

Lecture Notes in Civil Engineering

Stefanus Adi Kristiawan
Buntara S. Gan
Mohamed Shahin
Akanshu Sharma *Editors*

Proceedings of the 5th International Conference on Rehabilitation and Maintenance in Civil Engineering

ICRMCE 2021, July 8–9, Surakarta,
Indonesia

 Springer

Lecture Notes in Civil Engineering

Volume 225

Series Editors

Marco di Prisco, Politecnico di Milano, Milano, Italy

Sheng-Hong Chen, School of Water Resources and Hydropower Engineering,
Wuhan University, Wuhan, China

Ioannis Vayas, Institute of Steel Structures, National Technical University of
Athens, Athens, Greece

Sanjay Kumar Shukla, School of Engineering, Edith Cowan University, Joondalup,
WA, Australia

Anuj Sharma, Iowa State University, Ames, IA, USA

Nagesh Kumar, Department of Civil Engineering, Indian Institute of Science
Bangalore, Bengaluru, Karnataka, India

Chien Ming Wang, School of Civil Engineering, The University of Queensland,
Brisbane, QLD, Australia

Lecture Notes in Civil Engineering (LNCE) publishes the latest developments in Civil Engineering - quickly, informally and in top quality. Though original research reported in proceedings and post-proceedings represents the core of LNCE, edited volumes of exceptionally high quality and interest may also be considered for publication. Volumes published in LNCE embrace all aspects and subfields of, as well as new challenges in, Civil Engineering. Topics in the series include:

- Construction and Structural Mechanics
- Building Materials
- Concrete, Steel and Timber Structures
- Geotechnical Engineering
- Earthquake Engineering
- Coastal Engineering
- Ocean and Offshore Engineering; Ships and Floating Structures
- Hydraulics, Hydrology and Water Resources Engineering
- Environmental Engineering and Sustainability
- Structural Health and Monitoring
- Surveying and Geographical Information Systems
- Indoor Environments
- Transportation and Traffic
- Risk Analysis
- Safety and Security

To submit a proposal or request further information, please contact the appropriate Springer Editor:

- Pierpaolo Riva at pierpaolo.riva@springer.com (Europe and Americas);
- Swati Meherishi at swati.meherishi@springer.com (Asia - except China, and Australia, New Zealand);
- Wayne Hu at wayne.hu@springer.com (China).

All books in the series now indexed by Scopus and EI Compendex database!

More information about this series at <https://link.springer.com/bookseries/15087>

Stefanus Adi Kristiawan ·
Buntara S. Gan · Mohamed Shahin ·
Akanshu Sharma
Editors

Proceedings of the 5th International Conference on Rehabilitation and Maintenance in Civil Engineering

ICRMCE 2021, July 8–9,
Surakarta, Indonesia

 Springer

Editors

Stefanus Adi Kristiawan
Department of Civil Engineering
Universitas Sebelas Maret
Surakarta, Indonesia

Buntara S. Gan
College of Engineering
Nihon University
Tokyo, Japan

Mohamed Shahin
Department of Civil Engineering
Curtin University
Perth, WA, Australia

Akanshu Sharma
Institute of Construction Materials
University of Stuttgart
Stuttgart, Germany

ISSN 2366-2557

ISSN 2366-2565 (electronic)

Lecture Notes in Civil Engineering

ISBN 978-981-16-9347-2

ISBN 978-981-16-9348-9 (eBook)

<https://doi.org/10.1007/978-981-16-9348-9>

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2023

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd. The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Foreword

The International Conference on Rehabilitation and Maintenance in Civil Engineering (ICRMCE) is a triennial conference that aims to provide a forum for researchers, academicians (professors, lecturers, and students), government agencies, consultants, and contractors to exchange experiences, technological advancement, and innovations in the world of civil engineering, specifically in the fields of rehabilitation and maintenance. The previous four ICRMCE conferences took place successfully in 2009, 2012, 2015, and 2018. Hundreds of researchers worldwide attended these events to present their scientific papers in various areas of civil engineering such as material engineering, structural engineering, geotechnical engineering, transportation engineering, and construction management.

This year's conference was organized by Sebelas Maret University in collaboration with Mataram University. The conference was initially scheduled offline in Mataram, Indonesia. However, due to the escalating coronavirus (COVID-19) outbreak and the need for social distancing, we decided to hold the conference online. Some reputable universities and institutions are participating in the current ICRMCE as partners. Among them are Nihon University, University of Stuttgart, National Taiwan University, TU Delft, Hiroshima University, Diponegoro University, Muhammadiyah University of Yogyakarta, Jenderal Soedirman University, University of Jember, UPN Veteran East Java, the National Center for Research on Earthquake Engineering (NCREE) Taiwan, Himpunan Ahli Konstruksi Indonesia (HAKI), and Himpunan Ahli Teknik Tanah Indonesia (HATTI).

The ICRMCE 2021 was successfully held on July 8–9. Presenters who joined this conference came from Japan, Singapore, Malaysia, China, Vietnam, Taiwan, England, the Netherlands, Kuwait, and Indonesia. Furthermore, several outstanding keynote speakers gave a presentation of the state-of-the-art findings in the field of civil engineering. Our esteemed speakers are Prof. Shyh-Jiann Hwang (National Taiwan University), Prof. Buntara Sthenly Gan (Nihon University), Dr. Edgar Bohner (VTT Technical Research Centre of Finland), and Prof. Mohamed Shahin (Curtin University).

In the process of organizing this conference, we received invaluable motivation, advice, and support from several individuals and institutions. I intend to express my gratitude and appreciation to all of them. First, my most profound appreciation goes to all organizing committee members who worked day and night preparing this conference. Special thanks to the conference and media partners for their generous support. We also express our gratitude to Prof. S.A. Kristiawan (Sebelas Maret University), Dr. Ing. Akanshu Sharma (University of Stuttgart), Prof. Mohamed Shahin (Curtin University), and Prof. Buntara Sthenly Gan (Nihon University) for their willingness to serve as the editors of the 5th ICRMCE proceedings.

Halwan Alfisa Saifullah
The 5th ICRMCE Chairman

Preface

Civil engineering infrastructures are the backbone for the continuous development of civilization. Managing these infrastructures is essential in keeping the quality of services they provide to the community. A decline in the performance of key infrastructure will have an impact on the quality of these services, which in turn can cause social and economic problems. A variety of factors affects the performance of infrastructure. In each case, the declining performance of infrastructure requires an appropriate and adaptive response to offer effective solutions. Protection, maintenance, repair, and retrofitting are part of the various solutions that can be implemented. All of these solutions are assisted by technological developments related to repair materials, methodologies, systems, management, and operational efficiency, as well as economic and social considerations.

