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Table of Contents

Development of Digital Scale Based on Fluxgate Sensor

Zannuraini, Mitra Djamal, and Widyaningrum Indrasari

8 pages, DOI 10.18502/keg.v1i1.476

Microseismic Wave Measurements to Detect Landslides in Bengkulu Shore with Attenuation Coefficient and Shear Strain Indicator

Muhammad Farid and Wiwit Suryanto

7 pages, DOI 10.18502/keg.v1i1.477

Sinogram Restoration for Sparse Projections Applied to Noisy Data in Ultrasound Tomography

Kusminarto, Catur Edi Widodo, Gede Bayu Suparta, Suryono

5 pages, DOI 10.18502/keg.v1i1.478

Preliminary Study of Double Beta Decay: Simulation of CaMoO_4 Scintillation Detector Response Function to the Gamma Ray Radiation

Mitra Djamal, Rahadi Wirawan, Syeilendra Pramuditya, and Hongjoo Kim

5 pages, DOI 10.18502/keg.v1i1.479

Experiment on Laser Speckle Imaging of Apples Using A CMOS Camera

Minarni Shiddiq, Zulkarnain, and Rasmiana Poja

7 pages, DOI 10.18502/keg.v1i1.480

Evaluation of TLCD Damping Factor from FRF Measurement Due to Variation of The Fluid Viscosity

Lovely Son, Mulyadi Bur, and Meifal Rusli

6 pages, DOI 10.18502/keg.v1i1.481

Design and Development of Gas Sensor Based On Acoustic Resonance

Melany Febrina, Mitra Djamal, Martin Liess

6 pages, DOI 10.18502/keg.v1i1.482

Efficient Mixer in Baking "Galamai" Process by Using Camera Sensor

Rahmadi Kurnia and Faris AlFaruqi

7 pages, DOI 10.18502/keg.v1i1.483

Application of Gold Nanoseeds in Surface- Enhanced Raman Spectroscopy for Detection of Urea

Nur Adliha Abdullah, Norhayati Abu Bakar, Muhamad Mat Salleh, and Akrajas Ali Umar
6 pages, DOI 10.18502/keg.v1i1.484

Colour Classification Using Entropy Algorithm in Real Time Colour Recognition System for Blindness People

Gurum Ahmad Pauzi and Warsito
5 pages, DOI 10.18502/keg.v1i1.485

Room Searching Performance Evaluation for the JagaBot™ Indoor Surveillance Robot,”

Mohamad Hanif Md Saad, Rabiah Adawiyah Shahad, and Aini Hussain
6 pages, DOI 10.18502/keg.v1i1.486

Performance of OFDM-Based WiMAX System Using Cyclic Prefix

Benriwati Maharmi
7 pages, DOI 10.18502/keg.v1i1.487

Application of Short Time Fourier Transform and Wavelet Transform for Sound Source Localization Using Single Moving Microphone in Machine Condition Monitoring

Meifal Rusli, Lovely Son, Mulyadi Bur, and Agus Arisman
6 pages, DOI 10.18502/keg.v1i1.488

Design and Implementation of SMS Based Anomalous Event Mitigation Process for Complex Event Processing Application

Mohamad Hanif Md Saad, Rabiah Adawiyah Shahad, and Aini Hussain
5 pages, DOI 10.18502/keg.v1i1.489

First Principles Calculations Study of Lithium-Montmorillonite for Humidity Sensor Application

Triati Dewi Kencana Wungu and Suprijadi
6 pages, DOI 10.18502/keg.v1i1.490

Integrated Remote Sensing and GIS for Calculating Shoreline Change in Rokan Estuary

Sigit Sutikno, Ferry Fatnanta, Ari Kusnadi, and Keisuke Murakami

9 pages, DOI 10.18502/keg.v1i1.491

New Approach for Airflow Measurement Using Thermal Resistance Simulation

Lazuardi Umar, Yanuar Hamzah, and Rahmondia N. Setiadi

7 pages, DOI 10.18502/keg.v1i1.492

Methods and Applications of Label-Free Cell-Based Systems

Joachim Wiest

5 pages, DOI 10.18502/keg.v1i1.493

Preparation and Characterization of Calcium Oxide Heterogeneous Catalyst Derived from Anadara Granosa Shell for Biodiesel Synthesis

