7 / G	Middle Zone	The Hills 2	2186	
TES 8 / J	East Zone	The Rainbow	5325	
TES 9 / I	East Zone	The Sanctuary	6602	
TES 10 / E	Middle Zone	The West Circle Hub	3055	TES and TEA
TES 11 / K	East Zone	The East Circle Hub	4649	TES and TEA

3.5 Design of TES

TES built for Mandalika Moto GP circuit region is also intended as tourist attraction that take advantage of beautiful scenery and interesting culture in Lombok. As such, prize contest to design architectural concept for TES facility for Mandalika Moto GP circuit region was held.

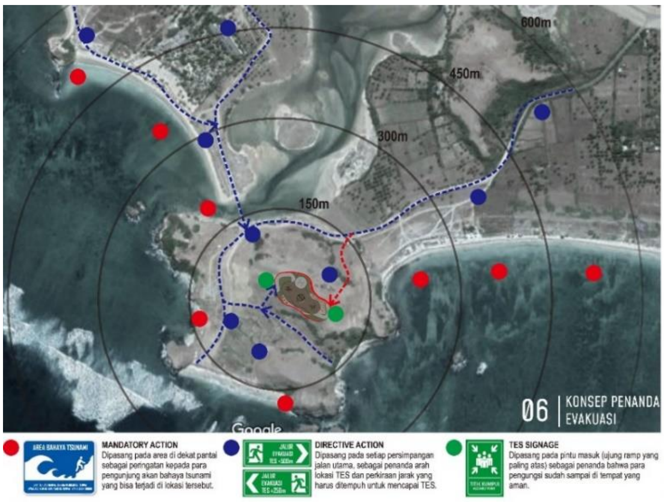


Fig. 9 – Location of TES B in Mandalika MotoGP circuit region and Evacuation Routes

The TES location is selected for the contest is at TES B (shown in Fig. 9), which has hilly topography contour and protrudes to the sea. This becomes the main parameter in the design because from tourism perspective the location is close to the sea and has beautiful scenery. The winner of contest is shown in Fig. 10. In addition, evacuation path to TES B located on top of the hill must be designed in detail so that it will be easy to be accessed whether there is disaster or not.

Figure 10 – The Winner Of Architectural Contest For TES Design

The theme of TES building architecture concept was named ‘Nibing Sasak’, which means to be protected in one. That is reflecting the function of Temporary Evacuation Shelter (TES). The iconic shape of its rooftop reflecting the importance of ‘Bale Lumbung’ (Rice Storage Building) for the people of Lombok.

Fig. 11 – Front view of TES buildings

In addition to its function as temporary evacuation place, TES is also designed to have restaurant and viewing station as new tourism objects. Clinics and rest rooms, as shown in Fig. 11, are also provided to support evacuee that have to stay a long period of time in TES during tsunami disaster.

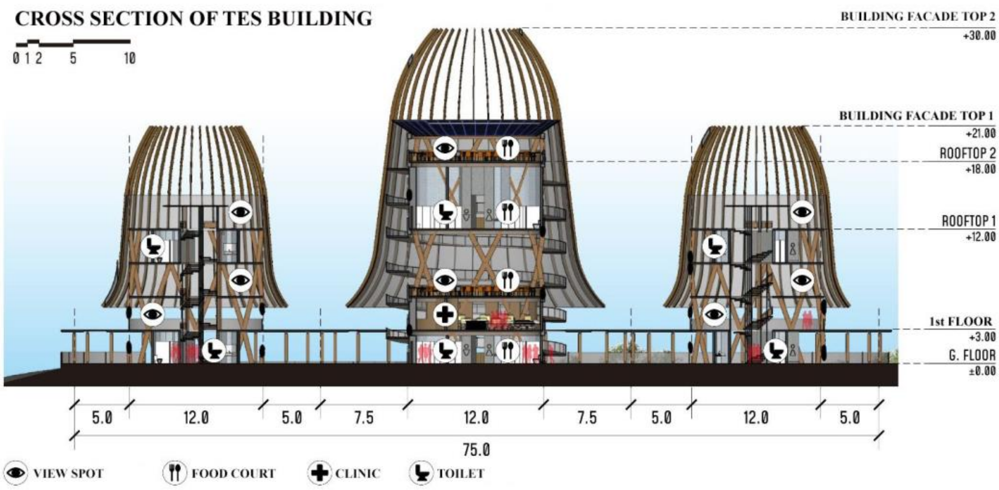


Fig. 12 – Sections of TES buildings

3. Conclusions

Mandalika Moto GP circuit region is located in high level of earthquake and tsunami hazard area. As such the development of the area must be planned and designed against earthquake and tsunami.

Buildings and infrastructures in the areas must be designed to be earthquake resistant by adhering to structural and seismic design code applicable in Indonesia. In relation to tsunami, mitigation system has been developed to minimize the impact of tsunami disaster. Included in tsunami mitigation plan are:

a) Develop building code requirements that implement natural disaster mitigation plan.
b) Design evacuation path, muster point, TES.
c) Implement coastal line protection along 100 m or adjusted with tsunami hazard level at that location.
d) Community preparedness program against natural disasters.

Finally, in addition to its main purpose, mitigation plan for natural disaster management is also designed as a tourist attraction and a natural disaster education. The facilities built for mitigation plan is specifically planned and designed to fulfill those intended purposes.

4. Acknowledgements

The Financial support provided by Indonesia Tourism Development Corporation (ITDC) for this research is highly appreciated.

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