Infrastructure performance is also inevitably affected by exposure to hazards originating from natural and environmental conditions such as earthquakes, landslides, and floods, among others. Therefore, hazard mitigation is also an interesting topic of discussion. In addition, risk reduction and safety are among the most important issues of infrastructure management. Finally, various perspectives on sustainability in civil engineering are also covered in this conference.

This book is a collection of papers presented at the 5th International Conference on Rehabilitation and Maintenance in Civil Engineering (ICRMCE) 2021 that deals with the issues stated above. The papers are grouped into sequential themes representing the structure of this book:

- Part I: Factors affecting performance of buildings and infrastructures
- Part II: Assessment, protection, maintenance, repair, and retrofitting of buildings and infrastructures
- Part III: Maintenance management of buildings and infrastructures
- Part IV: Hazard mitigation
- Part V: Risk reduction and safety management
- Part VI: Sustainability aspects in transportation engineering
- Part VII: Sustainability aspects in construction projects

- Part VIII: Sustainability aspects in water resources management
- Part IX: Construction materials for sustainable infrastructures

Postgraduate students, researchers, and practitioners who would like to update their knowledge on the topics above will find this book very useful.

Surakarta, Indonesia

Stefanus Adi Kristiawan
Chief Editor

Contents

Factors Affecting Performance of Buildings and Infrastructures	
A Review on Application of Machine Learning in Building Performance Prediction	3
R. W. Triadji, M. A. Berawi, and M. Sari	
The Effect of P-Delta and P-Delta Plus Large Displacements Modelling on Lateral and Axial Displacement	11
Jonie Tanijaya and Robby S. Kwandou	
Effect of Regulatory Change in Earthquake Load Analysis on Structures with Irregular Shapes	27
Hendramawat Aski Safarizki and Dini Ayu Saputri	
Seismic Performance of Tall and Slender Minaret Structure with Hexagonal RC Wall Section by Means Fragility Curve Development	37
Erik Wahyu Pradana, Senot Sangadji, and Angga Destya Navara Noor	
Role of Diagonal Bars in Reinforced Concrete Deep Beams Tested Under Static Load	47
Erwin Lim and Rahmat Ramli	
Analysis of Reinforced Concrete Capacity for Irregular Cross-Sections Using Numerical Methods	57
Nuroji	
Assessment of Retaining Wall Design in Harris Skyline Tower’s Basement, Surabaya	69
Siti Nurlita Fitri and Ahmad Soimun	
Additional Vertical Movement of the Single Pile Foundation with Combined Loads	83
Sumiyati Gunawan, Niken Silmi Surjandari, Bambang Setiawan, and Yusep Muslih Purwana	

The Influence of the Number and Height Steps of Terraced Model on Slope Stability Analysis	95
Niken Silmi Surjandari, Siti Nurlita Fitri, and Fenty Madani	
Validation of TRMM Rainfall Data on Slope Stability in Karanganyar, Indonesia	107
David Raja Simare Mare, Rr Rintis Hadiani, and Raden Harya Dananjaya	
Rubberized Asphalt Pilot Road Trial in Kuwait	117
H. Al-Baghli, Z. S. Awadh, and S. E. Zoorob	
Application of the Updated PSHA on the Stability Analysis of the Meninting Diversion-Spillway Tunnel in Lombok Island—Indonesia . . .	129
Didi S. Agustawijaya, Ria R. Marlaningtyas, Suryawan Murtiadi, Mudji Wahyudi, Muhajirah, Hartana, and Ausa R. Agustawijaya	
Risk and Stability Evaluation of Klego Dam, Boyolali, Indonesia	141
Suharyanto, Kresno Wikan Sadono, Rizqi Iqbal Maulana, P. Arie Bagus, and Dyah Ari Wulandari	
Impact of Climate Change on Dam Safety	157
Heri Sulistiyono, Ery Setiawan, and Humairo Saidah	
Assessment, Protection, Maintenance, Repair, and Retrofitting of Buildings and Infrastructures	
Investigating Materials for Refurbishment Strategies of Heritage Buildings: A Case Study of Soesman Kantoor, Semarang	169
Ferry Hermawan, Didi Wibowo Tjokro Winoto, Ismiyati, Bambang Purwanggono, and Robby Soetanto	
Self-monitoring and Localization of Crack of Concrete Beam with Fibers and Carbon Black Subjected to Bending	179
Genjin Liu and Yining Ding	
Seismic Performance Analysis of Multi-story Buildings with Addition of Bracing Based on SNI 1726: 2019 (Case Study: Airlangga University Parking Building)	189
Krisnamurti, Willy Kriswardhana, and Achmad Wahyu Ramadiyan	
Various Strut—Macro Modelings for Infilled Frame Analysis	199
Isyana Ratna Hapsari, Marwahyudi, Edy Purwanto, Senot Sangadji, and Stefanus Adi Kristiawan	
Strengthening of Non-engineered Building Beam-Column Joint to Increase Seismic Performance with Variation of Steel Plate Width	215
Edy Purwanto, P. Amarta Adri, S. A. Kristiawan, Senot Sangadji, and S. Halwan Alfisa	

A Proposed Method of FRP Anchorage for FRP Confined Over-Reinforced Concrete Beam 225
 Nuroji, Ay Lie Han, Sri Tudjono, Lena Tri Lestari, and Tiara Murtisari

Experimental Investigation on the Shear Behavior of Patched RC Beams Without Web Reinforcements: Efficacy of Patching Position with Respect to the Shear Span 233
 Adji P. Abrian, Stefanus A. Kristiawan, Halwan A. Saifullah, P. Muhammad Rafi, R. Muhammad Hafizh, Andreas M. Simanjuntak, and D. Abel Bismo

Secondary AE Analysis of Pre-corroded Concrete Beam 243
 Ahmad Zaki and Zainah Ibrahim

Cable Force Prediction Technique Using Subspace and Effective Vibration Length Method 257
 Muhammad Ibnu Syamsi, Hao-Lin Wang, and Chung-Yue Wang

Implementation of Microbially Induce Calcite Precipitation (MICP) by Bacillus Subtilis and Adding Sand in Repairing Shear Strength Parameters of Peat 267
 Firman Syarif and Dian M. Setiawan