Nurhayati, Muhdarina, Amilia Linggawati, Sofia Anita, and Tengku Ariful Amri

8 pages, DOI 10.18502/keg.v1i1.494

Charge Carriers Motion in P3HT:CappedZnO Nanoparticles Blend Films; Impact of Capping Agents

Ayi Bahtiar, Yayah Yuliah, Lusi Safriani, Nagisa Kawate, and Yukio Furukawa

8 pages, DOI 10.18502/keg.v1i1.495

Substitution of Local TiO₂ on the Synthesis of Li₄Ti₅O₁₂(LTO) for Anodes Lithium Ion batteries

Slamet Priyono, Arin Gudesma, Ramlan, and Bambang Prihandoko

6 pages, DOI 10.18502/keg.v1i1.496

Meso Carbon Micro Bead (MCMB) Based Graphitized Carbon for Negative Electrode in Lithium Ion Battery

Fadli Rohman, Kartika Sari, Achmad Subhan, and Bambang Prihandoko

6 pages, DOI 10.18502/keg.v1i1.497

The role of SiC on the Desorption Temperature of Mg-based Hydrogen Storage Materials Prepared by Intensive Milling Method

Zulkarnain Jalil, Adi Rahwanto, Erfan Handoko, and Bambang Soegijono
6 pages, DOI 10.18502/keg.v1i1.498

Preparations and Characterizations of Hierarchical Macropore Activated Carbon Monolith Electrode from Rubber Wood for Supercapacitor Application

Erman Taer, Yusriwandi, Rika Taslim, I.D.M. Syam, and Mohamad Deraman
6 pages, DOI 10.18502/keg.v1i1.499

Effect of Aging Time on the Synthesis of Fe-doped TiO₂ Thin Films by Spin Coating Method

Dahyunir Dahlan and Muhammad Anshori
6 pages, DOI 10.18502/keg.v1i1.500

Numerical Study of Plasmon Resonance Silver Nanoparticles Coated Polyvinyl Alcohol (PVA) using Bohren-Huffman-Mie Approximation

Dede Djuhana, Cuk Imawan, Vivi Fauzia, Adhi Harmoko, Windri Handayani, and Miftahussurur H. Putra
7 pages, DOI 10.18502/keg.v1i1.501

Effect of Methylammonium Iodide (CH₃NH₃PbI₃) Perovskite Concentration on the Performance of Perovskite Solar Cell

AltafYahya AL-she'irey, Akrajas Ali Umar, Muhamad Mat Salleh, and MohdYusriAbd Rahman
6 pages, DOI 10.18502/keg.v1i1.502

Transmission Electron Microscopy Study of Magnetic Domain of Cobalt-Samarium Thin Films Fabricated Using DC Magnetron Sputtering Technique

Erwin Amiruddin and Adhy Prayitno
8 pages, DOI 10.18502/keg.v1i1.503

First Principle Calculation of Electronic, Optical Properties and Photocatalytic Potential of CuO Surfaces

Faozan Ahmad, M Kemal Agusta, and Hermawan K Dipojono
7 pages, DOI 10.18502/keg.v1i1.504

Preparation and Characterisation of PVdF-LiBOB-Based Solid Polymer Electrolyte

Christin Rina Ratri, R. Ibrahim Purawiardi, Titik Lestariningsih, Achmad Subhan, and Ety Marti Wigayati

7 pages, DOI 10.18502/keg.v1i1.505

Effect of Co-Ti Substitution on Magnetic Properties of Nanocrystalline BaFe₁₂O₁₉

Erfan Handoko, Mangasi AM, Zulkarnain, and Bambang Soegijono

5 pages, DOI 10.18502/keg.v1i1.506

Synthesis of Novel Nano-Strawberry TiO₂ Structures with the Aid of Microwave Inverter System: Growth Time Effect on Optical Absorption Intensity

