# IJTI

International Journal of Transportation and Infrastructure

**Vol 6 No 1** ( September 2022 )

www.jurnal.narotama.ac.id/index.php/ijti

**ISSN 2017**
2597-4769
2597-4734

Volume 4 Number 2 March 2021

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IJTI (International Journal Of Transportation And Infrastructure)
Available Online @ http://jurnal.narotama.ac.id/index.php/ijti
ISSN : 2597-4769 (ONLINE) ISSN : 2597-4734 (CETAK)
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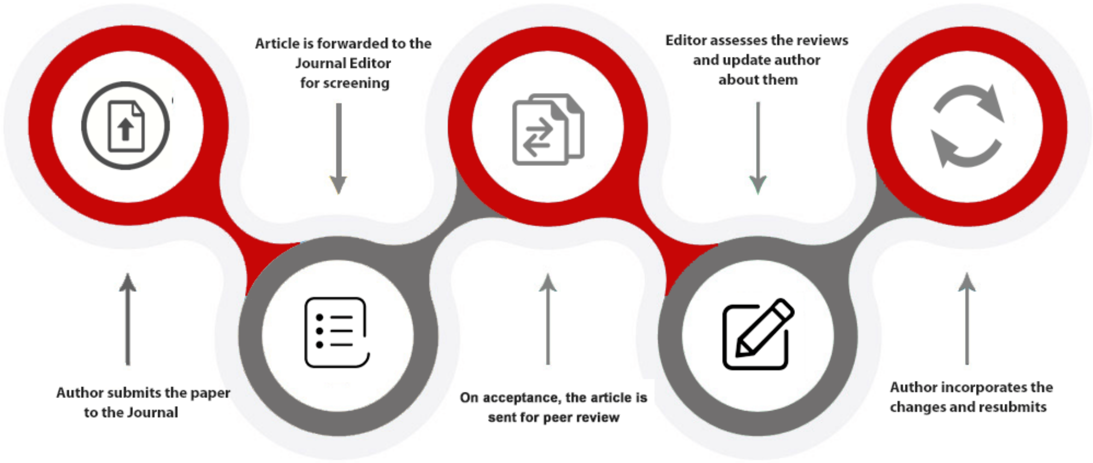


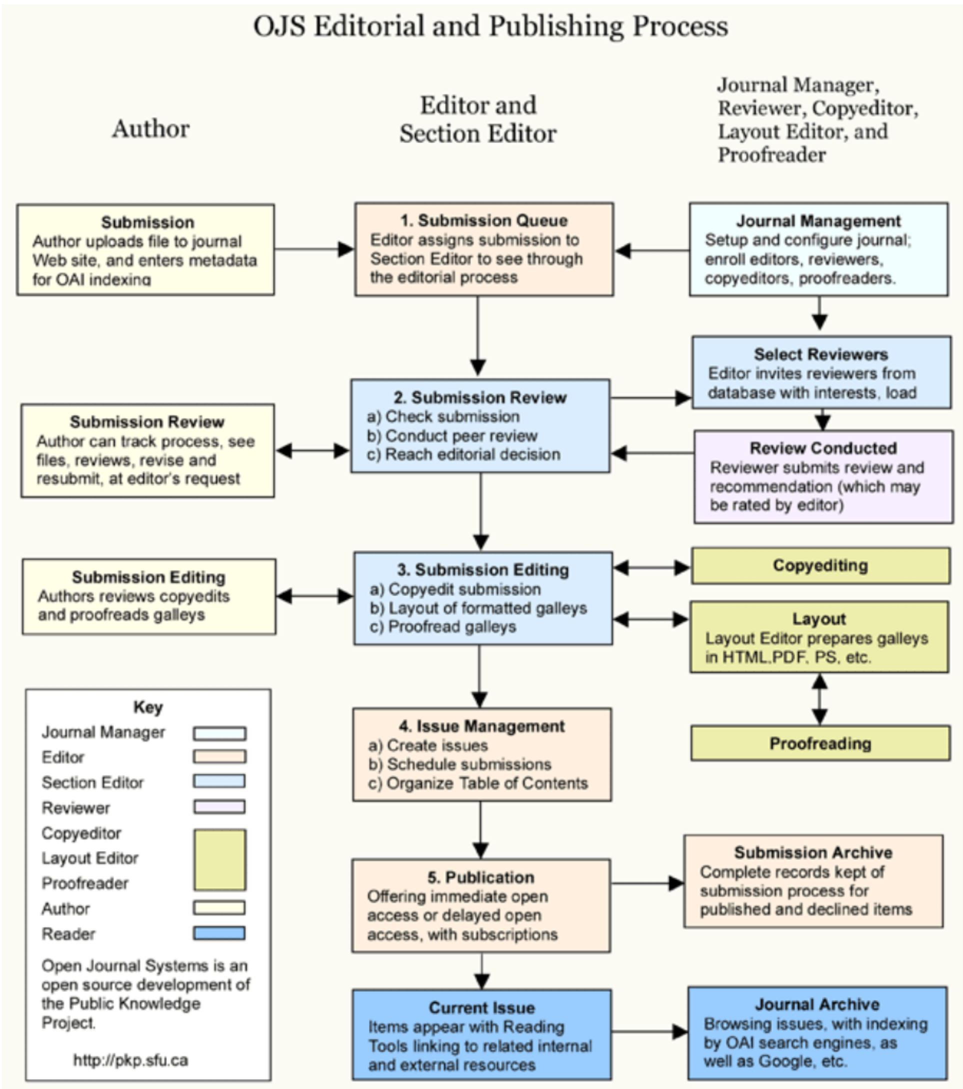

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ISSN : 2597-4769 (ONLINE) ISSN : 2597-4734 (CETAK)
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IJTI

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# Soil Improvement Using the Stone Column Method at the International Port of Tibar, Timor-Leste

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## Abstract
Stone column (stone column) is one of the soil improvement methods that fall into the category of "reinforcement" or soil strengthening which uses aggregate in the form of gravel or crushed stone to make columns with a certain diameter and depth in the soil layer with the aim of increasing the carrying capacity of the soil and reducing settlement. . The stone column method is intended to detail the soil improvement work in this project both on land and at sea. The stone column method has been used to improve weak soils since the 1950s. The rigid granular elements of the stone column increase the stiffness and shear resistance of the weak soil and the permeable nature of the column accelerates consolidation settlement so that residual settlement can be limited to a tolerable value. Various design methods have been used to design stone columns over the years ranging from simple hand calculations to complex and highly complex numerical models. Important considerations include the type of structure to be supported, in-situ soil properties of stone column material parameters, area replacement ratio, stress concentration and consolidation time. Like other geotechnical methods, the stone column method requires stability checks and workability checks. Not only the stone column method but there are several design methods that will be discussed in this journal paper and will highlight some of the advantages and disadvantages of each approach. Importantly, all soil improvement methods, whether simple or complex, must be verified by post-treatment testing with field measurements.

**Keywords:**
Another Design Method, Stone Column

## 1. Introduction

Stone column(stone column) is one of the soil improvement methods that fall into the category of "reinforcement" or soil strengthening which uses aggregate in the form of gravel or crushed stone to make columns with a certain diameter and depth in the soil layer with the aim of increasing the carrying capacity of the soil and reducing settlement. . The stone column method is intended to detail the soil improvement work in this project both on land and at sea. In the case of the dry feed-bottom method, the vibrator penetrates deep into the soil using its own weight, a 'pull-down' force and compressed air. Once the required depth is reached, a vibrator with a depth is extracted gradually, accompanied by an up-and-down motion, allowing the stone to flow into the void that has been created. The up-and-down movement of the vibrator inward allows the formation of a compacted granular column. The column formed is larger than the initial hole created by the penetration process. The stone column construction with a depth vibrator ensures the rock column is properly compacted to the required diameter and depth and compacts the surrounding soil.

## 2. Research methods

The research was conducted for three months starting on August 24, 2020 until December 4, 2020, the location of this research was carried out at an international port located in Tibar, Timor-Leste. The data collection technique was carried out by collecting data at the location and getting help from the owner, namely PMU-TBPP, looking for references from journals on the internet, and getting support from supervisors.

## 3. Results and Discussion

Compared to rigid concrete or steel piles, the vibro stone column (VSC) load-carrying mechanism is different. Instead of shaft friction and end bearing resistance, VSC transmits loads to the ground primarily by bulging and mobilizing lateral soil stresses. Usually a VSC is designed as a group of columns that work together, not as individual columns that work separately. Typical column diameters range from 0.6 m to 1.1 m, and column standards. Columns are triangular or rectangular, with center-to-center distances ranging from 1.5 m to 2.5 m. When the columns are placed at a reasonable distance, they influence each other and act as a group. When uniform loading is applied to the treated soil, especially where there is a granular platform.

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### 3.1. Soil Classification

Soil can be classified into several parts as follows:

1. gravel (gravel)

Gravel is a coarse-grained soil because the grains are more than 2 mm. Ideally using compaction soil reinforcement techniques.

2. sand (sand)

Same with gravel but what distinguishes it is in its size, sand with a size of 0.6 mm – 2 mm. Ideally using compaction soil reinforcement techniques.

3. Clay (clay)

It consists of very small grains and exhibits the properties of plasticity and cohesion. Particle size <0.002 mm, very suitable for using consolidation and reinforcement soil reinforcement techniques.

4. silt (silt)

It is a transition between clay and fine sand. The particle size is 0.002 mm – 0.06 mm. It is very suitable to use consolidation and reinforcement soil reinforcement techniques.

### 3.2. Soil Reinforcement Technique

#### 3.2.1. Consolidation

It is a consolidation technique to drain the water content in the soil and reduce the pore water pressure. This technique will be very effective for use on fine-grained soil types. Soil improvement is carried out by accelerating the consolidation process, namely by providing drainage (vertical or horizontal) on the soil so that it is possible to reduce or eliminate pore water pressure.

#### 3.2.2. Reinforcement

It is a reinforcement technique by adding another material that is more rigid to improve soil properties in the field. This technique is intended for soils that behave non-granular. Soil improvement is carried out by increasing the shear strength of the soil by providing a stiffer soil reinforcement element to increase soil mass and can be combined with providing drainage to reduce pore water pressure.

#### 3.2.3. Compaction

It is a soil improvement technique using compaction energy. This technique will be very effective for use on granular soil types. Increased soil density, bearing capacity, and liquefaction mitigation by using energy from rollers, vibrators, or impacts.

### 3.3. Work at outdoor

#### 3.3.1. Preparation

The stone column drive is equipped with a pile frame and steel tube with the valve end at the bottom, the tube diameter will be slightly smaller than the design diameter of the stone column. This work uses a rock column vibrating tube from a manufacturer named Ruian Bada Engineering Machinery Co., Ltd, and a vibroflot from a manufacturer named Beijing Vibro-flotation Engineering Machinery Co., Ltd. The types of rock column vibrating tubes that will be used in this trial are ZJB-200A-DZ240A and BJZC-BFS-400-180 from vibroflot.