Sensitivity Analysis on the Effect of Reinforcement Materials Addition for Soil Stabilization 277
 Ida Agustin Nomleni, Raden Harya Dananjaya, and Yusep Muslih Purwana

Numerical Simulation of Slope Stability for Soil Embankment Reinforced with Inclined Bamboo Piles 287
 Ngudiyono and Tri Sulistyowati

Analysis of Community Satisfaction Level on the Road Rehabilitation and Reconstruction Project (Learn from Palu Disasters Area) 297
 Andri Irfan Rifai, Eko Prasetyo, and Rhismono

Seepage and Piping Control of Earth Fill Dam 311
 Muhammad Zainal Arifin, Yusep Muslih Purwana, and Raden Harya Dananjaya

Maintenance Management of Buildings and Infrastructures

State-of-the-Art of Artificial Intelligence Methods in Structural Health Monitoring 325
 I. G. E. A. Putra

Development of Preventive Maintenance Guidelines for Simple-Classification Government Buildings Based on Work Breakdown Structure Within the DKI Jakarta Provincial Government. 339
 Dyah Ayu Pangastuti and Yusuf Latief

Development of Preventive Maintenance Guidelines for Electrical Components on Government Building Based on Work Breakdown Structure 355
 Azhara Yudha Pradipta, Yusuf Latief, and Rossy Armyrn Machfudiyanto

Evaluation of the Implementation of Fire Safety Management Based on Work Breakdown Structure Affecting the Insurance Premium Costs of High-Rise Lecture Buildings 369
 E. P. Mahardika, F. Muslim, Y. Latief, and P. S. Nugroho

A Critical Review of Bridge Management System in Indonesia 381
 Surya Dewi Puspitasari, Sabrina Harahap, and Pinta Astuti

Crack and Corrosion Inspections for Coastal and Marine Concrete Infrastructure: A Review 391
 Sabrina Harahap, Surya Dewi Puspitasari, and Ahmad Aki Muhaimin

e-Peralatan System as an Equipment Management for Disaster Mitigation on Indonesia National Roads 401
 Adityo Budi Utomo, P. Gitaning, and S. Tosan Kunto

The Implementation of Functional Road Assessment on Pramuka Road Section in Klaten District 411
 Amirotul Musthofiah H. Mahmudah, Syahrul Anggara Wuryatmaja, and Ary Setyawan

The Evaluation of Irrigation Maintenance in Pacal Irrigation Area at Bojonegoro Regency, East Java 425
 Mahdika Putra Nanda, Rintis Hadiani, and Antonius Suryono

Hazard Mitigation

Landslide Analysis Subject to Geological Uncertainty Using Monte Carlo Simulation (A Study Case in Taiwan) 437
 Joni Fitra, Wen-Chao Huang, and Yusep Muslih Purwana

The Performance of Horizontal Drain as a Landslide Mitigation Strategy 449
 Putu Tantri K. Sari

The Analysis of Impact and Mitigation of Landslides Using Analytical Hierarchy Process (AHP) Method 457
 A. Andriani, B. M. Adji, and S. Ramadhani

The Stability of a Slope on Soft Soil Using the Hardening Soil Model 467
 Yerry Kahaditu Firmansyah and Maharani Putri Dewanty

Software Performance of Risk-Targeted Maximum Considered Earthquake (MCE_R) Calculation 479
 Windu Partono

Seismic Microzonation of Yogyakarta Province Based on 2019 Risk-Targeted Maximum Considered Earthquake 489
 Windu Partono, Ramli Nazir, Frida Kistiani, and Undayani Cita Sari

Liquefaction Potential of Volcanic Deposits During Lombok Earthquake in 2018 499
 Muhajirah

Fault Structure Interpretation on the Western Part of East Java Using Second Vertical Derivative 511
 Wien Lestari, Amien Widodo, Dwa Desa Warnana, Firman Syaifuddin, Rusba Saputra Rivensky, and Bagoes Idcha Mawardi

Lesson Learned from Weathering Clay Shale Residual Interface Shear Strength Testing Method 523
 Fathiyah Hakim Sagitaningrum, Samira Albati Kamaruddin, Ramli Nazir, Budi Susilo Soepandji, and Idrus M. Alatas

Shear Strain Evaluation on Analysis of Additional Clay Liner Layer Modeling in Ngipik Landfill, Gresik 533
 Siti Nurlita Fitri

Tsunami Hazard in Cilacap City Due to the Megathrust of West-Central Java Segment 543
 Wahyu Widiyanto and Sanidhya Nika Purnomo

Assessment of the Conditioning Factor for Flash Flood Susceptibility Potential Based on Bivariate Statistical Approach in the Wonobojo Watershed in East Java, Indonesia 553
 Entin Hidayah, Gusfan Halik, and Wiwik Yunarni Widiarti

Flood Management Strategies in Indonesia: A Lesson Learned from Pepe River, Central Java 575
 Rian Mantasa Salve Prastica and Amalia Wijayanti

Comparison of Suitable Drought Indices for Over West Nusa Tenggara 587
 Humairo Saidah, Heri Sulistiyono, and I Dewa Gede Jaya Negara

Small Debris Flow Simulation Using MORPHO2DH 601
 Puji Harsanto, Dandy Darwin Septiandy, Berli Paripurna Kamiel, and Nursetiawan

Simulation of Debris Flow Using “SIMLAR” in the Watershed of Gendol River, Indonesia	609
Hendy Dwi Cahyo, Jazaul Ikhsan, and Ani Hairani	
Wind-Generated Wave Simulation on Payangan Beach Utilizing DELFT3D	619
Enggar Setia Baresi, Retno Utami Agung Wiyono, and Wiwik Yunarni Widiarti	
Risk Reduction and Safety Management	
Incorporating Cultural Attributes into Disaster Risk Reduction-Based Development Plans in Indonesia	631
Yusron Saadi	
Identification Risk Potential Hazard of Railway Project Based on the Work Breakdown Structure to Improve Safety Performance	641
D. V. Aryanto, L. S. Riantini, R. A. Machfudiyanto, and Y. Latief	
Identification Factors of Safety Climate, Awareness, and Behaviors to Improve Safety Performance in Telecommunication Tower Construction at PT X	651
B. F. Athaya, L. S. Riantini, and R. A. Machfudiyanto	
Cost Structure of Construction Safety on High Residential Buildings in Indonesia	659
Ratih Fitriani, Yusuf Latief, and Rossy A. Machfudiyanto	
Adaptive Traffic Signal Control Using Fuzzy Logic Under Mixed Traffic Conditions	669
Budi Yulianto	
Application of Fuzzy Inference System Mamdani at Pelican Crossing	681
Salsabila Naura Putri	
Determining the Maximum Speed Limit in Residential Area	693
Gito Sugiyanto, Fadli Wirawan, Eva Wahyu Indriyati, Yanto, and Mina Yumei Santi	
Identification of Traffic Accident Hazardous Location and Cost of Accidents in Developing Country (Case Study of Tabanan Regency, Bali-Indonesia)	705
Putu Alit Suthanaya and Made Oka Sugiana	
Characteristics of Foreign Motorcyclists in Tourism Areas in Bali	717
Cokorda Putra Wirasutama, Putu Alit Suthanaya, Dewa Made Priyantha Wedagama, and Anak Agung Gde Agung Yana	