Athar Ali Shah, Akrajas Ali Umar, and Muhamad Mat Salleh

6 pages, DOI 10.18502/keg.v1i1.507

Synthesis and Characterization of Fibrous Bimetallic CuPt Nanoparticles

Elvy Rahmi, Setia Erlila, Mardiani Samsir, Akrajas Ali Umar, Muhamad Mat Salleh, and Mohd Yusri Abd Rahman

6 pages, DOI 10.18502/keg.v1i1.508

Effect of Growth Temperature on ZnO Nanorod Properties and Dye Sensitized Solar Cell Performance

Marjoni Imamora Ali Umar, Fitri Yenni Naumar, Muhamad Mat Salleh, Akrajas Ali Umar, and Mohd. Yusri Abd. Rahman

6 pages, DOI 10.18502/keg.v1i1.509

Effect of Concentration Ratio of Precursor-Surfactant Solution on The Performance of Boron-doped ZnO Nanotubes Dye Sensitized Solar Cells

Iwantono, Gusyeri Andika, Fera Anggelina, Liszulfah Roza, and Akrajas Ali Umar

7 pages, DOI 10.18502/keg.v1i1.510

Cyclic Voltammometry of Binderless Activated Carbon Monoliths based supercapacitor from Mixtures of Pre-carbonized of Fibers of Empty Fruit Bunches and Green Petroleum Coke

AwitdrusAwitdrus, Mohamad Deraman, IbrahimAbuTalib, Rakhmawati Farma, Najah Syahirah M. Nor, Maria MuhammadIshak, and Besek Nurdiana M. Dolah

8 pages, DOI 10.18502/keg.v1i1.511

Performance Analysis of Solar Updraft Power Generator in Indonesia

Hadyan Hafizh, Hiromichi Shirato, and Daiki Yui

6 pages, DOI 10.18502/keg.v1i1.512

Comparison of Remotely Sensed Wind Data over Sulawesi and Maluku Islands Sea Areas

Faisal Mahmuddin, Misliah Idrus, Hamzah, Juswan Sade, and Rosmani

6 pages, DOI 10.18502/keg.v1i1.513

Value Chain Analysis of Palm Oil Biodiesel through a Hybrid (ISO-Eco) Life Cycle Assessment Approach

Yosef Manik and Anthony Halog

6 pages, DOI 10.18502/keg.v1i1.514

Numerical Studies on Pinching Radius Effects to Current Densities of NX_2 Plasma Focus

Nina Diana Nawi, Rakhmawati Farma, ST.Ong, Kashif Tufail Chaudhary, Jalil Ali, and Saktioto

6 pages, DOI 10.18502/keg.v1i1.515

Effect of Input Amplitude to Power Amplification in Various Orientation of Ring Resonator

Haryana Mohd Hairi, Toto Saktioto, Jalil Ali, and Siti Nor Hafiza Mohd Yusoff

7 pages, DOI 10.18502/keg.v1i1.516

Comparison of Fabry – Perot Filter of Fiber Bragg Grating for Visible and Ultraviolet Spectra

Didik Puji Sutriyono, Saktioto, and Dedi Irawan

6 pages, DOI 10.18502/keg.v1i1.517

Left-Handed Metamaterial Structure for Side Lobe Suppression of Microstrip Array Antenna

Fitri Yuli Zulkifli, Pamela Kareen, Basari, and Eko Tjipto Rahardjo

6 pages, DOI 10.18502/keg.v1i1.518

Binary Composite Fiber Elasticity Using Spring-Mass and Non-Interacting Parallel Sub-Fiber Model

Widayani, Sparisoma Viridi, and Siti Nurul Khotimah

6 pages, DOI 10.18502/keg.v1i1.519

Mechanical Properties of Metal Al/SiC and AlCu/SiC Metal Matrix Composites (MMCs)

Anggara B. S. and Bambang Soegijono

5 pages, DOI 10.18502/keg.v1i1.520

The Critical Load Measurements of Pineapple Leaf Fibre Reinforced Polyester Composite Using Single Edge Notched Beam (SENB) Testing