Table 1. Ruian Bada Pile Frame System Information

| SN | Items | Parameter |
|---|---|---|
| 1 | Mobile Mode | Walking Type |
| 2 | Moving Step(mm) | 2500 |
| 3 | Tube Diameter (mm) | 560 and 760 |
| 4 | Penetration Depth (m) | 27 |
| 5 | Main Hoist Tensile Stiffness (KN) | 100 |
| 6 | Main Hoist Pulling Speed (m/min) | 19 |
| 7 | Auxiliary Hoist Tensile Force (KN) | 50 |
| 8 | Auxiliary Hoist Pulling Speed (m/min) | 18 |
| 9 | Steel Wire Rope | 39/Φ28/Φ24 |
| 10 | Pile Height(m) | 31 |
| 11 | Overall Size(m) | 14x6.5x35 |
| 12 | Weight (kg) excluding vibro-hammer and tube | 80000 |

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Table 2. Ruian Bada Vibro-Hammer Information

| SN | Items | Parameter |
|---|---|---|
| 1 | Type | DZ-240A |
| 2 | Start Mode | Variable Frequency Start |
| 3 | Power (KW) | 240 |
| 4 | Vibration Frequency (r/min) | 0-680 |
| 5 | Eccentric Torque | 3525 |
| 6 | Vibration Strength(KN) | 0-1822 |
| 7 | Area (mm) | 0-23.8 |
| 8 | Weight (kg) | 18500 |

Table 3. Vibroflot Information from Beijing Vibroflotation

| No | Items | BZJC-BFS-400-180 |
|---|---|---|
| 1 | Motor Power (kW) | 180 |
| 2 | Vibrating Strength (kN) | 20-30 |
| 3 | Rotation Speed (rpm) | 1200-1800 |
| 4 | Hopper Capacity (m3) | 1.2 |
| 5 | System Pressure (bar) | 6 |
| 6 | Stone Tube Diameter (mm) | DN250 |
| 7 | Vibroflot Size (mm) | 2600 x 600 x 700 |
| 8 | Vibroflot Weight (kg) | 2860 |

Table 4. SPT point coordinates

| SPT Coordinates in the Experimental Area | | | | | |
|---|---|---|---|---|---|
| No | Area | ID of SPT | X | Y | Remark |
| 1 | Experiment Area 1 | Pre-BL09 | 9051362.634 | 772147,353 | |
| 2 | | Post-BL09-1 | 9051363.836 | 772148.042 | |
| 3 | | Post-BL09-2 | 9051362.236 | 772148,047 | |
| 4 | | Post-BL09-3 | 9051361.434 | 772147,356 | |
| 5 | Experiment Area 2 | Pre-BL08 | 9051391.153 | 772151.000 | |
| 6 | | Post-BL08-1 | 9051392.155 | 772151.574 | |
| 7 | | Post-BL08-2 | 9051390.821 | 772151,578 | |
| 8 | | Post-BL08-3 | 9051390.153 | 772151.003 | |
| 9 | Experiment Area 4 | Pre-BL11 | 9051360.2721 | 772159.8386 | |
| 10 | | Post-BL11-1 | 9051361.4678 | 772159.1382 | |
| 11 | | Post-BL11-2 | 9051360.8656 | 772158.7956 | |
| 12 | | Post-BL11-3 | 9051362.2340 | 772159.0756 | |
| 13 | Experiment Area 5 | Post-TA5-1 | 9051394.429 | 772143.306 | |
| 14 | | Post-TA5-2 | 9051393.778 | 772142,938 | |
| 15 | | Post-TA5-3 | 9051395.296 | 772143.309 | |

### 3.3.2. Stone Column Operation

This section defines the operations relevant to moving the rock column in the experimental area. Before moving the stone column, determine the center point of each stone column based on the RTK-GPS tool.

1. Move the rock column vibrating tube to the marked area, aligning the vibrating tube to the design point. The vibrating tube must be perpendicular to the ground.
2. Turn on the vibrating tube, lower the vibrating tube into the ground at a speed of 1-2 m/min. The monitor will record current during penetration, and usually higher values will indicate hard layers and lower values will indicate loose areas. Then the area of relative looseness will be identified by

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the penetration current. A range value will be selected for the identification of the layer for the official SC construction after completion of the experimental area.

3. Load rocks around1.5m3-3m3into the hopper then send it to the top of the vibrating tube, open the tube valve and slowly the stone which is in the hopper is released and into the hole through the vibrating tube. Keep vibrating for one minute, then lift the tube and keep vibrating.
4. To compact the soil layer to the required density, the vibrating tube will be lifted up to 1.5m at each step and penetrated back into the soil to a depth of 0.6m. The 1.5m lift will be divided into two sub-steps to free up enough rock to fill the hole. A lift of 0.75m and a shaking time of about 10 seconds must be ensured for each substep. When re-penetrating, the entire time to a depth of 0.6m is about 5-10 seconds to ensure sufficient compaction. When the current reaches the specified value then the depth is considered solid. The time period and depth will be recorded by the monitor automatically.
5. Repeat processes (3) and (4) until the column is complete.
6. During SC construction, check SC length, SC diameter, stone volume, with monitor guide.

The recommended formula for estimating the relative density of standard penetration resistance as measured by the SPT is shown below:

$$DR = \sqrt{\frac{(N1)60}{46}}$$

$$(N1)60 = N * CN * CE * CB * CR * CS$$

Where:

N = standard rated penetration resistance
CN = factor to normalize N
CE = correction for hammer energy ratio
CB = borehole diameter correction factor
CR = correction factor for rod length
CS = correction for sampler with or without linear

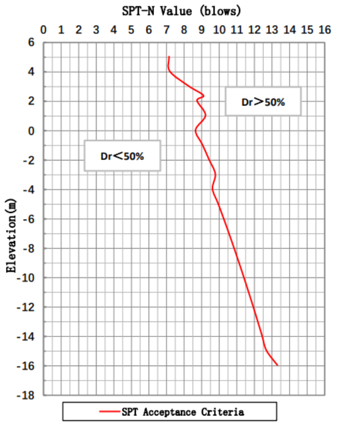


Figure 1. SPT curve for 6.05m elevation (TBPP-PMU)

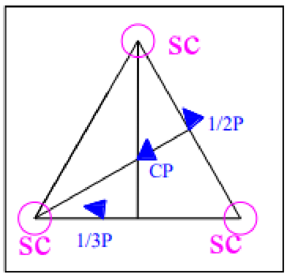


Figure 2. SPT Scheme (TBPP-PMU)

1/2P = at the midpoint between adjacent stone columns
1/3P = at a third of the distance from the stone column
CP = center of mass of rock column network

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# 4. Conclusions and recommendations

## 4.1. Conclusion

Based on the results of research that has been carried out at the Tibar International Port, more precisely in the stone column section, there are conclusions as follows:

1. All SPT values meet Dr 50% as determined by design.
2. The coordinates of the stone column in each experimental area have shown good results, so they can carry out the process or work of the stone column.
3. Supervision carried out on stone column work is very strict, to minimize non-compliance with the standards that have been set together.
4. The level of safety especially in stone column work has met the established standards, and the workers complied with them.

## 4.2. Suggestion

From the conclusions that have been given above, the suggestions given are:

1. The coordinates of the stone column in the experimental area must be reproduced, so that the data obtained is even more accurate.
2. The control system for the damaged stone column machine must be better, so that the stone column work is not delayed too long.

Set aside a certain area on the construction site to store trash that must be disposed of after the daily work is done.

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# Biography

**Raimundo Novena Maria Tito Gomes**, was born on September 4, 1999 in Laclo, Atsabe District, Ermera Timor-Leste. The eldest of four children. The author started school in elementary to junior high school in Externato De Sao Jose, Dili Timor-Leste. In 2014 the author decided to continue his education at the Frater Senior High School Makassar. Currently the author is studying for a bachelor's degree at Narotama University Surabaya majoring in Civil Engineering.

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Available Online @ http://jurnal.narotama.ac.id/index.php/ijti
ISSN : 2597-4769 (ONLINE) ISSN : 2597-4734 (CETAK)
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# Study of Behavioral of Vertical Irregular Building Structure by Applying Column Variation Due to Earthquake using Dynamic Analysis

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## Abstract

The development of high-rise buildings in Indonesia is now increasingly diverse. The need for increasingly narrow land functions affects the shape of the building which tends to be irregular. Irregularity in the building requires structural planners to build buildings that are safe against earthquakes but also do not forget the aspect of user comfort. In this study, an analysis of the dynamics of earthquakes was carried out in buildings that have vertical geometric irregularities by varying the dimensions and reinforcement of the columns. The behavior of the building structure produces structural responses in the form of base shear, fundamental period, displacement and story drift. Analysis of earthquake using dynamic analysis of response spectrum based on SNI 1726 2019 with the help of ETABS software version 9.7.4. The results of this research indicate that the variation of column dimensions and column reinforcement in buildings with irregular vertical geometry reduces the stiffness of the building thereby reducing the forces in the structure, increasing the fundamental period, reducing the base shear force, increasing the displacement and the story drift.

**Keywords:**
Vertical Geometric Irregularity, Dynamic Analysis Response Spectrum, Base Shear, Fundamental Period, Displacement, Story Drift.

## 1. Introduction

Indonesia is a country that is flanked by two oceans and is located in a tectonic plate area. Indonesia's geographical location is at the confluence of four major tectonic plates, namely the Eurasian, Indo-Australian, Pacific and Philippine plates, which is often referred to as the ring of fire or earthquake-prone area. Earthquakes that occur in Indonesia often take lives. However, it is certain that the cause of the death toll was not directly caused by the earthquake, but caused by the damage to the building which caused the collapse of the building and resulted in casualties. With these conditions, the challenges in the construction world in Indonesia are very large, especially in designing earthquake-resistant high-rise buildings.

The development of high-rise buildings in Indonesia is now increasingly diverse. The need for increasingly narrow land functions, affects the shape of the building which tends to be irregular. Irregularity in the building requires structural planners to build buildings that are safe against earthquakes but also do not forget the aspect of user comfort. One type of irregularity in a building is vertical geometric irregularity, where according to SNI 03-1726:2019, vertical geometric irregularity is a building if the horizontal dimension of the seismic force bearing system at any level is more than 130% of the horizontal dimension of the adjacent seismic force resisting system.

Buildings with regular, simple, and symmetrical shapes will behave better against earthquakes than buildings with irregular shapes (Paulay & Priestley, 1992). The irregular shape of the building will be more unstable than the regular building. These irregularities can affect the stiffness of the building to withstand earthquake loads. One of the indicators to see earthquake response is displacement. The displacement resulting from irregular buildings is greater, so the building has a lower strength against earthquake loads (Purba, 2014).

Regardless of the complexity of the earthquake problems that occur, the main task of experts and practitioners, especially those engaged in civil engineering, is to create a new order regarding the design of earthquake-resistant buildings that are even better. Another thing that must be considered in planning earthquake-resistant buildings is to be guided by the latest regulations or standards that apply in Indonesia, SNI 1726:2019 (2019) concerning *Tata cara perencanaan ketahanan gempa untuk struktur bangunan gedung dan nongedung*. To review the magnitude of the earthquake load that occurs in the building structure, it can be seen from the factors that influence it. There are several factors, including the mass and stiffness of the structure, soil conditions and the seismic area where the building structure is erected. The mass of the building structure is a

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ISSN : 2597-4769 (ONLINE) ISSN : 2597-4734 (CETAK)



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very important factor, because the earthquake load is an inertial force that acts on the center of mass, the amount of which is very dependent on the mass of the structure (Indarto et al., 2013).

In this research, we will review the behavior of buildings against earthquakes through changes in mass. One of the ways to reduce the mass of the building is by reducing the dimensions and reinforcement of the column. The analysis method used is the dynamic analysis of the response spectrum. The building being analyzed is the Social Security Tower (SS Tower) which has vertical geometric irregularities in 3 (three) types of columns. The building has a building area of 50,000 $m^2$, a height of 125.2 meters with 30 stories and 3 basements.