Analysis of the Behaviour Model of Foreign Motorcyclists in Tourism Areas in Bali 729
 Cokorda Putra Wirasutama, Putu Alit Suthanaya,
 Dewa Made Priyantha Wedagama, and Anak Agung Gde Agung Yana

Knowledge and Practice of Helmet Usage Among Senior High School Students in Klaten Regency 743
 Dewi Handayani, Putri Dewi Prasetianingrum,
 and H. M. Amirotul Musthofiah

Sustainability Aspects in Transportation Engineering

Investigation of CO₂ Emissions on Two Local Streets by Means of IPCC and Direct Method 753
 Florentina Pungky Pramesti, Annisa Tri Utami, Iva Yenis Septiariva,
 and Fajar Sri Handayani

Reducing the Release of Greenhouse Gases in the Rigid Pavement Material Transportation Process Unit 763
 Fajar Sri Handayani, Florentina Pungky Pramesty, and Ary Setyawan

Cost Effectiveness Analysis of Greenhouse Gas Emissions Reduction in the Flexible Pavement Material Transportation Process Unit 771
 Fajar Sri Handayani, Florentina Pungky Pramesti, and Ary Setyawan

A Probabilistic Model of Container Port Demand in Java Concerning the Port Hinterland Connectivity 781
 Lydia Novitriana Nur Hidayati, Gerard de Jong, Anthony Whiteing,
 and Munajat Tri Nugroho

Evaluation of Logistics System Performance-Based on Indonesian Government Policy 791
 Muhammad Rizky Prakoso, Mohammed Ali Berawi, and Gunawan

Analysis of the Influence of Region Development Factors, Individual and Activity, Internal Operator and External Operator on the Demand for the Jakarta Bandung High-Speed Rail 799
 Samijan, Mohammed Ali Berawi, and Andyka Kusuma

Investigating the Factors Influencing the Demand of School Bus 811
 Willy Kriswardhana, Syamsul Arifin, and Ainal Akbar

Sustainability Aspects in Construction Projects

Key Performance Indicator for Analytical Hierarchy Process Used for Determining the Effect of Reverse Supply Chain Toward Green Building Projects 823
 Hermawan, Jati Utomo Dwi Hatmoko, and Jovana Neilkelvin

Development of Blockchain and Machine Learning System in the Process of Construction Planning Method of the Smart Building to Save Cost and Time 833
 Christiantono Tedjo, Mohammed Ali Berawi, and Mustika Sari

The Development of Blockchain Based Knowledge Management System Model at EPC Projects to Improve Project Time Performance 843
 D. Y. Priyambodo, M. A. Berawi, and M. Sari

Risk Allocation Implementation Analysis of Public-Private Partnership for Infrastructure Project (Case Study of the Solo-Yogyakarta-NYIA Kulon Progo Highway Project) 853
 Widi Hartono, Aloysia Putri Hastari Purnomo, and Sunarmasto

Risk Assessment of Construction Project Scheduling 863
 Zetta Rasullia Kamandang

Investigating Construction Project Delay Using Fault Tree Analysis Based on Its Dominant Risk on Private Project 873
 Jojok Widodo Soetjpto, Amalia Martha Sukmana, and Syamsul Arifin

Implementing a Relational Database in Processing Construction Project Documents 891
 Mik Wanul Khosiin and Ardian Umam

Evaluation of the Public Procurement Principles Implementation in Surabaya Construction Projects 901
 Patrisius Valdoni Sandi and Mohammad Arif Rohman

Relationship Model Between Conceptual Cost Estimation Process of Flyover Development in the Provincial Government of DKI Jakarta with the Accuracy Level 913
 Putika Yussi, Yusuf Latief, and Rossy Army Machfudiyanto

The Sustainability Aspect of the Consulting Firm in Terms of Its Competitiveness in Indonesia 933
 Nofita Harwin, Mairizal, Zelmi Sriyolja, Abd Rahman Mohd Sam, and Mohd Zaimi Abd Majid

Sustainability Aspects in Water Resources Management

Sustainability Analysis of Minimization of Spills from a Reservoir 945
 Syamsul Hidayat, Ery Setiawan, Ida Bagus Giri Putra, M. Bagus Budiarto, and Salehudin

Infiltration Wells as an Alternative Eco Drainage System a Case Study in Mangkubumen Surakarta 953
 Retnayu Molya, R. R. Rintis Hadiani, and Adi Yusuf Muttaqien

Analysis of Leb Irrigation Patterns of Pipe System in Sorghum Plants in Sand Dry Lands Akar Akar Village. 965
 I Dewa Gede Jaya Negara, Sasmito Soekarno, Suwardji, Humairo Saidah, and Atha Adi

Hourly Rainfall Simulation Using Daily Data. 975
 Suroso, Fatimatus Sholihah Marush, Purwanto Bekti Santoso, Irfan Sudono, Edvin Aldrian, and Nelly Florida Riama

Water Quality Mapping on the Coast of Bangkalan Madura Based on the Acidity Value from Aqua MODIS Satellite Imagery 989
 Hendrata Wibisana, Zetta Rasullia Kamandang, and Kartini

Multi-attribute Analysis of Raw Water Treatment from Deep Wells at PDAM Tirta Mahottama, Klungkung Regency, Bali 999
 Ni Kadek Dian Utami Kartini, Nurulbaiti Listyendah Zahra, Ariyanti Sarwono, Intan Rahmalia, Almira Davina Nastiti, Iva Yenis Septiariva, and I. Wayan Koko Suryawan

Determination of Produced Wastewater Treatment Systems for Reclaim Water in the Oil and Gas Industry. 1009
 Novena Lany Pangestu, Nurulbaiti Listyendah Zahra, Ariyanti Sarwono, Intan Rahmalia, Iva Yenis Septiariva, and I. Wayan Koko Suryawan