Hendery Dahlan, Mulyadi Bur, Isratul Rahmad and Meifal Rusli

5 pages, DOI 10.18502/keg.v1i1.521

Renewable Silica-Carbon Nanocomposite and Its Use for Reinforcing Synthetic Wood Made of Rice Straw Powders

I Wayan Karyasa, I Wayan Muderawan, and I Made Gunamantha

6 pages, DOI 10.18502/keg.v1i1.522

Compressive Load Effect on Electrical Properties of Carbon Composite

Nuning Anugrah Putri Namari, Irfan Dwi Aditya, and Suprijadi

5 pages, DOI 10.18502/keg.v1i1.523

Synthesis of Electrospun Nanofibers Membrane and Its Optimization for Aerosol Filter Application

Abdul Rajak, Asti Sawitri, Muhammad Miftahul Munir, Ferry Iskandar, and Khairurrijal

7 pages, DOI 10.18502/keg.v1i1.524

Predicting the Motion of an Intruder in a Vertically Vibrated 2D-Granular-Bed using Contact Points Approximation

Siti Nurul Khotimah, Sparisoma Viridi, Widayani, Trise Nurul Ain, and

Hari Anggit Cahyo Wibowo

6 pages, DOI 10.18502/keg.v1i1.525

The Application of Artificial Neural Networks in Predicting Structural Response of Multistory Building in The Region of Sumatra Island

Reni Suryanita, Hendra Jingga, and Enno Yuniarto

6 pages, DOI 10.18502/keg.v1i1.526

Development of a FAHP Algorithm Based Performance Measurement System for Lean Manufacturing Company

Anita Susilawati and John Tan

7 pages, DOI 10.18502/keg.v1i1.527

Preface

The 1st Conference on Science and Engineering for Instrumentation, Environment and Renewable Energy (ICoSE) 2015 was held at the Hotel Pangeran Pekanbaru, Indonesia, September 28-29, 2015.

This is a forum for more than 200 researchers, scientists and students from around 9 countries to share the latest research findings and exchange ideas regarding the innovations in measurement systems, and improvements to instrumentation for environmental analysis as well as selected topics in renewable energy. It also provides a medium for direct contacts among researchers and scientists for new international relationships and spark future collaborative research projects. The conference is jointly organized by the University of Riau (UNRI) Indonesia, cellasys GmbH R&D, Institute of Microengineering and Nanoelectronics (IMEN) Universiti Kebangsaan Malaysia and the Technische Universitaet Muenchen (TUM) Germany.

We have received approximately 160 abstracts to be presented in the seminar and around 108 papers are going to a peer-review process by at least two expert referees for a publication in this periodical and 70 papers have been accepted under rigorous and through revisions by editors and reviewers in respected fields. The accepted papers are organized into 7 chapters:

Chapter 1: Measurements, Sensors and Control Systems

Chapter 2: Materials for Electronics, Energy Conversion and Photocatalysts

Chapter 3: Renewable Energy Utilization

Chapter 4: Optoelectronics and Photonics

Chapter 5: Composites

Chapter 6: Environmental Monitoring

Chapter 7: Computational and Modelling

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Finally, we would like to take this opportunity to thank also all the members of the organizing committee, all the authors, all the reviewers, and all the local volunteers for their effort and valuable support to make ICoSE 2015 a reality. Special thanks go to the ICoSE staff for their outstanding service.



Conference Paper

The Application of Artificial Neural Networks in Predicting Structural Response of Multistory Building in The Region of Sumatra Island

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Abstract

Artificial Neural Network (ANN) method is a prediction tool which is widely used in various fields of application. This study utilizes ANN to predict structural response (story drift) of multi-story reinforced concrete building under earthquake load in the region of Sumatra Island. Modal response spectrum analysis is performed to simulate earthquake loading and produce structural response data for further use in the ANN. The ANN architecture comprises of 3 layers: an input layer, a hidden layer, and an output layer. Earthquake load parameters from 11 locations in Sumatra Island, soil condition, and building geometry are selected as input parameters, whereas story drift is selected as output parameter for the ANN. As many as 1080 data sets are used to train the ANN and 405 data sets for testing. The trained ANN is capable of predicting story drift under earthquake loading at 95% rate of prediction and the calculated Mean-Squared Errors (MSE) as low as $1.6 \cdot 10^{-4}$. The high accuracy of story drift prediction is more than 90% can greatly assist the engineer to identify the building condition rapidly due to earthquake loads and plan the building maintenance routinely.