## 2. Methodology

### 2.1. Research Method

The research method used in this analysis is a quantitative method, which begins with studying survey data and some literature reviews and then proceed with structural modeling using the ETABS V.9.7.4 software. The calculation of earthquake analysis uses the SNI 1726:2019 concerning *Tata cara perencanaan ketahanan gempa untuk struktur bangunan gedung dan nongedung.*

### 2.2. General Data

Project name : Social Security (SS) Tower
Project location : Jalan Rasuna Said, Kav. 112 Blok B, Setia Budi, Jakarta Selatan
Latitude : -6.20697°
Longitude : 106.82862°

### 2.3. Technical Data

Object of research : Social Security (SS) Tower
Material properties : Reinforced concrete
Building function : Office
Structure system : Dual System
Soil type : Medium soil
Building area : 50.000 $m^2$
Structure height : 125,2 m
Number of stories : 30 stories and 3 basement
Drawing data : As planned drawing
Concrete strength : 35 MPa – 45 MPa (Column daand Core Wall)
30 MPa – 35 MPa (Beam and Slab)
Reinforecement yield strength: 400 MPa (Longitudinal)
240 MPa (Transversal)
Concrete Density : 24 $kN/m^3$

### 2.4. Gambar Desain Struktur

The following is a picture of the structure design of Social Security (SS) Tower.

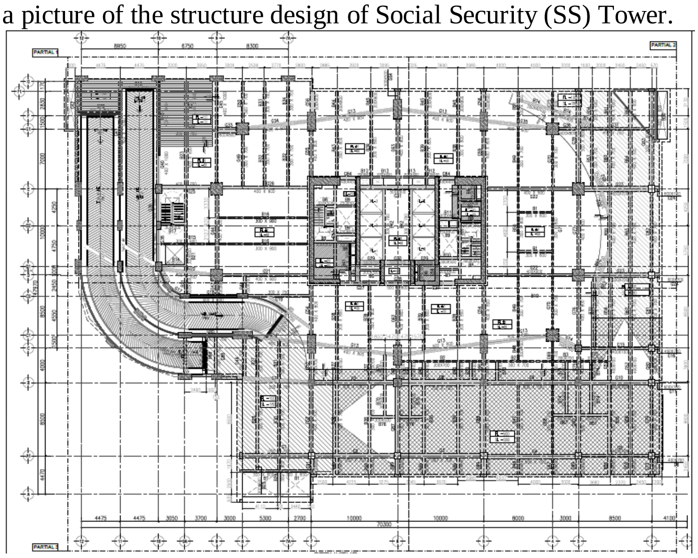

Figure 1. Ground Floor Structure Plan
(Source: Secondary data, 2022)

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### 2.5. Flowchart

The stages of analysis in the calculation of this study are as described in the following figure:

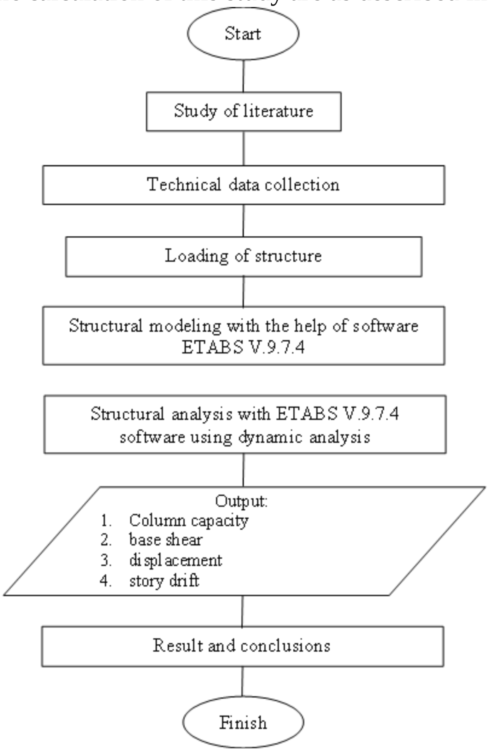


Figure 2. Flowchart
(Source: Author, 2022)

## 3. Analysis and Result

### 3.1. Spectra Response Design

Earthquake parameters are determined based on SNI 1726 2019 concerning *Tata cara perencanaan ketahanan gempa untuk struktur bangunan gedung dan nongedung* with the following details:

1. The category of building structure is seen from Table 1 of SNI 1726-2019. The Social Security (SS) Tower building which is included in an office building is categorized as a risk II building.
2. The earthquake priority factor (Ie) is seen from Table 2 of SNI 1726-2019. The risk category II building has an earthquake priority factor (Ie) of 1.00.
3. Based on Indonesia's spectral response design data released by Pusat Penelitian dan Pengembangan Permukiman, Kementrian Pekerjaan Umum, the response spectra parameters are obtained as follows:

Table 1. Parameter Response Spectra

| Variable | Value |
|---|---|
| PGA (g) | 0,361 |
| $S_S$ (g) | 0,686 |
| $S_1$ (g) | 0,300 |
| $C_{RS}$ | 0,995 |
| $C_{R1}$ | 0,940 |
| $F_{PGA}$ (g) | 1,139 |
| $F_A$ | 1,251 |
| $F_V$ | 1,799 |
| PSA (g) | 0,411 |
| $S_{MS}$ (g) | 0,858 |
| $S_{M1}$ (g) | 0,540 |
| $S_{DS}$ (g) | 0,572 |
| $S_{D1}$ (g) | 0,360 |
| $T_0$ (second) | 0,126 |
| $T_S$ (second) | 0,630 |

(Source: Pusat Penelitian dan Pengembangan Pemukiman – Kementerian Pekerjaan Umum)

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ISSN : 2597-4769 (ONLINE) ISSN : 2597-4734 (CETAK)
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Table 2. Connectivity Fundamental Period, T (second) and Spectral Response Acceleration, SA (g)

| T (second) | SA (g) |
|---|---|
| 0 | 0,229 |
| $T_0$ | 0,572 |
| $T_S$ | 0,572 |
| $T_S + 0$ | 0,494 |
| $T_S + 0,5$ | 0.293 |
| $T_S + 1$ | 0.208 |
| $T_S + 1,5$ | 0.162 |
| $T_S + 2$ | 0.132 |
| $T_S + 2,5$ | 0.112 |
| $T_S + 3$ | 0.097 |
| $T_S + 3,1$ | 0.094 |
| $T_S + 3,2$ | 0.092 |
| 4 | 0.090 |

(Source: Pusat Penelitian dan Pengembangan Pemukiman – Kementerian Pekerjaan Umum)

The connectivity between the natural vibration period (T) and SA (g) can be seen in the following spectrum response graph:

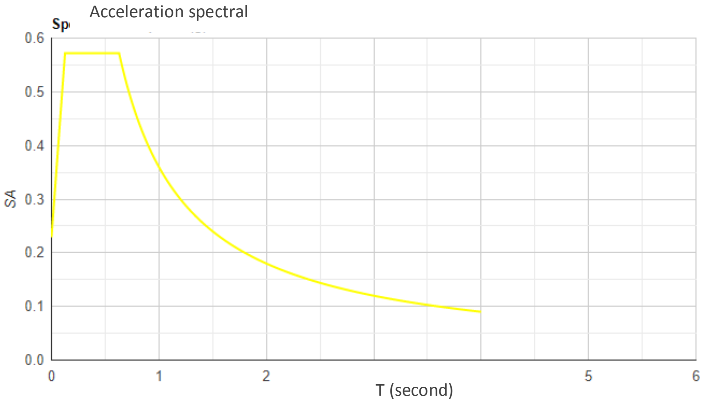


Figure 3. Response Spectrum Graph
(Source: Pusat Penelitian dan Pengembangan Pemukiman – Kementerian Pekerjaan Umum)

1. Seismic design categories are obtained from Table 8 and Table 9 of SNI 1726-2019. Based on the data in point 3, buildings with $S_{DS} \geq 0,50$ dan $S_{D1} \geq 0,20$ are categorized as type D seismic design categories.
2. Site classification is obtained from Table 5 of SNI 1726-2019. Buildings with N values between 15 and 50 are classified as type D site classification.
3. The response modification coefficient (R) is obtained from Table 12 SNI 1726-2019. Buildings with special moment-bearing reinforced concrete frame structures have a response modification coefficient value (R) of 8.

### 3.2. Column Capacity

In this research, the column capacity was carried out using pcaColumn software. The columns that are reviewed or varied are the types of columns K5, K7, K8, K22, K23, and K25. Based on the column interaction diagram, the condition of the column from the basement floor to the roof floor is still able to accept all variations of the building because the results of the analysis of all columns are still within the strong line of the plan. The ability of the column to receive axial loads and moments in the building to be analyzed, explains that all column dimensions are feasible to be analyzed based on the parameters of base shear, displacement, and story drift. The results of the analysis prove that the variation of column dimensions given in this study does not result in collapse of the concrete, failure will begin in the steel reinforcement first due to tensile forces, so that the concrete in the column is still strong.

### 3.3. Base Shear

Based on the results of the ETABS program analysis, the base shear values obtained with various variations of column dimension reduction. The response of the base shear structure is taken from the results of the ETABS program analysis seen from the base reaction.

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Table 3. Base Shear Value

| Variation | Base Shear (kN) Dynamic Analysis | | Base Shear (kN) Equivalent Static Analysis | Structure Weight (kN) | Fundamental Period (s) |
|---|---|---|---|---|---|
| | X Direction | Y Direction | | | |
| Existing | 4112,62 | 5971,23 | 3334,280 | 540050,1 | 7,288607 |
| Variation 1 | 4067,31 | 5893,29 | 3301,133 | 535275,6 | 7,296709 |
| Variation 2 | 4019,05 | 5812,28 | 3266,976 | 530716,4 | 7,310197 |
| Variation 3 | 3974,3 | 5732,11 | 3236,099 | 526820,4 | 7,325771 |

(Source: ETABS V9.7.4 software, 2022)

Based on the results that have been obtained, the value of the dynamic base shear of the entire modeling is 100% greater than the calculation of the static earthquake base shear. Therefore, the base shear obtained does not need to be re-evaluated. If we compare the results of the base shear analysis from the X direction and from the Y direction, it will be seen that the change in value is not too significant. However, the base shear value is constantly decreasing accompanied by a decrease in the column dimensions which are treated in variation 1, variation 2, and variation 3. The largest base shear value on the X and Y axes is found in the existing building model. While the lowest base shear value in terms of both the X and Y axes is found in the variation 3 building model.

### 3.4. Displacement

Displacement that occurs in every condition of the variation of the building is viewed from both directions, namely the X direction and the Y direction. The displacement value is taken from one point that has a continuous column from the basement floor to the roof story, and the point that has the largest displacement value as a sample to see the treatment of the building. The following is the displacement value of each modeling variation for the X direction and the Y direction.