Preference of Sludge Treatment Plan in IPA II Pejompongan Water Treatment Plant 1019
 Nailatul Fadhilah, Nurulbaiti Listyendah Zahra, Fatimah Dinan Qonitan, Imroatus Sholikhah, Intan Rahmalia, Iva Yenis Septiariva, and I. Wayan Koko Suryawan

Design of Typical Rainwater Harvesting Storage Tanks Based on Housing Type (Case Study in Indonesia) 1029
 Lina Indawati, Setyo Budi Kurniawan, Siti Rozaimah Sheikh Abdullah, and Raden Harya Dananjaya

Risk Analysis of Shared Marine Space in the View of Traditional Fishermen Perceptions in the National Tourism Strategic Area of Lombok, Indonesia 1043
 Ida Ayu Oka Suwati Sideman, R. M. Nyoman Budiarta, Ida Bagus Putu Adnyana, and Ngakan Ketut Acwin Dwijendra

Construction Materials for Sustainable Infrastructures

Residual Stress Evaluation on Cold-Formed Steel C-Section by X-Ray Diffraction 1057
 T. Widya Swastika, Heru Purnomo, M. R. Muslih, R. Apriansyah, Henki W. Ashadi, and Mulia Orientilize

Mechanical Properties of Fine-Grained Concrete Using Fine-Red Sand and Fly Ash for Road Construction: A Case Study in Vietnam 1067
 Nguyen Thanh Sang, Thai Minh Quan, May Huu Nguyen, and Lanh Si Ho

A Systematic Review of Concrete Material for Noise Reduction of Transportation Sectors 1077
 Ecky Ferry Ferdyan, Dewi Handayani, Sholihin As’ad, and Ubaidillah

Mapping Literature of Reclaimed Asphalt Pavement Using Bibliometric Analysis by VOSviewer 1085
 Mochammad Qomaruddin, Han Ay Lie, Widayat, Bagus Hario Setiadji, and Mochamad Agung Wibowo

Literature Study: Alternative Materials for Hot Rolled Sheet-Wearing Course (HRS-WC) Pavement 1095
 Elsa Eka Putri, Purnawan, Bayu Martanto Adji, and Bobby Herman

Marshall Characteristics of Asphalt Mixture with Water Hyacinth Ash as Filler 1109
 Dony Rohmad Dony, Bagus Hario Setiadji, and Bambang Riyanto

The Setting Time of Portland Composite Cement Mixed with Calcium Stearate 1119
 A. Maryoto, P. Hardini, and R. Setijadi

Evaluation of Silt Content in Natural Sand Used as Building Materials: A Statistical Analysis Approach 1133
 Jauhar Fajrin, Mulyadi, Hariyadi, and Agung Prabowo

Compressive and Flexural Strength Behavior of Banana Tree Fiber Hybrid Concrete 1143
 Fadillawaty Saleh, Fanny Monika, Hakas Prayuda, Bella Lutfiani Al Zakina, Martyana Dwi Cahyati, Adira Aldi, and Feri Adri Wibowo

Investigation of Polypropylene Fiber Reinforced Concrete After Elevated Temperature Using Color Quantification and Alkalinity Method 1153
 Ni Nyoman Kencanawati, Suryawan Murtiadi, and Zul Aida Nur

The Effect of 12.5% Metakaolin and Variations of Silica Fume on Split Tensile Strength and Modulus of Rupture of High Strength Self-Compacting Concrete (HSSCC) 1165
 Endah Safitri, Wibowo, Halwan Alfisa Saifullah, and Farhan Gilang Septian

**The Strength and Modulus of Elasticity of High Strength
Self-compacting Concrete (HSSCC) with 12.5% Metakaolin and
Variations of Silica Fume 1173**
Endah Safitri, Wibowo, Halwan Alfisa Saifullah,
and Fernanda Sarwatatwadhika Perdana

Factors Affecting Performance of Buildings and Infrastructures

A Review on Application of Machine Learning in Building Performance Prediction



R. W. Triadji, M. A. Berawi, and M. Sari

Abstract Designers usually use Building Performance Simulation (BPS) to support decision making in facing design requirements and expected building performance. However, the fact is that BPS still experiences several limitations, such as BPS requires high computation time in assessing various design options. Machine learning is considered capable of solving the problem that the existing BPS has. Research on this problem has been conducted to provide solutions and prove the reliability of machine learning in predicting building performance. Therefore, this paper aims to discuss the research and overview of how machine learning has been used in predicting building performance. The results show that, performance prediction using machine learning has been developed on energy and environmental performance. Also, machine learning can significantly reduce the prediction time without reducing its accuracy.

Keywords Machine learning · Building performance · Energy performance · Environmental performance

1 Introduction

The importance of digital technology and automation systems in playing a role in industry 4.0 makes every device now equipped with machine learning [1]. As the core of artificial intelligence [2], machine learning is a process where machines can learn various things by themselves based on their experiences [3]. Machines learn the relationship between input and output data received as information and turn it

R. W. Triadji (✉) · M. A. Berawi · M. Sari
Civil Engineering Department, Faculty of Engineering, Universitas Indonesia, Depok, Indonesia
e-mail: rizka.wulan@ui.ac.id

M. A. Berawi
e-mail: maberawi@eng.ui.ac.id

M. Sari
e-mail: mustikasari01@ui.ac.id

into an experience to offer solutions that can adapt according to given situations [4, 5]. Machine learning has been developed in the construction industry to solve complicated and difficult problems [6]. It is shown by the potential of machine learning in improving building performance [3].

Building performance is considered since the design stage; this step is taken as an effort for the building to perform its functions optimally when it is operating [7]. Designers usually use Building Performance Simulation (BPS) to support decision making in facing design requirements and expected building performance [8]. However, BPS is still experiencing several deficiencies in its application; first, BPS requiring a high computation time to assess various design options [8, 9]. Moreover, some factors have not been considered in implementing the simulation, thus making the predictions offered by BPS less accurate [7]. Machine learning is considered to have the potential and capability to answer these deficiencies [8]. Its ability to predict various designs in a second and incorporate factors not covered by existing BPS will improve the prediction results and replaced the existing Building performance Simulation [7, 9]. Below, we made the conceptual diagram to give a glance of insight (see Fig. 1). Building performance no longer predicts by the existing BPS; it replaced by machine learning and its algorithm to predict those predictions such as energy performance and environmental performance.