Keywords: Artificial Neural Networks, earthquake load, Mean-Squared Error, response spectrum, story drift

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 OPEN ACCESS

1. Introduction

Story drift is one of the most important limit states in multi-story building structure design. Building shall not drift excessively to provide better performance and prevent damage to non-structural elements such as walls and doors. Provisions that limit story drift vary depending on which code is used [1-3]. Frequently, story drift governs the design of structural elements rather than strength.

Finite Element Method (FEM) is currently the best available method to analytically calculate the story drift of multi-story buildings. Performing FEM for such complex buildings could be very tedious to be hand-calculated if not practically impossible. To help in faster and more accurate calculations, many FEM softwares specialized for Civil Engineering application are developed and widely available in the market. However, precisely modeling and running analysis for building structures in FEM softwares is indeed very time-consuming especially for nonlinear and dynamic analysis. Though

Finite Element Method for structural analysis is accurate, it is relatively slow. To provide an adequate early prediction on story drift at faster rate, Artificial Neural Network (ANN) method may be used. ANN method is a general prediction tool which is widely used in various fields of application, including Civil Engineering. Many researchers have studied the application of ANN in multistorey shear structure to predict the health of building, such as [4] and [5]. In this study, the ANN is used to predict story drift of reinforced concrete multi-story building under earthquake loading in the region of Sumatra Island. The Sumatra Island is located between the Indo-Australian and Southeastern Eurasian plates. This region has fault slip up to 15 meters occurred near Banda Aceh, Sumatra [6].

Artificial Neural Networks are simplified models of the biological nervous system and have drawn their motivation from the kind of computing performed by a human brain [7]. An Artificial Neural Network is organized into a sequence of layer with full or random connections between the layers. A typical Neural Networks is fully connected, which means there is a connection between each neuron in any given layer to each neuron in the next layer. Artificial Neural Network (ANN) is capable of modeling nonlinear relationship between input and output parameters. ANN works by processing weighted input data using certain algorithm to produce a desired output [8]. The relationship between neurons in ANN is represented by weight factors that will be modified through a training process. If sufficient data sets are available and learning algorithm is correctly chosen, the training process will modify the weight factors by each iteration performed and eventually the desired output will be achieved. The high accuracy of story drift prediction can greatly assist the engineer to identify the building condition rapidly due to earthquake loading in the region of Sumatra Island and plan the building maintenance routinely.

2. Methodology

2.1. Modal Response Spectrum Analysis

The data sets to be fed into the ANN are collected through a Modal Response Spectrum (MRS) analysis. The MRS analysis is performed using Finite Element Method software. The selected reinforced concrete (RC) building models are: Model 1 (10 stories or 40.5 m in total height), Model 2 (15 stories or 60.5 m in total height), and Model 3 (20 stories or 80.5 m in total height) as shown in Fig. 1. For all models, the floor plan is identical (Fig. 2).

The reinforced concrete building models are already proportioned to satisfy the dynamic requirements provided in SNI 1726-2012 [3]. The RC building models are subject to earthquake loading. The design response spectrum functions are obtained from the latest Seismic Hazard Map for Indonesia. Eight capital cities and three other cities in Sumatera Island are selected as seismic location (eleven in total). By taking three ground conditions (hard, medium, and soft) into account, 33 response spectrum functions are obtained. Then for 3 building models, a total of 1485 story drift data sets are generated from all stories in MRS analysis.