Table 4. Displacement of X Direction

| Story | Displacement of X Direction (mm) | | | |
|---|---|---|---|---|
| | Existing | Variation 1 | Variation 2 | Variation 3 |
| Roof Story | 195,424 | 196,190 | 197,270 | 197,935 |
| ME Story | 192,665 | 193,424 | 194,633 | 195,147 |
| Story 28 | 188,198 | 188,872 | 189,971 | 190,386 |
| Story 27 | 183,177 | 183,764 | 184,755 | 185,075 |
| Story 26 | 177,772 | 178,271 | 179,149 | 179,372 |
| Story 25 | 173,086 | 173,520 | 174,312 | 174,460 |
| Story 24 | 168,051 | 168,416 | 169,116 | 169,187 |
| Story 23 | 162,722 | 163,026 | 163,645 | 163,653 |
| Story 22 | 157,075 | 157,320 | 157,860 | 157,907 |
| Story 21 | 151,098 | 151,289 | 151,753 | 152,646 |
| Story 20 | 144,791 | 144,931 | 145,323 | 146,166 |
| Story 19 | 138,182 | 138,276 | 138,602 | 139,403 |
| Story 18 | 131,266 | 131,318 | 131,581 | 132,344 |
| Story 17 | 124,110 | 124,132 | 124,345 | 125,083 |
| Story 16 | 116,679 | 116,689 | 116,832 | 117,547 |
| Story 15 | 109,401 | 109,570 | 110,495 | 110,597 |
| Story 14 | 101,494 | 101,544 | 101,630 | 102,222 |
| Story 13 | 93,362 | 93,597 | 93,751 | 94,040 |
| Story 12 | 85,056 | 85,982 | 86,012 | 86,706 |
| Story 11 | 76,589 | 76,713 | 76,925 | 77,233 |
| Story 10 | 67,797 | 67,919 | 68,915 | 69,638 |
| Story 9 | 59,101 | 59,329 | 59,516 | 60,062 |
| Story 8 | 50,133 | 50,672 | 50,858 | 51,436 |

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| | | | | |
|---|---|---|---|---|
| Story 7 | 40,107 | 40,360 | 40,548 | 41,172 |
| Story 6 | 30,560 | 30,624 | 30,813 | 31,378 |
| Story 5 | 23,160 | 23,340 | 24,340 | 24,544 |
| Story 4 | 17,431 | 17,626 | 17,834 | 18,368 |
| Story 3 | 12,032 | 12,049 | 12,074 | 13,046 |
| Story 2 | 7,034 | 7,068 | 7,109 | 7,123 |
| Story 1 | 1,362 | 1,433 | 1,506 | 1,574 |
| Basement 1 | 0,209 | 0,217 | 0,226 | 0,234 |
| Basement 2 | 0,065 | 0,068 | 0,070 | 0,072 |
| Basement 3 | 0,000 | 0,000 | 0,000 | 0,000 |

(Source: ETABS V 9.7.4, 2022)

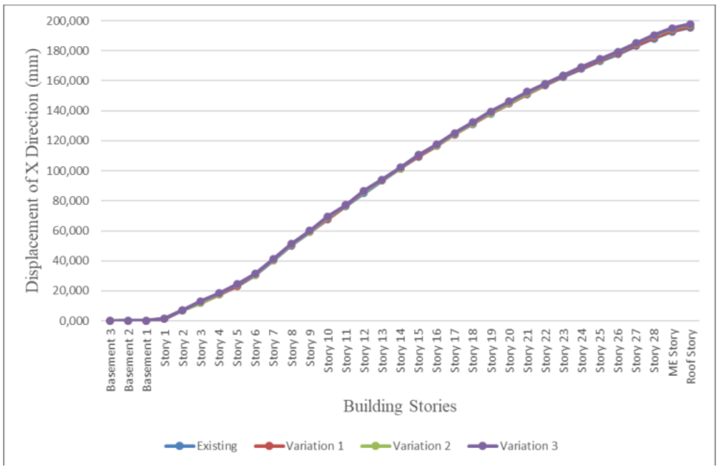


Figure 4. The Graph of X-Direction Displacement All Variations
(Source: Author's analysis, 2022)

Table 5. Displacement of Y Direction

| Story | Displacement of Y Direction (mm) | | | |
|---|---|---|---|---|
| | Existing | Variation 1 | Variation 2 | Variation 3 |
| Roof Story | 168,149 | 168,508 | 168,478 | 168,834 |
| ME Story | 160,515 | 160,910 | 160,929 | 161,312 |
| Story 28 | 153,054 | 153,493 | 153,566 | 153,981 |
| Story 27 | 145,474 | 145,948 | 146,069 | 146,512 |
| Story 26 | 137,923 | 138,430 | 138,598 | 139,065 |
| Story 25 | 131,623 | 132,157 | 132,360 | 132,847 |
| Story 24 | 125,318 | 125,875 | 126,113 | 126,617 |
| Story 23 | 119,048 | 119,623 | 119,890 | 120,405 |
| Story 22 | 112,799 | 113,387 | 113,679 | 114,204 |
| Story 21 | 106,583 | 107,180 | 107,493 | 108,023 |
| Story 20 | 100,406 | 101,007 | 101,337 | 101,868 |
| Story 19 | 94,277 | 94,876 | 95,219 | 95,746 |
| Story 18 | 88,187 | 88,781 | 89,132 | 89,653 |
| Story 17 | 82,165 | 82,747 | 83,100 | 83,610 |
| Story 16 | 76,189 | 76,755 | 77,107 | 77,602 |
| Story 15 | 70,557 | 71,104 | 71,451 | 71,928 |
| Story 14 | 64,695 | 65,217 | 65,555 | 66,009 |
| Story 13 | 58,893 | 59,388 | 59,712 | 60,141 |
| Story 12 | 53,181 | 53,642 | 53,949 | 54,349 |

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| | | | | |
|---|---|---|---|---|
| Story 11 | 47,556 | 47,981 | 48,266 | 48,634 |
| Story 10 | 42,054 | 42,440 | 42,703 | 43,038 |
| Story 9 | 36,766 | 37,112 | 37,349 | 37,647 |
| Story 8 | 31,657 | 31,958 | 32,165 | 32,424 |
| Story 7 | 25,687 | 25,939 | 26,114 | 26,332 |
| Story 6 | 20,115 | 20,317 | 20,460 | 20,634 |
| Story 5 | 16,030 | 16,192 | 16,305 | 16,444 |
| Story 4 | 12,637 | 12,761 | 12,847 | 12,952 |
| Story 3 | 9,509 | 9,597 | 9,656 | 9,731 |
| Story 2 | 6,652 | 6,713 | 6,755 | 6,808 |
| Story 1 | 3,401 | 3,439 | 3,468 | 3,501 |
| Basement 1 | 1,258 | 1,272 | 1,282 | 1,293 |
| Basement 2 | 0,314 | 0,319 | 0,322 | 0,326 |
| Basement 3 | 0,000 | 0,000 | 0,000 | 0,000 |

(Source: ETABS V 9.7.4, 2022)

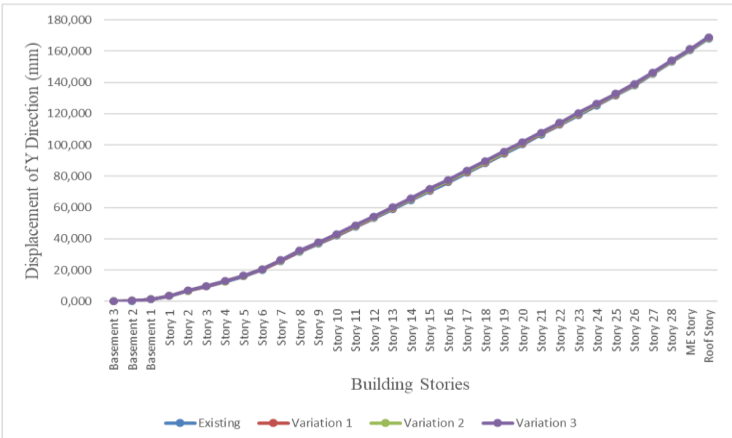


Figure 5. The Graph of Y-Direction Displacement All Variations
(Source: Author's analysis, 2022)

In accordance with SNI 1726 2019, the deviation value for all variations of the X-direction and Y-direction modeling obtained must not exceed the allowable deviation value under review, where the magnitude of the displacement under review should not exceed 0.020 times the building height. This is done to avoid the danger of excessive deviation so that it can cause the building to collapse. Based on the results of the deviation values for all modeling variations in the X and Y directions, they are still in the safe category. The following describes the displacement value for the displacement allowable.

Table 6. Displacement Allowable

| Variation | Displacement (mm) | | Displacement Allowable (mm) | Result |
|---|---|---|---|---|
| | X-Direction | Y-Direction | | |
| Existing | 195,424 | 168,149 | 2748 | Safe |
| Variation 1 | 196,190 | 168,508 | 2748 | Safe |
| Variation 2 | 197,270 | 168,478 | 2748 | Safe |
| Variation 3 | 197,935 | 168,834 | 2748 | Safe |

(Source: Author's analysis, 2022)

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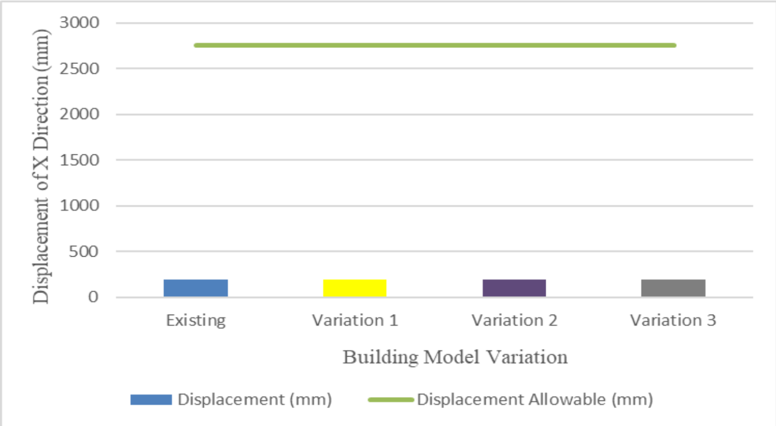


Figure 6. Displacement Allowable of X Direction
(Source: Author's analysis, 2022)

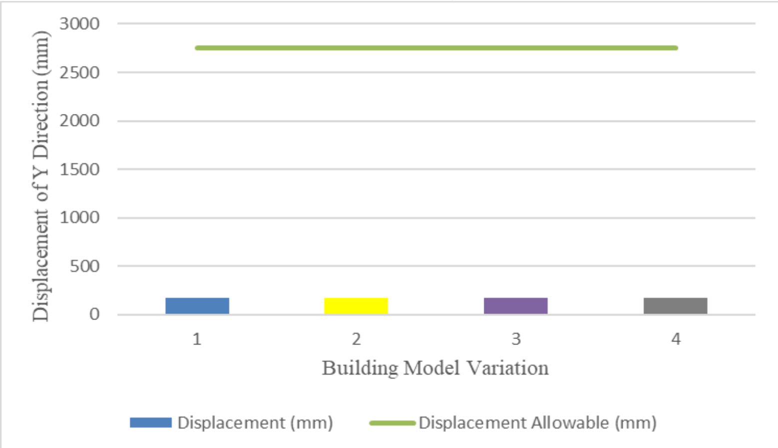


Figure 7. Displacement Allowable of Y Direction
(Source: Author's analysis, 2022)

### 3.5. Story Drift

Story drift is the deviation between floors measured from the base of the story below. The value of the story drift is taken from the displacement value between stories that has been obtained in the previous sub-chapter. The following is the story drift value that occurs in each condition of the variation of the X-direction and Y-direction buildings.