Therefore, this paper aims to examine studies related to machine learning in building performance and an overview of how machine learning has been used to predict building performance. The review expected can provide more extensive reference and insight in involving machine learning in the construction industry to enhance building performance prediction.

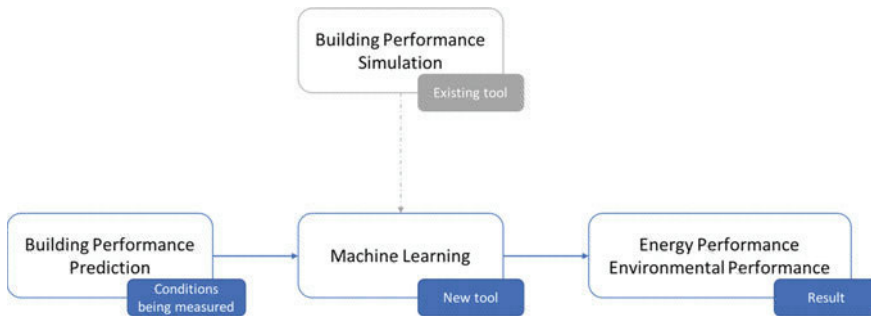


Fig. 1 Conceptual diagram of machine learning and existing BPS

2 Methods

In this study, we collected literature through Scopus as the central database for academic publications. The keywords used are “machine learning”, “building performance”, “energy performance”, “energy consumption”, “environment” “indoor environment”, “thermal comfort”, “visual comfort”, the selected documents are limited to journal articles and conference papers that have been published in the last ten years (2011–2021). The search structure example for Scopus is as follows:

```
TITLE-ABS-KEY ("machine learning" AND "building performance") AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT TO (DOCTYPE, "cp")) AND (EXCLUDE (PUBYEAR, 2010))
```

The authors conducted the first screening by reviewing abstracts and matching predetermined keywords so irrelevant documents could be separated from the search results. 37 documents are deemed relevant to the topics we discussed. Then, the second screening will be carried out by reading the entire document. 17 papers were not selected to be discussed, after the second screening. Thus, 20 papers will be discussed and grouped based on two primary performances that become the main concern in a building: energy performance and environmental performance [10, 11]. The algorithm of machine learning in each paper will also be discussed in this review.

3 Result and Discussion

3.1 Energy Performance

Several building energy performance tools such as TrnSys, EnergyPlus, ESP-r, DOE-2 and Modelica have been widely used, but these tools still require high computation time for various designs with multiple inputs; this also makes simulation tools difficult in delivering precise result [9, 12, 13]. In this section, the discussion will be grouped into two main parts, which are thermal and electricity; due to the current study that we discussed in this section focuses on thermal performance and follows by electricity performance.

Thermal Energy

In previous studies, machine learning has been developed to predict the thermal (cooling and heating energy) performance of buildings using an Artificial Neural Network (ANN) [9, 12, 14–16]. Comesaña et al. [12] developed a machine learning model based on outdoor and indoor temperatures and radiation levels. Meanwhile, Geyer and Singaravel's [14] model based on building components such as walls, windows and floors. Geyer and Singaravel [14] stated that the computation time to make predictions using machine learning is reduced drastically. In line with this, Ascione et al. [16] ensure a computation time savings of 98% can be achieved using

machine learning, this has been proven in their research. They develop a model for predicting energy performance and the energy retrofitting scenario for each building element. Similarly, Seyedzadeh et al. [17] also made a model to predict energy performance and support decision-making about energy retrofit scenarios, the algorithm used is gradient boosted regression trees.

Singh et al. [9] make energy predictions by creating four schematic methods for making predictions. The first three using EnergyPlus, and the last method is using machine learning. The result is that machine learning can achieve the objectives of reducing computation time than EnergyPlus. Westermann et al. [18] using the Convolutional Neural Network (CNN) algorithm to develop a machine learning model to displace a building energy simulation tool. It can predict thermal energy based on input from various design and climate variations. The model is representative enough to be used in various climates of building locations and does not affect its accuracy. On the other hand, Ciulla and D'Amico [19] developed a model without the intention of replacing the existing simulation model. The model was developed with the Multiple Linear Regression algorithm, built as simple as possible, so even non-expert users can use it.

Chakraborty and Elzarka [20] developed their model using three different algorithms (XGBoost, ANN and Degree-day-based OLS regression); the result is XGBoost the most accurate algorithm in predicting thermal performance. In contrast to other studies, Attanasio et al. [21] developed a model only to predict heating energy by comparing four machine learning algorithms. Meanwhile, Yu et al. [13] combine two algorithms, genetic algorithm (GA) and back-propagation (BP), to optimize energy performance predictions and thermal comfort based on the building design and design envelope in residential building. Similarly, Robinson et al. [22] developed a model for commercial building using CBECS (Commercial Building Energy Consumption Survey) data released by the US Energy Information Administration (EIA). It is intended that the proposed model can be used in any city in the US.

Electricity Energy

Zeng et al. [23] developed machine learning to predict electrical energy consumption in a building using the Gaussian Process algorithm. The model developed is based on three types of buildings: offices, shopping centres, and hotels with various design configurations. Later, the model can be used in several kinds of buildings. Moreover, Pangaribuan et al. [24] also build a model to predict electrical energy using a support vector regression algorithm for residential homes.

3.2 Environmental Performance

Environmental performance is also one of the criteria that need to be considered in the design to balance each building's performance and achieve optimal sustainability goals [25, 26]. In this case, the environmental performance consists of an indoor or outdoor environment. The indoor performance focuses on the comfort of occupants

in the building [13]. Meanwhile, outdoor performance pays more attention to the impact caused by buildings on the outdoor environment, such as CO₂ gas emissions [11]. Mazuroski et al. [27] developed a recurrent neural network-based model to predict indoor temperature based on density, specific heat and thermal conductivity of each building material that will be used. The same idea was done by Kamel et al. [28]. The difference between these two studies is the data used as input to predict indoor temperature, i.e. humidity, radiations, airspeed, door open/close status, and motion from sensors installed in the room. In their research, the model developed by Yu et al. [13] with GA-BP algorithm is not only to predict energy performance but also to predict thermal comfort.