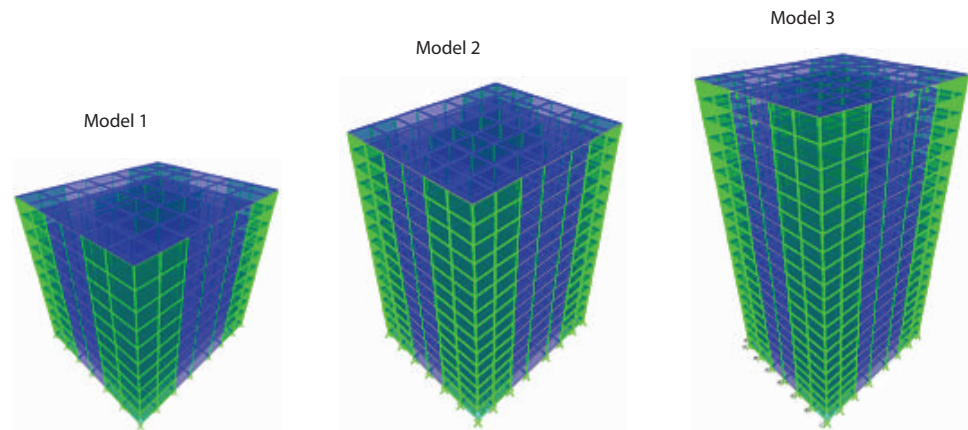


Figure 1: Reinforced Concrete Building Models.

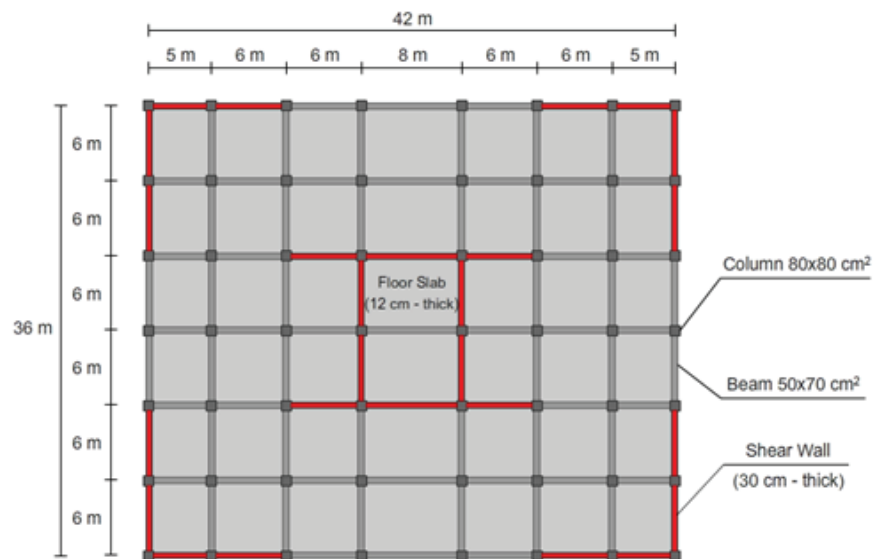


Figure 2: Floor Plan of Reinforced Concrete Building Model.

2.1.1. ANN Architecture

The Neural Network used in this study is Backpropagation ANN (algorithm details can be found at [9]). The ANN architecture consists of 3 layers: input layer, hidden layer, and output layer (Fig. 3). Input layer contains 8 neurons which represent 8 input parameters: 5 earthquake response spectrum function parameters (PGA , S_{DS} , S_{D1} , T_0 , T_s), ground or soil condition, and 2 geometric characteristics (total building height and i -th story elevation). Whereas output layer has 2 neurons, that is, to represent story drift in both X and Y horizontal direction. The target story drift data obtained from modal response spectrum analysis is fed into the ANN, and then errors and rate of predictions are calculated. The number of neurons in hidden layer and training parameters such as learning rate, momentum coefficient, and variable normalization range are selected by trial and error to achieve highest rate of prediction. With this architecture, the neural network is intended to learn the capability to predict story drift for any given elevation of the RC building models.