Table 7. Story Drift of X Direction

| Story | Story Drift of X Direction (mm) | | | |
|---|---|---|---|---|
| | Existing | Variation 1 | Variation 2 | Variation 3 |
| Roof Story | 2,759 | 2,767 | 2,637 | 2,788 |
| ME Story | 4,467 | 4,552 | 4,661 | 4,761 |
| Story 28 | 5,021 | 5,107 | 5,216 | 5,310 |
| Story 27 | 5,405 | 5,493 | 5,606 | 5,703 |
| Story 26 | 4,686 | 4,751 | 4,838 | 4,912 |
| Story 25 | 5,035 | 5,105 | 5,196 | 5,273 |
| Story 24 | 5,329 | 5,390 | 5,471 | 5,533 |
| Story 23 | 5,647 | 5,706 | 5,786 | 5,746 |
| Story 22 | 5,977 | 6,032 | 6,107 | 5,262 |
| Story 21 | 6,307 | 6,358 | 6,430 | 6,480 |
| Story 20 | 6,609 | 6,655 | 6,721 | 6,763 |
| Story 19 | 6,916 | 6,958 | 7,022 | 7,059 |
| Story 18 | 7,155 | 7,186 | 7,236 | 7,261 |
| Story 17 | 7,432 | 7,443 | 7,513 | 7,537 |

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| | | | | |
|---|---|---|---|---|
| Story 16 | 7,278 | 7,119 | 6,337 | 6,950 |
| Story 15 | 7,907 | 8,027 | 8,865 | 8,375 |
| Story 14 | 8,132 | 7,947 | 7,879 | 8,182 |
| Story 13 | 8,306 | 7,614 | 7,739 | 7,334 |
| Story 12 | 8,467 | 9,269 | 9,087 | 9,473 |
| Story 11 | 8,792 | 8,794 | 8,010 | 7,595 |
| Story 10 | 8,696 | 8,590 | 9,399 | 9,576 |
| Story 9 | 8,968 | 8,657 | 8,658 | 8,626 |
| Story 8 | 10,026 | 10,312 | 10,310 | 10,265 |
| Story 7 | 9,547 | 9,736 | 9,735 | 9,794 |
| Story 6 | 7,401 | 7,284 | 6,473 | 6,834 |
| Story 5 | 5,728 | 5,714 | 6,507 | 6,176 |
| Story 4 | 5,399 | 5,577 | 5,760 | 5,322 |
| Story 3 | 4,998 | 4,981 | 4,964 | 5,923 |
| Story 2 | 5,672 | 5,635 | 5,604 | 5,548 |
| Story 1 | 1,153 | 1,216 | 1,280 | 1,341 |
| Basement 1 | 0,145 | 0,149 | 0,155 | 0,162 |
| Basement 2 | 0,065 | 0,068 | 0,070 | 0,072 |
| Basement 3 | 0,000 | 0,000 | 0,000 | 0,000 |

(Source: Author’s analysis, 2022)

Tabel 8. Story Drift Arah Y

| Story | Story Drift of Y Direction (mm) | | | |
|---|---|---|---|---|
| | Existing | Variation 1 | Variation 2 | Variation 3 |
| Roof Story | 7,633 | 7,598 | 7,549 | 7,522 |
| ME Story | 7,461 | 7,417 | 7,363 | 7,331 |
| Story 28 | 7,580 | 7,545 | 7,496 | 7,469 |
| Story 27 | 7,551 | 7,518 | 7,472 | 7,447 |
| Story 26 | 6,300 | 6,274 | 6,237 | 6,218 |
| Story 25 | 6,305 | 6,281 | 6,247 | 6,230 |
| Story 24 | 6,270 | 6,253 | 6,224 | 6,212 |
| Story 23 | 6,250 | 6,236 | 6,211 | 6,202 |
| Story 22 | 6,216 | 6,207 | 6,186 | 6,181 |
| Story 21 | 6,177 | 6,173 | 6,156 | 6,155 |
| Story 20 | 6,129 | 6,131 | 6,118 | 6,121 |
| Story 19 | 6,090 | 6,095 | 6,087 | 6,093 |
| Story 18 | 6,022 | 6,034 | 6,031 | 6,043 |
| Story 17 | 5,977 | 5,992 | 5,993 | 6,008 |
| Story 16 | 5,632 | 5,651 | 5,657 | 5,675 |
| Story 15 | 5,862 | 5,887 | 5,896 | 5,918 |
| Story 14 | 5,801 | 5,830 | 5,843 | 5,869 |
| Story 13 | 5,713 | 5,746 | 5,763 | 5,792 |
| Story 12 | 5,625 | 5,661 | 5,682 | 5,714 |
| Story 11 | 5,502 | 5,540 | 5,563 | 5,596 |
| Story 10 | 5,288 | 5,329 | 5,355 | 5,391 |
| Story 9 | 5,110 | 5,154 | 5,184 | 5,223 |
| Story 8 | 5,970 | 6,019 | 6,051 | 6,092 |
| Story 7 | 5,572 | 5,621 | 5,655 | 5,698 |
| Story 6 | 4,085 | 4,126 | 4,154 | 4,190 |
| Story 5 | 3,393 | 3,431 | 3,458 | 3,492 |
| Story 4 | 3,128 | 3,164 | 3,191 | 3,222 |

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| | | | | |
|---|---|---|---|---|
| Story 3 | 2,858 | 2,884 | 2,901 | 2,923 |
| Story 2 | 3,251 | 3,274 | 3,288 | 3,307 |
| Story 1 | 2,143 | 2,167 | 2,186 | 2,208 |
| Basement 1 | 0,944 | 0,953 | 0,959 | 0,967 |
| Basement 2 | 0,314 | 0,319 | 0,322 | 0,326 |
| Basement 3 | 0,000 | 0,000 | 0,000 | 0,000 |

(Source: Author's analysis, 2022)

## 4. Conclussion

Based on the results of modeling analysis with variations in column dimensions in buildings that have vertical geometric irregularities, it can be concluded that variations in column dimensions in the behavior of building structures with vertical geometric irregularities will affect building behavior against earthquakes, namely reducing building stiffness. The decrease in building stiffness is seen from the parameter results, increasing the fundamental structure, reducing the base shear, and increasing the displacement.

The difference in the behavior of the irregular structure of the vertical geometry which has varied the dimensions of the column shows that the reduction in mass in the building will cause the stiffness of the building to be smaller. This is evidenced by the existing building as a variation that does not experience a reduction in column dimensions so that the mass of the building does not decrease and has a greater building rigidity when compared to other modeling variations. This is reviewed based on the parameters of base shear, fundamental period, displacement, and story drift.

The variation of the planned column dimension reduction is still within safe limits in accordance with the permitted displacement of SNI 1726 2019 in terms of displacement parameters and story drift.

The value of the base shear in each building model, namely, the existing model in the X direction is 4112.62 kN, while the Y direction is 5971.23 kN. Variation Model 1 in X direction is 4067.31 kN, while the Y direction is 5893.29 kN. Variation Model 2 in X direction is 4019.05 kN, while the Y direction is 5812.28 kN. Variation Model 3 in X direction is 3974.3 kN, while the Y direction is 5732.11 kN. The critical story displacement value is obtained in the Variation model 3 with a displacement value of 195.424 mm in the X direction and 168,834 mm in the Y direction. The largest story drift in the X direction is found in the structure model variation 3 with a story drift value of 10.312 mm and the Y direction in the existing structural model with a value of 7.580 mm.

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IJTI (International Journal Of Transportation And Infrastructure)
Available Online @ http://jurnal.narotama.ac.id/index.php/ijti
ISSN : 2597-4769 (ONLINE) ISSN : 2597-4734 (CETAK)

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# Analysis and Design of Precast Cast-In Situ Concrete Composite (Tibar Liquiça Quay, Timor-Leste)

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## Abstract
The quay is a building structure made at sea to connect the land and harbor parts that function as a place for docking or mooring ships that will carry out loading and unloading activities of loading and unloading passengers. The wharf at the Tibar port is operated for loading/unloading general cargo containers. The dimensions of the floor plate for the wharf are 75cm, T4 transverse beams 6,900 x 1,500 x 1,500 m, longitudinal beams 5,400 x 1,750 x 1,500 m, pile cap 1.69 m² and pile foundation length The pile for the diameter of 1.5 m is 80 m, the Pile of 1.8 m is 81 m. The wharf has a length of 630 m, a width of 62 m and a depth of 16 m and the structure type of this pier is reinforced concrete and steel piles.

## Keywords :
Beam, Piles, Precast, Quay

## 1. Introduction
Port an important infrastructure, especially for sea transportation, with this transportation, the distance needed will be felt faster, especially for the economic development of an area where the center of consumer goods production can be marketed quickly and smoothly The wharf itself is a building structure made at sea to connect the land and harbor parts that function as a place for docking or tying ships that will carry out loading and unloading activities of loading and unloading passengers. The port of Tibar is operated for loading/unloading general cargo, and containers/goods. This wharf has a length of 630 m, a width of 62 m and a depth of 16 m and the type of structure of this pier is reinforced concrete and steel piles. Precast or precast concrete itself, as the name implies, this type of concrete is concrete that has been printed and made first somewhere before being used on a construction site.

## 2. Research methods
The research was conducted for three months starting on August 24, 2020 until December 4, 2020, the location of this research was carried out at an international port located in Tibar, Timor-Leste. The data collection technique was carried out by collecting data at the location and getting help from the owner, namely PMU-TBPP, looking for references from journals on the internet, and getting support from supervisors.

## 3. Results and Discussion
For the pile foundation under crane beam, steel tubular pile with diameter of 1.8m used, other row of piles use 1.5m steel tubular piles. The thickness of all the pile will be changed at elevation of -20.0m CD based on the the bending moment distribution (around the second zero point of bending moment) and the minimum embedded length requirement., The thickness of the section above -20.0m CD for the two rows of Φ1500 steel tubular piles on landside is 24mm, and 22mm adopted for other steel tubular piles. The thickness of the section below -20.0m CD for all the steel tubular piles are 20mm. Piles and beams are modeled using beam elements, and slabs that supported on the beams are modeled by shell elements. And other longitudinal beam dimension is 5400 x 1,750 x 1,500 mm and transverse beam dimension is 6,900 x 1,500 x 1,500 , 5230 x 1500 x 1500.

### 3.1 Quai Contruction part
Quay can be classified into several parts as follows:

1. Upper : Structure
   The superstructure of the wharf consists of:
2. Slab : Is part of the pier plate to be passed by vehicles going to the ship or from the ship to the mainland.
3. Beam : Is a series of girders extending from the construction of the pier and is a stiffener and supports the floor slab.

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The foundation is a part of the pier that is embedded or connected to the ground, the function of the foundation is to withstand the load of the building on it and pass it on to the subgrade. The goal is to obtain a solid and stable state or in other words there will be no large decline, both vertically and horizontal.

## 3.2. Results

For the calculation result of 1800mm piles and 1500mm piles,longitudinal beams and transverse bean are calculated using exel and the results are ok.