On the other hand, Symonds et al. [29] used an artificial neural network to predict indoor environmental quality. The model developed can make predictions in overheating metric, PM2.5 ratio, relative humidity and heating energy use with a reasonable degree of accuracy. In his study, Chen [30] said that difference results between the building performance analysis predictions and reality could not be avoided. Machine learning was developed to improve the accuracy of green BIM by using an artificial neural network algorithm and daylight luminance level as an outcome of the prediction. The model can also predict climate analysis, thermal comfort, energy calculation, and other BPA dimensions. Chatzikonstantinou and Sariyildiz [31] focused their study on office space's visual comfort; a model developed can predict Daylight Glare Probability and Daylight Autonomy. Algorithms feed-forward networks (FFNs) were chosen as the algorithm with the highest level of accuracy compared to support vector machines (SVMs) and random forests (RFs).

While some of the studies focused on indoor performance, Feng et al. [11] developed a model to discover the environmental impact from the building design. They were using GWP/unit area as an indicator of environmental performance. The input of the model is the early design parameter, and fuzzy c means algorithm approach was used to perform the model. The model expected can help designers in testing several design scenarios and the resulting performance.

4 Conclusion

Machine learning has been used to predict buildings performance in terms of energy and the environment. From our review, energy performance is a performance that is widely used in developing machine learning models. Also, artificial neural networks are found as an algorithm that is widely used in model development. The potential of machine learning in predicting performance in a second and accurately can help designers make decisions of a wide variety of designs. It reveals that machine learning can be a promising and powerful tool, mainly when used at the design stage. However, while machine learning has promising potential, it still has its limitations. First, to make good predictive, machine learning requires big data to train the algorithm [3]. Moreover, some studies apply machine learning to only one building type, and this makes the model unable to be used for other building types. It is expected that with

these reviews, the construction industry can take advantage of machine learning capabilities in predicting building performance.

Acknowledgements The author is grateful to Universitas Indonesia for giving support in this research.

References

1. Muhuri PK, Shukla AK, Abraham A (2019) Industry 4.0: a bibliometric analysis and detailed overview. *Eng Appl Artif Intell* 78:218–235. <https://doi.org/10.1016/j.engappai.2018.11.007>
2. Jordan MI, Mitchell TM (2015) Machine learning: trends, perspectives, and prospects. *Science* (80-)349:255–260. <https://doi.org/10.1126/science.aaa8415>
3. Hong T, Wang Z, Luo X, Zhang W (2020) State-of-the-art on research and applications of machine learning in the building life cycle. *Energy Build* 212. <https://doi.org/10.1016/j.enbuid.2020.109831>
4. Dimiduk DM, Holm EA, Niezgodá SR (2018) Perspectives on the impact of machine learning, deep learning, and artificial intelligence on materials, processes, and structures engineering. *Integr Mater Manuf Innov* 7:157–172. <https://doi.org/10.1007/s40192-018-0117-8>
5. Yücel M, Nigdeli SM, Bekdaş G (2021) Artificial intelligence and machine learning with reflection for structural engineering: a review. In: *Studies in systems, decision and control*. Springer Science and Business Media Deutschland GmbH, Department of Civil Engineering, Istanbul University-Cerrahpaşa, Avcılar, Istanbul, 34320, Turkey, pp 23–72
6. Darko A, Chan APC, Adabre MA et al (2020) Artificial intelligence in the AEC industry: scientometric analysis and visualization of research activities. *Autom Constr* 112:103081. <https://doi.org/10.1016/j.autcon.2020.103081>
7. Chokwitthaya C, Zhu Y, Mukhopadhyay S, Collier E (2020) Augmenting building performance predictions during design using generative adversarial networks and immersive virtual environments. *Autom Constr* 119:103350. <https://doi.org/10.1016/j.autcon.2020.103350>
8. Singaravel S, Suykens J, Geyer P (2018) Deep-learning neural-network architectures and methods: using component-based models in building-design energy prediction. *Adv Eng Inform* 38:81–90. <https://doi.org/10.1016/j.aei.2018.06.004>
9. Singh MM, Singaravel S, Klein R, Geyer P (2020) Quick energy prediction and comparison of options at the early design stage. *Adv Eng Inform* 46:101185. <https://doi.org/10.1016/j.aei.2020.101185>
10. Kim J, Hong T, Hastak M, Jeong K (2020) Intelligent planning unit for the artificial intelligent based built environment focusing on human-building interaction. *J Asian Archit Build Eng* 00:1–18. <https://doi.org/10.1080/13467581.2020.1803076>
11. Feng K, Lu W, Wang Y (2019) Assessing environmental performance in early building design stage: an integrated parametric design and machine learning method. *Sustain Cities Soc* 50:101596. <https://doi.org/10.1016/j.scs.2019.101596>
12. Comesaña MM, Febrero-Garrido L, Troncoso-Pastoriza F, Martínez-Torres J (2020) Prediction of building's thermal performance using LSTM and MLP neural networks. *Appl Sci* 10:1–16. <https://doi.org/10.3390/app10217439>
13. Yu W, Li B, Jia H et al (2015) Application of multi-objective genetic algorithm to optimize energy efficiency and thermal comfort in building design. *Energy Build* 88:135–143. <https://doi.org/10.1016/j.enbuid.2014.11.063>
14. Geyer P, Singaravel S (2018) Component-based machine learning for performance prediction in building design. *Appl Energy* 228:1439–1453. <https://doi.org/10.1016/j.apenergy.2018.07.011>
15. Hwang JK, Yun GY, Lee S et al (2020) Using deep learning approaches with variable selection process to predict the energy performance of a heating and cooling system. *Renew Energy* 149:1227–1245. <https://doi.org/10.1016/j.renene.2019.10.113>