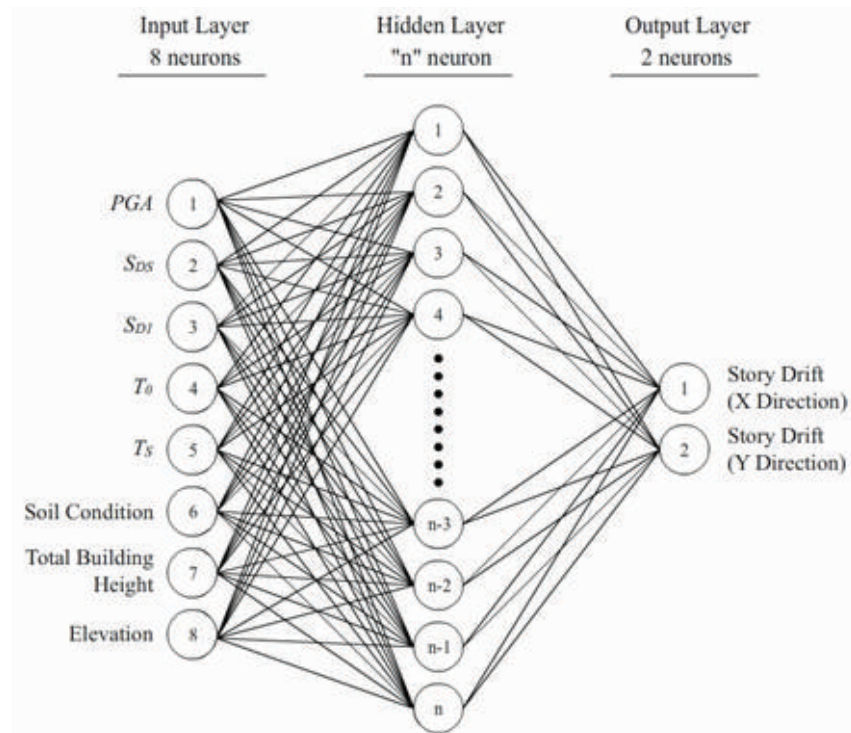


Figure 3: ANN Architecture to Predict Story Drift.

Num.	Seismic Location	Input Parameters							Output Parameters		
		PGA (g)	S_{DS} (g)	S_{DI} (g)	T_0 (sec)	T_s (sec)	Soil Condition	Building Height (m)	Elevation (m)	Target Story Drift (X Direction)	Target Story Drift (Y Direction)
1.	B. Aceh	0.621	0.899	0.557	0.124	0.619	0	40.5	4.5	0.0067	0.0075
2.	B. Aceh	0.621	0.899	0.557	0.124	0.619	0	40.5	8.5	0.0146	0.0161
3.	B. Aceh	0.621	0.899	0.557	0.124	0.619	0	40.5	12.5	0.0237	0.0260
4.	B. Aceh	0.621	0.899	0.557	0.124	0.619	0	40.5	16.5	0.0338	0.0368
5.	B. Aceh	0.621	0.899	0.557	0.124	0.619	0	40.5	20.5	0.0442	0.0480
6.	B. Aceh	0.621	0.899	0.557	0.124	0.619	0	40.5	24.5	0.0548	0.0594
...
1077.	B. Lampung	0.369	0.604	0.587	0.195	0.973	2	80.5	68.5	0.2385	0.2526
1078.	B. Lampung	0.369	0.604	0.587	0.195	0.973	2	80.5	72.5	0.2542	0.2691
1079.	B. Lampung	0.369	0.604	0.587	0.195	0.973	2	80.5	76.5	0.2695	0.2852
1080.	B. Lampung	0.369	0.604	0.587	0.195	0.973	2	80.5	80.5	0.2846	0.3009

TABLE 1: Story Drift Data Sets for ANN Training Process.

3. Discussion

The story drift data sets obtained from MRS analysis is tabulated in Table 1 and Table 2. The 1080 data sets in Table 1 is related to 8 capital cities in Sumatera Island as seismic location, whereas another 405 data sets in Table 2 is related to 3 other cities in Sumatera Island as seismic location. Table 1 and Table 2 is used for ANN training and testing process respectively.

Based on trial and error process, the ANN achieve the lowest error with 24 neuron at hidden layer and the following training parameters; learning rate 0.1, momentum coefficient 0.1, variable normalization range 0 ~ 0.5.