Table 1. The Dimention Of Transvers Beam

| Structure Member | | Dimension LxBxH (mm) | NOS |
|---|---|---|---|
| Transverse Beams | T1 | 5230x1500x1500 | 71 |
| | T1’ | 5230x1500x1500 | 86 |
| | T1-1 | 5230x1500x1500 | 10 |
| | T1-2 | 5230x1500x1500 | 5 |
| | T2 | 5500x1500x1500 | 172 |
| | T3 | 6630x1500x1500 | 71 |
| | T3-1 | 6630x1500x1500 | 15 |
| | T4 | 6900x1500x1500 | 86 |

Table 2. The Dimention Of Longitudinal Beam and slab

| | | | |
|---|---|---|---|
| Longitudinal Beams | L1 | 5400x1000(1500)x1500 | 320 |
| | L2 | 5400x1250(2000)x1500 | 80 |
| Slabs | PS1 | 6400x6050x350 | 60 |
| | PS1-1 | 6400x6050x350 | 5 |
| | PS1-1’ | 6400x6050x350 | 5 |
| | PS1-2 | 6400x6050x350 | 10 |
| | PS2 | 6600x6050x350 | 160 |
| | PS3 | 6480x6050x350 | 80 |
| | PS4 | 7720x6050x350 | 60 |
| | PS4-1 | 7720x6050x350 | 5 |
| | PS4-1’ | 7720x6050x350 | 5 |

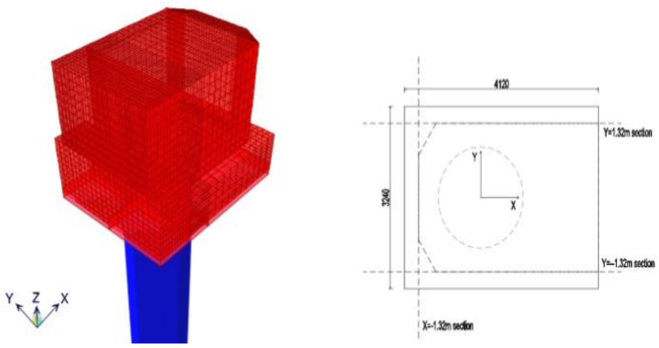
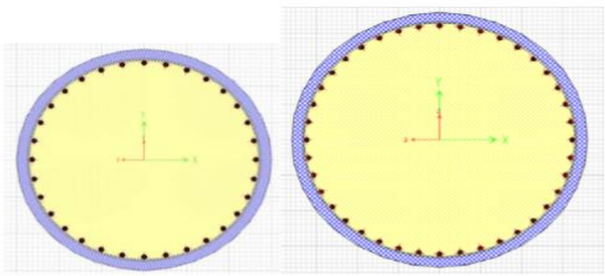


Figure 1. The Dimention of Pile Cap

Pile is part of the structure that is use to receive and transfer (chanel ) the load from the superstructure to the soporting soil which is located at a certain depth


(a) Φ1500mm Pile (b) Φ1800mm Pile
Figure 2. The Dimention Of Pile

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## 4. Conclusions and recommendations

### 4.1. Conclusion

1. Therefore, the time factor should always be considered. That is also why in the geotechnical industry, majority of the downdrag on pile occurs for piles installed in deep soft clay.
2. For the calculation result from slab to pile are just using manual calculation.

### 4.2. Suggestion

1. The Control system for precast must be better,so that the work is nor delayed too long.
2. Set aside a certain area on the construction site to store trash that must be disposed of after the daily work is completed.

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IJTI (International Journal Of Transportation And Infrastructure)
Available Online @ http://jurnal.narotama.ac.id/index.php/ijti
ISSN : 2597-4769 (ONLINE) ISSN : 2597-4734 (CETAK)
IJTI

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# The Foundations in Construction a General and Comprehensive Study from an Engineering and Historical Perspective

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## Abstract
The bottom base of the structure is the very uppermost part because it connects the superstructure of the body to the ground. This bottom base is known as the foundation. In this paper we will discuss and analyze the types of foundations used in the construction industry, there is a design and also in alternative materials that we can use as foundation materials in construction that can make it more solid, durable and environmentally friendly. It is critical to build a stable base that maintains the superstructure in all climatic conditions without collapsing or deteriorating the concrete structure. If any unsuitable material is used for the foundation of the structure, the high risk is the collapse of the structure. Different types of foundation base are used in different types of structural structures, each with a unique design and specific configuration that makes a particular structure more durable and stable. A different type of foundation is used in cottages and high-rise buildings. This study presents the use of foundations for the superstructure, and appropriate design, and we will discuss more precisely about how to make the foundation foundation environmentally friendly, cost-effective for the structural building, and make it more durable and strong to withstand natural and environmental disasters.

**Keywords:**
Building Foundation, Construction Foundation, Foundation Engineering.

## 1. Introduction

Foundation engineering is an important branch of geotechnical engineering that applies soil mechanics, structural engineering, and project service requirements to the design and construction of foundations for onshore and offshore structures. Foundation engineering can be achieved as a technical approach rather than a routine procedure because well-designed and built foundations continue to perform efficiently during the life of the project. The main task and objective of the foundation engineer is to create a technically sound, practicable, and economical design of the foundation system to support the infrastructure.

Foundation systems are structural units that transfer various combinations of loads from the superstructure to the underlying soil or rock. Foundation units may bear loads individually or through the contribution of other elements such as basement walls, floors, slabs, etc.

## 2. Literature Review

### 2.1 Comprehensive Study of the Mechanical and Durability Properties of High-Performance Concrete Materials for Grouting Underwater Foundations of Offshore Wind Turbines:

With the increasing importance of offshore wind turbines, a critical issue in their construction is the high-performance concrete (HPC) used for grouting underwater foundations, as such materials must be better able to withstand the extremes of the surrounding natural environment. This study produced and tested 12 concrete sample types by varying the water/binder ratio (0.28 and 0.30), the replacement ratios for fly ash (0%, 10%, and 20%) and silica fume (0% and 10%), as substitutes for cement, with ground granulated blast-furnace slag at a fixed proportion of 30%. The workability of fresh HPC is discussed with setting time, slump, and V-funnel flow properties. The hardened mechanical properties of the samples were tested at 1, 7, 28, 56, and 91 days, and durability tests were performed at 28, 56, and 91 days. Our results show that both fly ash (at 20%) and silica fume (at 10%) are required for effective filling of interstices and better pozzolanic reactions over time to produce HPC that is durable enough to withstand acid sulfate and chloride ion attacks, and we recommend this admixture for the best proportioning of HPC suitable for constructing offshore wind turbine foundations under the harsh underwater conditions of the Taiwan Bank. We established a model to predict a durability parameter (i.e., chloride permeability) of a sample using another mechanical property (i.e., compressive strength), or vice versa, using the observable relationship between them. This concept can be generalized to other pairs of parameters and across different parametric categories, and the regression model will make future experiments

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ISSN : 2597-4769 (ONLINE) ISSN : 2597-4734 (CETAK)
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less laborious and time-consuming. This paper traces the development of the craft and science of foundation engineering in the UK during the last 100 years drawing mainly on papers published in The Structural Engineer.


Figure 1. Building Foundation in Construction

### 2.2 Analytical Calculation of Critical Anchoring Length of Steel Bar and GFRP Antifloating Anchors in Rock Foundation:

Antifloating anchors are widely used during the construction of slab foundations to prevent uplift. However, existing methods for calculating the critical length of these anchors have limited capabilities and therefore require further research. As the mechanisms which govern the displacement and stability of antifloating anchors are closely related to those of piles subject to uplift, a simplified anchor model has been developed based on existing concentric thin-walled cylinder shear transfer models used for pile design. Analytical expressions for the critical length of the steel bar and GFRP (glass fiber reinforced polymer) antifloating anchors in rock are derived accordingly before demonstrating the validity of the method through engineering examples. The research results show that when the length of an antifloating anchor is less than a critical length, shear slip failure occurs between the anchor and surrounding material due to excessive shear stress. When the length of an anchor approaches the critical length, the shear stress gradually decreases to the undisturbed state. If the anchor length is larger than the critical length, the uplift loads are safely transferred to the ground without causing failure. The ratio of elastic modulus between the anchor and rock mass was found to be positively correlated with the critical anchoring length. Because the elastic modulus of GFRP bars is lower than that of steel bars, the critical anchoring length of GFRP bars is greater than that of steel bars under the same anchor-to-rock modulus ratio (Ea/Es). The results show that the proposed calculation method for the critical length of antifloating anchors appears valid and could provide a theoretical basis for the design of antifloating anchors after further refinement.

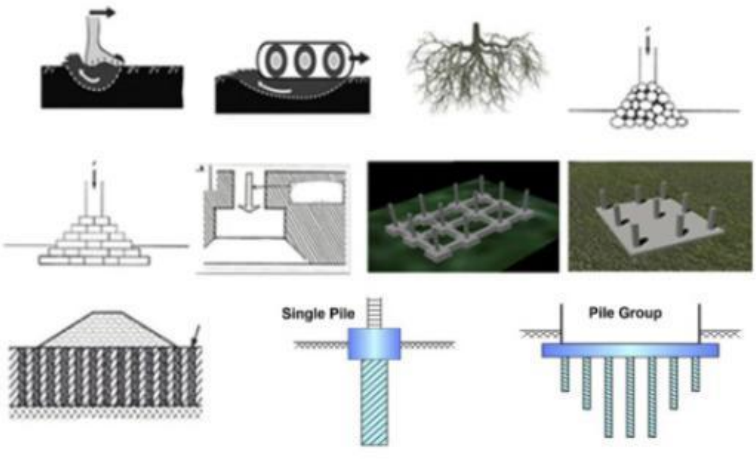

Figure 2. Various elements acting as foundation systems.

### 2.3. Historical and Engineering View on Foundations of Construction

The foundation is the concrete structural base that stands on the ground and supports the rest of the building. Therefore, some concrete foundation design must include extensive study of the land under the

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foundation as well as the constructive design and materials used in the foundation itself (American Concrete Institute).

The foundations are designed so that the loads imposed by the building are transferred uniformly to the contact surface to transmit and carry the wind to the ground. The net bearing capacity coming into the soil shall not exceed the bearing capacity of the soil. The design of the foundation must also take into account the stability expected from the building to ensure that all movements are controlled and standardized to prevent damage to the concrete structure. The overall design and land characteristics must be studied to determine potentially beneficial construction strategies (Malabi Eberhardt et al. 2020).

Foundation building is one of the oldest human activities, as foundations provide support for structures by transferring their load to the layers of soil or rock beneath them. Over 12,000 years ago, Neolithic Switzerland built homes on tall wooden piles, keeping people high above dangerous animals and hostile neighbors. A few thousand years later, the Babylonians raised their footprints on reed mats, and the ancient Egyptians supported the pyramids on stone blocks that rested on the bedrock. In ancient Rome foundation engineering really took a leap forward, with rules set and concretely used that chart the history of modern building elements in the UK We take a look at how foundation engineering has changed over the past century.

Building history embraces many other fields such as structural engineering, civil engineering, city growth and population growth who are close relatives of the branches of technology and history to investigate building preservation and record their achievements. These fields allow it to be used to analyze modern or the most recent and prehistoric constructions, such as the structures, building and materials. The foundations are designed so that the loads imposed by the building are transferred uniformly to the contact surface to transmit and carry the wind to the ground. The net bearing capacity coming into the soil shall not exceed the bearing capacity of the soil. The design of the foundation must also take into account the stability expected from the building to ensure that all movements are controlled and standardized to prevent damage to the concrete structure. The overall design and land characteristics must be studied to determine potentially beneficial construction strategies. The outline and design of shallow and deep foundation construction are analyzed, designed and built, as well as the methods used in other countries are discussed. Presents the main methods used by geotechnical and structural engineers, and the necessary precautions in the planning and design of concrete infrastructure (Office 2006).

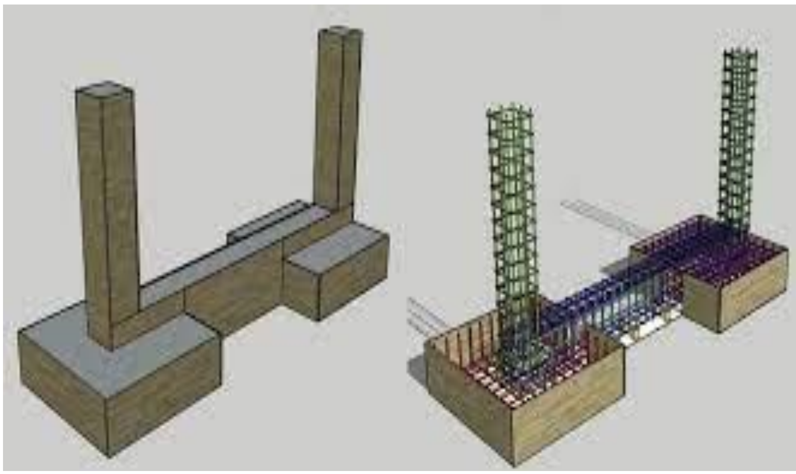

Figure 3. View on foundations of construction

# 3. Methodology

## 3.1. Research Method

There are a variety of methods for determining the bearing capacity of guard foundations on soils. Typical unpolished shear strength and values are also given for different types of materials. The assumed stresses allowed are usually based on empirical correlations and are intended to be used without much testing and design evaluation and quantitative analysis will be used. A preliminary estimate of the permissible bearing pressure can be obtained on the basis of soil descriptions. Other methods involve correlating bearing stresses with internal field test results, such as the tip value and resistance.