16. Ascione F, Bianco N, De Stasio C et al (2017) Artificial neural networks to predict energy performance and retrofit scenarios for any member of a building category: a novel approach. *Energy* 118:999–1017. <https://doi.org/10.1016/j.energy.2016.10.126>
17. Seyedzadeh S, Pour Rahimian F, Oliver S et al (2020) Machine learning modelling for predicting non-domestic buildings energy performance: a model to support deep energy retrofit decision-making. *Appl Energy* 279:115908. <https://doi.org/10.1016/j.apenergy.2020.115908>
18. Westermann P, Welzel M, Evins R (2020) Using a deep temporal convolutional network as a building energy surrogate model that spans multiple climate zones. *Appl Energy* 278:115563. <https://doi.org/10.1016/j.apenergy.2020.115563>
19. Ciulla G, D'Amico A (2019) Building energy performance forecasting: a multiple linear regression approach. *Appl Energy* 253:113500. <https://doi.org/10.1016/j.apenergy.2019.113500>
20. Chakraborty D, Elzarka H (2019) Advanced machine learning techniques for building performance simulation: a comparative analysis. *J Build Perform Simul* 12:193–207. <https://doi.org/10.1080/19401493.2018.1498538>
21. Attanasio A, Piscitelli MS, Chiusano S et al (2019) Towards an automated, fast and interpretable estimation model of heating energy demand: a data-driven approach exploiting building energy certificates. *Energies* 12. <https://doi.org/10.3390/en12071273>
22. Robinson C, Dilkina B, Hubbs J et al (2017) Machine learning approaches for estimating commercial building energy consumption. *Appl Energy* 208:889–904. <https://doi.org/10.1016/j.apenergy.2017.09.060>
23. Zeng A, Ho H, Yu Y (2020) Prediction of building electricity usage using Gaussian Process Regression. *J Build Eng* 28:101054. <https://doi.org/10.1016/j.jobe.2019.101054>
24. Pangaribuan AB, Octa A, Pradnyana IWW, Afrizal S (2019) Predictive analytic for estimating electric consumption of smart grid platform in residential single-family building using support vector regression approach. *J Phys Conf Ser* 1196. <https://doi.org/10.1088/1742-6596/1196/1/012022>
25. Geng Y, Ji W, Wang Z et al (2019) A review of operating performance in green buildings: energy use, indoor environmental quality and occupant satisfaction. *Energy Build* 183:500–514. <https://doi.org/10.1016/j.enbuild.2018.11.017>
26. Jalaei F, Jalaei F, Mohammadi S (2020) An integrated BIM-LEED application to automate sustainable design assessment framework at the conceptual stage of building projects. *Sustain Cities Soc* 53. <https://doi.org/10.1016/j.scs.2019.101979>
27. Mazuroski W, Berger J, Oliveira RCLF, Mendes N (2018) An artificial intelligence-based method to efficiently bring CFD to building simulation. *J Build Perform Simul* 11:588–603. <https://doi.org/10.1080/19401493.2017.1414880>
28. Kamel E, Javan-Khoshkholgh A, Abumahfouz N et al (2020) A case study of using multi-functional sensors to predict the indoor air temperature in classrooms. In: *ASHRAE Transactions*, pp 3–11
29. Symonds P, Taylor J, Chalabi Z et al (2016) Development of an England-wide indoor over-heating and air pollution model using artificial neural networks. *J Build Perform Simul* 9:606–619. <https://doi.org/10.1080/19401493.2016.1166265>
30. Chen SY (2019) Enhancing validity of green building information modeling with artificial-neural-network-supervised learning—taking construction of adaptive building envelope based on daylight simulation as an example. *Sens Mater* 31:1831–1845. <https://doi.org/10.18494/SAM.2019.2147>
31. Chatzikonstantinou I, Sariyildiz S (2016) Approximation of simulation-derived visual comfort indicators in office spaces: a comparative study in machine learning. *Archit Sci Rev* 59:307–322. <https://doi.org/10.1080/00038628.2015.1072705>

The Effect of P-Delta and P-Delta Plus Large Displacements Modelling on Lateral and Axial Displacement



Jonie Tanijaya and Robby S. Kwandou

Abstract The structural analysis programs have become increasingly sophisticated along with the advancement of science. However, engineers need to be more careful and understand the use of the options in the program. One program that can incorporate non-linear effects is SAP2000. In the SAP2000 program, non-linear modeling options are classified into two options, namely non-linear and non-linear plus large displacements. The SAP2000 program is a finite element-based program. The finite element method is a method that solves problems by dividing a large element into several small element segments or commonly referred to as meshing. The smaller the meshing segment used, the more accurate the output will be. However, its significance remains to be studied further. Therefore, this study was conducted to determine the significance of differences in modeling options (linear, non-linear, non-linear plus large displacements), as well as the effect of segment division in the analysis. The analysis results show that the linear model cannot capture the effect of the lateral displacement that changes due to the incremental of the compression force. The compression force has significant effect to moment value especially for the higher compression force. Therefore, the P-Delta effect should be analyzed carefully, especially for element with high compression force since the linear model could not capture this effect. The meshing by divide segment does not provide significance difference for both P-Delta and P-Delta plus large displacement model in this case.

Keywords P-Delta · P-Delta plus large displacements · Lateral displacement

J. Tanijaya (✉)

Civil Engineering Department, Universitas Kristen Indonesia Paulus Makassar, Makassar, Indonesia

R. S. Kwandou

Postgraduate Alumni of Hasanuddin University, Makassar, Indonesia

1 Introduction

The structural analysis programs have become increasingly sophisticated along with the advancement of science. However, engineers need to be more careful and understand the use of the options in the program. The assumptions of modelling need to be considered carefully. The effect of lateral load on horizontal displacement should be checked in analysis. The elastic-linear analysis condition can produce an underestimated result, especially in the case of structural elements that experience large deformation, such as thin glass panel structures and mono-poles that are exposed to the wind load. A structural analysis that can take into account the large deformations effect will certainly provide a more accurate result. When using linear elastic analysis, the effect of changes in geometry due to large deflection cannot be taken into account in the analysis [1]. One program that can incorporate non-linear effects is SAP2000. In the SAP2000 program, non-linear modeling options are classified into two options, namely non-linear and non-linear plus large displacements. The SAP2000 program is a finite element-based program. The finite element method is a method that solves problems by dividing a large element into several small element segments or commonly referred to as meshing. The smaller the meshing segment used, the more accurate the output will be. Different output values would be provided when including the meshing effect. However, its significance remains to be studied further. Therefore, this study was conducted to determine the significance of differences in modeling options (linear, non-linear, non-linear plus large displacements), as well as the effect of segment division in the analysis.

2 Literature Review

The P-Delta effect occurs due to gravity load (P) that produces the increasing of horizontal displacement (Δ) [2]. The eccentricity of the gravitational load (P) against the column axis causes an increase in horizontal displacement when the structure is subjected to lateral loads. Thus, the P-Delta effect will cause an increase in the moment value as well as the structural drift [3]. Indonesia is surrounded by active tectonic faults so that the lateral load due to earthquakes needs to be considered [4]. The lateral force due to earthquake loads which is influenced by the P-Delta effect becomes critical, especially when the P-Delta effect needs to be considered in the analysis. Based on the research results of Isitono and Ramadhan, the increasing moment value is about 10% on the building structure model [2]. The average percentage increase in moment value that occurs due to P-Delta is between 19 and 27% based on the results of Suhana and Pello's research on a 15-story building [5].

P-Delta effect as one type of geometric nonlinearity, typically produce relatively small additional displacement due to large external force. If deformations become