Num.	Seismic Location	Input Parameters					Output Parameters				
		PGA (g)	S_{DS} (g)	S_{DI} (g)	T_0 (sec)	T_s (sec)	Soil Condition	Building Height (m)	Elevation (m)	Target Story Drift (X Direction)	Target Story Drift (Y Direction)
1.	Dumai	0.143	0.221	0.22	0.2	0.998	0	40.5	4.5	0.0017	0.0019
2.	Dumai	0.143	0.221	0.22	0.2	0.998	0	40.5	8.5	0.0036	0.0042
3.	Dumai	0.143	0.221	0.22	0.2	0.998	0	40.5	12.5	0.0058	0.0067
4.	Dumai	0.143	0.221	0.22	0.2	0.998	0	40.5	16.5	0.0083	0.0095
5.	Dumai	0.143	0.221	0.22	0.2	0.998	0	40.5	20.5	0.0109	0.0124
6.	Dumai	0.143	0.221	0.22	0.2	0.998	0	40.5	24.5	0.0135	0.0153
...
402.	Bukittinggi	0.611	0.915	0.969	0.212	1.059	2	80.5	68.5	0.3936	0.4172
403.	Bukittinggi	0.611	0.915	0.969	0.212	1.059	2	80.5	72.5	0.4195	0.4444
404.	Bukittinggi	0.611	0.915	0.969	0.212	1.059	2	80.5	76.5	0.4448	0.4710
405.	Bukittinggi	0.611	0.915	0.969	0.212	1.059	2	80.5	80.5	0.4697	0.4970

TABLE 2: Story Drift Data Sets for ANN Testing Process.

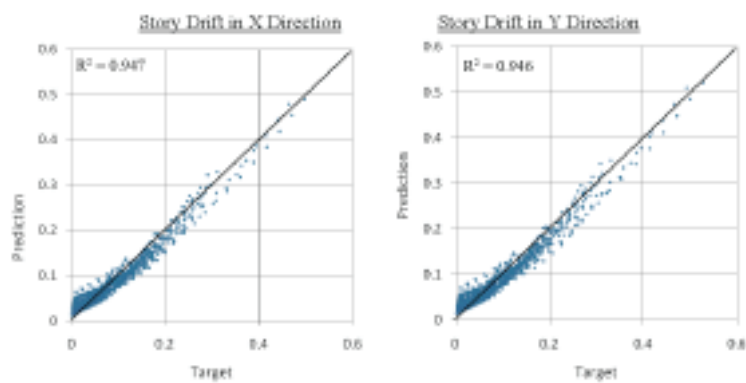


Figure 4: Target vs. Prediction Plot for Story Drift at Training Process.

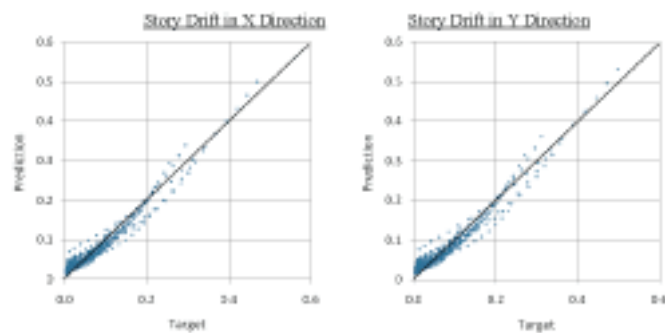


Figure 5: Target vs. Prediction Plot for Story Drift at Testing Process.

After 5000 iterations with the configurations stated above, the calculated MSE at training and testing process is 1.7×10^{-4} and 1.9×10^{-4} , respectively. Fig. 4 and Fig. 5 shows the target vs. prediction plot for story drift at training and testing process. From the plots, it can also be seen that the trained ANN has 95% of prediction rate, which indicates that the trained ANN is capable of predicting story drift at adequate accuracy especially at higher elevation on the building.

4. Summary

After 5000 iterations during ANN training with 1080 data sets, the rate of prediction is calculated as high as 95 percent and MSE is 1.6×10^{-4} . From this study, it can be concluded that ANN is a very promising tool to provide early prediction on structural response such as story drift at multi-story building in the region of Sumatra Island to assist further FEM analysis.

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