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## 3.2 Research Design and Sample for the Topic of the Research and its Theories:

$$q_u = \frac{Q_u}{B_f' L_f'} = c' N_c \zeta_{cs} \zeta_{ci} \zeta_{ct} \zeta_{cg} + 0.5 B_f' \gamma_s' N_\gamma \zeta_{\gamma s} \zeta_{\gamma i} \zeta_{\gamma t} \zeta_{\gamma g} + q N_q \zeta_{qs} \zeta_{qi} \zeta_{qt} \zeta_{qg}$$

where $N_c, N_\gamma, N_q$ = general bearing capacity factors which determine the capacity of a long strip footing acting on the surface of a soil in a homogenous half-space

$Q_u$ = ultimate resistance against bearing capacity failure
$q_u$ = ultimate bearing capacity of foundation
$q$ = overburden pressure at the level of foundation base
$c'$ = effective cohesion of soil
$\gamma_s'$ = effective unit weight of the soil
$B_f$ = least dimension of footing
$L_f$ = longer dimension of footing
$B_f'$ = $B_f - 2e_B$
$L_f'$ = $L_f - 2e_L$
$e_L$ = eccentricity of load along L direction
$e_B$ = eccentricity of load along B direction
$\zeta_{cs}, \zeta_{\gamma s}, \zeta_{qs}$ = influence factors for shape of shallow foundation
$\zeta_{ci}, \zeta_{\gamma i}, \zeta_{qi}$ = influence factors for inclination of load
$\zeta_{cg}, \zeta_{\gamma g}, \zeta_{qg}$ = influence factors for ground surface
$\zeta_{ct}, \zeta_{\gamma t}, \zeta_{qt}$ = influence factors for tilting of foundation base

Figure 4.the generalized loading and geometric parameters for the design of shallow foundation

In selecting φ ' value for foundation design, attention should be given to the stress-dependency of the strength envelope of soils.

Kimmerling (2002) suggested using the actual dimensions, Bf and L f, to compute the influence factors for shape of shallow foundation. The equations for computing shape factors given in Figure 4.III.2 use the full dimensions of a shallow foundation.

## 3.2. Method of data collection

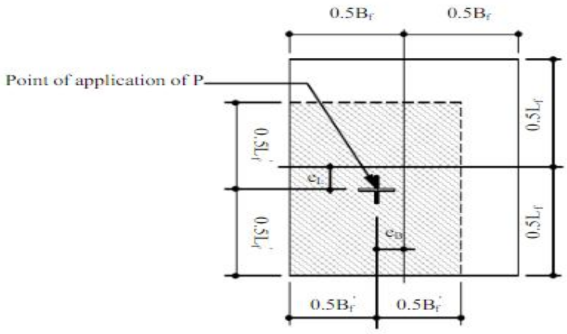


Figure 5. Force Acting on a Spread Foundation

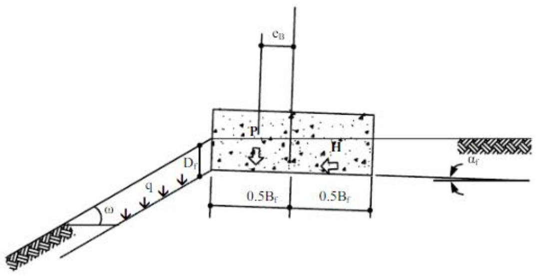


Figure 6. Effective Dimensions of Foundation Base

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### 3.3. Method of data analysis:

The presence of geological features such as weak strata or discontinuities can lead to failure mechanisms different from those assumed to derive the equation. An approximate method for determining the final bearing capacity of a foundation is given near the slope top. Therefore, the presence of geological features, especially weak soil layers, should be checked in investigations floor.

The final bearing capacity can be obtained by linear interpolation between the value of the foundation resting at the edge of the slope and the following equation can be used to estimate the final bearing capacity of the foundation on the top of the slope and the evaluation of the bearing capacity should take into account the geological characteristics of the land.

$$Sc = \frac{C\alpha}{1 + eo} \text{ Ho} \log \frac{ts}{tp}$$

Where:

Sc = secondary consolidation
Cα = secondary compression index
eo = initial void ratio
Ho = thickness of soils subject to secondary consolidation
Tp = time when primary consolidation completes
ts = time for which secondary consolidation is allowed

## 4. General Analysis:

Foundation is suitable when the underlying soil has a low bearing capacity or large differential settlements are expected. It is also suitable for land with pockets of loose and soft soil. The advantage of a cellular raft is that it can reduce the overall weight of the foundation and therefore the net pressure applied to the ground. The cell raft must be provided with sufficient rigidity to reduce differential flattening. In some cases, the raft foundation is designed as a cellular structure where deep hollow boxes are formed in the concrete slab.

Where qnet = net ground bearing pressure
δp = settlement of the test plate
Is = shape factor
b = width of the test plate
νs = Poisson's ratio of the soil
Es = Young's modulus of soil

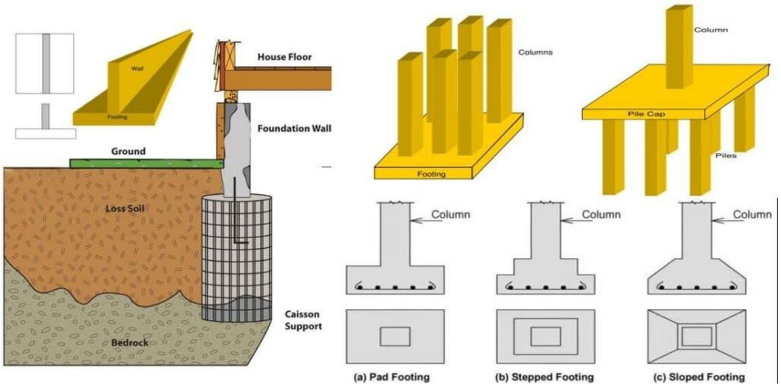


Figure 7. Types of Foundation

The method for extrapolating plate loading test results to estimate the settlement of a full-size footing on granular soils is not standardized. The increase of stress in soils due to foundation load can be calculated by assuming an angle of stress dispersion from the base of a shallow foundation. This angle may be approximated as a ratio of 2 (vertical) to 1 (horizontal) (Bowles 1992). The settlement of the foundation can then be computed by calculating the vertical compressive strains caused by the stress increases in individual layers and summing the compression of the layers.

### 4.1. The reason for the global trend of connected rather than separate foundations:

### 4.1.1 Connected foundations

Is an effective structural type of foundation that can improve the sustainability of electrical transmission towers in soft soils to serve as a resilient energy supply system. In this study, the performance of electrical transmission towers reinforced with connected beams was investigated using a series of field load tests. Model transmission tower structures were manufactured and adopted into the tests. Based on the load capacity mobilization and failure mechanism, a criterion to define the load carrying capacity for connected foundation was proposed. It was found that the performance of connected foundation varies with the mechanical property of connection beam.

The load capacity and differential settlement increased and decreased, respectively, with increasing connection beam stiffness. Such effect of connection beam was more pronounced as the height of load application point or tower height increases. Based on the load test results, a design model was proposed that can be used to evaluate the sustainable performance and load carrying capacity of connected foundations. Field load tests with prototype transmission tower structure models were conducted to check and confirm the performance of connected foundation and the proposed design method.

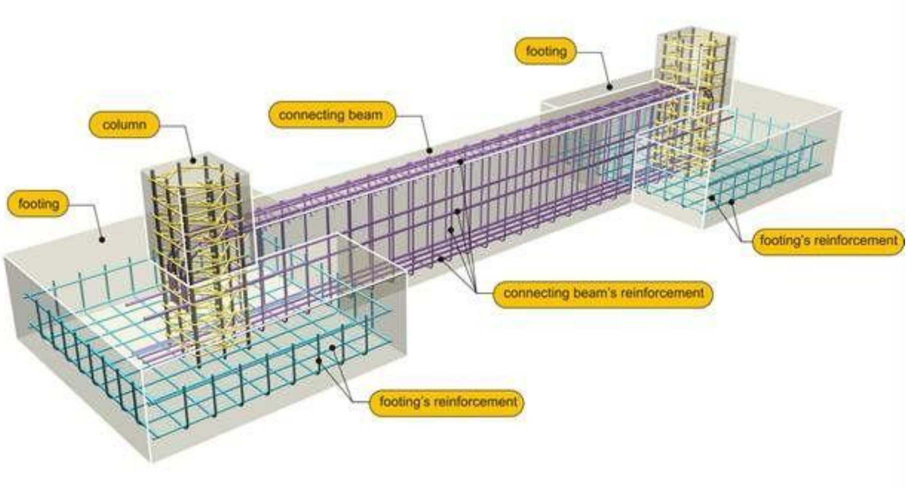


Figure 8. Connected foundations

### 4.1.2 Unconnected foundations

The piled raft foundations are an economical solution as well as a settlement reducer in the construction of high-rise buildings. Unconnected piled raft foundation is an innovative technique where a cushion separates the pile and raft. The cushion takes the load transferred from the raft and safely distributes over the piles beneath.

This article analyses the seismic behaviour of connected and unconnected piled raft foundation of a multistorey building using ANSYS software based on the finite element method. An 8 m × 8 m × 1 m raft and 0.4 m × 0.4 m square concrete piles with depth of 12 m resting on a very soft clay stratum were modelled. The soil block of 16 m × 16 m plan dimension with a depth of 16 m was provided with transmitting boundaries at all lateral edges with properties corresponding to shear wave velocity of clay (150 m/s) and was analysed for the response under the ground motion corresponding to El Centro 1940 earthquake.

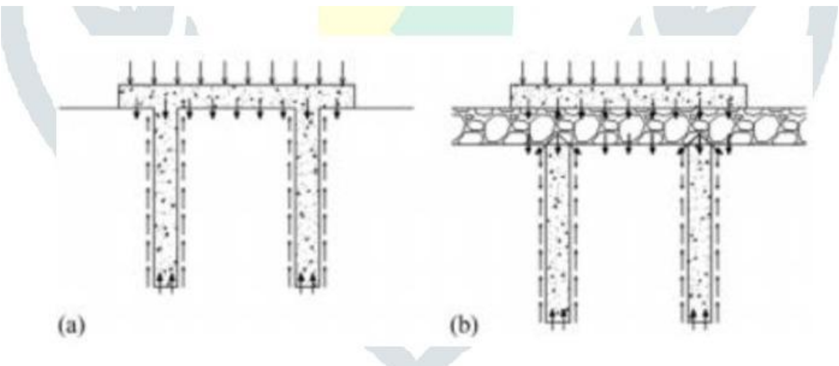


Figure 9. Unconnected foundations

### 4.2. Engineering influences in the future on the foundations of all kinds and the extent to which this will affect the quality of construction in the future:

The world is changing faster than ever. Just think of one of the world major trends shake up the construction industry: the world's population urban areas are increasing by 200,000 people per day, all of them need affordable cost housing as well as social infrastructure, transportation and utilities. In a confrontation such challenges, the industry is almost under an ethical obligation to transform that it the shift will have transformative effects elsewhere: on the broader society.

## 5. Summary and Conclusions:

This paper identified the following three-stage process for
Design of foundations for tall buildings:

1. An initial design stage, which initially provides basis for the development of foundation concepts and the cost.
2. The detailed design stage in which some previous studies are done and the foundations are selected and the concept is analyzed and incremental improvements are made to the layout and details of the foundation system. It is recommended that this stage be done collaboratively with the structural designer, such as the concrete structure.
3. The final design stage, in which both the concrete foundation analysis is done and the parameters used in the analysis are completed.

## 6. Acknowledgement

This research was made possible by funding from research grant provided by Narotama University, Indonesia. The author would also like to thank the Faculty of Engineering and Computer Science, civil engineering department, Narotama University and also Dr. M. Ikhsan Setiawan, S.T., M.T, for their support and all parties that helped preparing this paper.

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IJTI (International Journal Of Transportation And Infrastructure)
Available Online @ http://jurnal.narotama.ac.id/index.php/ijti
ISSN : 2597-4769 (ONLINE) ISSN : 2597-4734 (CETAK)
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# Analysis of Health and Safety Risk Management (OHS) (Case Study of KPP Sidoarjo State House Rehabilitation Project)

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## Abstract

This study intends to identify OHS risks in the workforce, control risks, and assess risks that occur in construction projects. This implementation was carried out in the KPP Sidoarjo State House Rehabilitation project. This data collection uses the interview method and filling out questionnaires directly to the workforce as many as 15 respondents who then arrange the risk potential variables based on each job so that 37 potential risk variables are produced. In the conclusion, there are results of the risk level assessment based on the AS/NZS 4360 standard, there are 20 variables that are categorized as medium level and 17 variables that are categorized as low level. exposed to noise when using a grinding machine when cutting ceramics (ceramic installation process), while for the lowest value of 1.47 which is included in the low level, the workers' eyes are exposed to paint splashes (painting process).

**Keyword:**
Control, Occupational Health and Safety (K3), Risk Identification, Risk Management, Risk Assessment

## 1. Introduction

### 1.1. Background of the Study

Occupational Health and Safety (OHS) is important for a company to avoid negative impacts from work accidents. So it is necessary to apply a risk management system and control of OHS, but the implementation of OHS in the field is still not optimal and often ignores the requirements and regulations on OHS with the implementation of the Construction Safety Management System by the government where work accidents still occur which can cause losses. thus causing the failure of construction projects because workers do not care about the magnitude of the risks that occur (Hidayat 2018). In the KPP Sidoarjo State House Rehabilitation project, there is often negligence in the use of PPE and the application of OHS by workers which will endanger themselves and also harm the company in carrying out construction project activities. Based on previous research and the problems that exist in the field, this study aims to identify the risk factors for the occurrence of OHS hazards and measure the risk factors of some of these jobs.

## 2. Research Method

### 2.1. Methodology

In this study, the method used is to use the calculation of the risk assessment that is formulated to allow the occurrence (probability) and (consequences). There is a risk index that is equal to the multiplication of the possible impacts.

Table 1. Risk Analysis Matrix

| Risk Value | Risk Category | Description |
|---|---|---|
| 1-3 | L | Low |
| 4-9 | M | Moderate |
| 10-16 | H | High |
| 17-25 | VH | Very High |

Description :
Very High: precarious and emergency assistance
High: dangerous, need management supervision.
Medium: medium risk, management accountability.
Low: small risk, handled by periodical decree.

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# 3. Analysis And Discussion

## 3.1. Data Analysis

In this data analysis, calculations are carried out by multiplying the average value of opportunities and consequences, after that an assessment of the risk level is carried out based on the AS/NZ 4360 risk matrix standard.

Table 2 Risk rating result based on AS/NZS 4360 risk matrix Source (Owned)

| No | Activity | Potential risk | Grade | Risk category |
|---|---|---|---|---|
| 1 | Ceramic installation process | Exposure to noise when using a grinding machine to cut ceramics | 7.86 | M |
| 2 | Iron cutting process | Employee's hand scratched | 7.6 | M |
| 3 | Painting process | Workers fall from a height | 7.2 | M |
| 4 | Ceramic installation process | Respiratory problems due to dust when cutting ceramics | 6.8 | M |
| 5 | Iron transfer process | Iron pierced worker's hand | 6.54 | M |
| 6 | Ironing Process | Iron pierced worker's hand | 6.54 | M |
| 7 | Ironing Process | Workers hit by Concrete Wire | 6.246 | M |
| 8 | Iron transfer process | The worker's hand caught in the iron | 5.88 | M |
| 9 | Ceramic installation process | Workers were injured as a result of being hit by a ceramic cutting machine | 5.6 | M |
| 10 | Iron cutting process | Workers' hands were hit by a bar cutter/bar bender | 5.08 | M |
| 11 | Demolition of formwork for beams, columns, and floor slabs | Workers fall from a height while dismantling formwork | 5.08 | M |
| 12 | Ceramic installation process | Workers exposed to material from ceramic chips | 5.06 | M |
| 13 | Wall and plaster installation process | Workers fall from a height | 4.8 | M |
| 14 | Casting Process | Worker slips while holding or moving concrete bucket | 4.54 | M |
| 15 | Iron cutting process | Worker's eyes caught by sparks | 4.483 | M |
| 16 | Iron cutting process | Worker's hand caught by sparks | 4 | M |
| 17 | Iron transfer process | The iron's foot hit the worker | 4 | M |
| 18 | Ironing process | Workers fall from a height | 4 | M |
| 19 | Demolition of formwork for beams, columns, and floor slabs | Worker falls from a height while installing formwork | 4 | M |
| 20 | Demolition of formwork for beams, columns, and floor slabs | The worker's hand is punctured and exposed to material (nails/wood) | 4 | M |
| 21 | Painting Process | Workers inhaled paint fumes | 3.8 | L |
| 22 | Wall and plaster installation process | Respiratory problems due to dust from sand/cement | 3.74 | L |
| 23 | Casting Process | Workers fall from a height | 3.6 | L |
| 24 | Iron cutting process | Iron pierced worker's hand | 3.6 | L |
| 25 | Iron transfer process | Iron pierced worker's hand | 3.46 | L |
| 26 | Ironing process | Iron pierced worker's hand | 3.46 | L |

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| | | | | |
|---|---|---|---|---|
| 27 | Demolition of formwork for beams, columns, and floor slabs | Worker crushed by formwork | 3 | L |
| 28 | Casting Process | The collapse of the concrete mold | 3 | L |
| 29 | Demolition of formwork for beams, columns, and floor slabs | Worker crushed by formwork | 3 | L |
| 30 | Iron cutting process | Workers are exposed to noise when cutting metal using a bar cutter | 2.982 | L |
| 31 | Installation of formwork beams, columns, and floor slabs | The worker's hand is punctured and exposed to material (nails/wood) | 2.73 | L |
| 32 | Casting process | Worker hit by a concrete bucket | 2.54 | L |
| 33 | Wall and plaster installation process | The worker's eyes are exposed to the material | 2.4 | L |
| 34 | Casting process | Workers' eyes are exposed to concrete mortar when pouring ready mix concrete into the mold | 1.6 | L |
| 35 | Installation of formwork beams, columns, and floor slabs | Worker's hand hit by a hammer | 1.6 | L |
| 36 | Installation of formwork beams, columns, and floor slabs | The worker's leg fell and was hit by a tool | 1.53 | L |
| 37 | Painting process | The worker's eyes are splashed with paint | 1.47 | L |

## 3.2. Discussion

From the data that has been presented, there are 37 risk variables identified in several existing jobs. From the results of the data, the risk matrix was processed and classified based on the AS/NZS 4360 standard which obtained 20 variables with a moderate risk level (Medium), such as: exposure to noise when using a grinding machine when cutting ceramics (ceramic installation process), workers' hands being scratched by iron. (iron cutting process), workers fall from a height (painting process), respiratory problems due to dust when cutting ceramics (ceramic installation process), workers' hands are pierced by iron (iron removal process), workers' hands are pierced by iron (iron process), workers are exposed to bendrat wire (iron process), workers' hands are pinched by iron (iron removal process), workers are injured due to being hit by a ceramic cutting machine (ceramic installation process), workers' hands are hit by a bar cutter/bar bender (iron cutting process), workers fall from a height while doing demolition of formwork (removal of formwork for beams, columns and floor plates), workers are exposed to from ceramic chips (ceramic installation process), workers fall from a height (wall and plaster installation process), workers slip when holding or moving concrete buckets (casting process), workers' eyes are exposed to sparks (iron cutting process), workers' hands are exposed to sparks (the process of cutting iron), the worker's feet are hit by iron (the process of moving iron), the worker falls from a height (the process of ironing), the worker falls from a height when installing the formwork (installation of formwork for beams, columns and floor plates), the worker's hand is punctured and exposed to material ( nails/wood) (removal of formwork beams, columns and floor slabs). And 17 variables with a low risk level (Low) such as: workers are inhaled by paint vapor (painting process), respiratory problems due to dust from sand/cement (wall and plaster installation process), workers fall from a height (casting process), workers' hands are pierced by iron. (iron cutting process), workers' hands are scratched by iron (iron removal process), workers' hands are scratched by iron (iron process), workers are crushed by formwork (removal of formwork for beams, columns and floor plates), concrete mold collapses (casting process), workers are crushed by formwork (installation of formwork for beams, columns and floor plates), workers are hit by a concrete bucket (casting process), workers are exposed to noise when cutting iron using a bar cutter machine (iron cutting process), workers' hands are punctured and exposed to material (nails/wood) (installation formwork of beams, columns and floor slabs),

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workers' eyes are exposed to material (wall and plaster installation process), workers' eyes are exposed to concrete mixture when pouring the ready mix concrete mixes into the mold (casting process), the hands of workers are hit by hammers (installation of formwork beams, columns and floor plates), the worker's feet fall and are hit by tools (removal of formwork beams, columns and floor plates), the eyes of workers are exposed to paint splashes ( painting process) on several activities. The highest value is 7.86 which is included in the medium level of the existing risk variables: noise exposure when using a grinding machine when cutting ceramics (ceramic installation process), while the lowest value is 1.47 which is included in the low level: workers' eyes are exposed to paint splashes (painting process).

# 4. Conclusion

## 4.1. Conclusion

1. By conducting a preliminary survey of literature study experts, and direct observations in the field on the Sidoarjo KPP State House Rehabilitation project. Then arrange the potential risk variables based on each job so that 37 potential risk variables are generated.
2. From the results of the risk level assessment based on the AS/NZS 4360 standard, 20 variables are categorized as a medium level which means they have a moderate risk value, and 17 variables are categorized as a low level which means they have a low-risk value. The highest value is 7.86 which is included in the medium level on the existing risk variables: noise exposure when using a grinding machine when cutting ceramics (ceramic installation process), while the lowest value is 1.47 which is included in the low level: workers' eyes are exposed to paint splashes (painting process).

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IJTI (International Journal Of Transportation And Infrastructure)
Available Online @ http://jurnal.narotama.ac.id/index.php/ijti
ISSN : 2597-4769 (ONLINE) ISSN : 2597-4734 (CETAK)
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# Identifying Accident Severity Factor on Surabaya Secondary Arterial Roads

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## Abstract

One of the CBD (Central Business District) areas of Surabaya is located at the center of the city, which is also known as the CBD Tunjungan area. CBD Tunjungan area is a hub for trade and services and has important accessibility which is surrounded by secondary arterial roads. Some secondary arterial roads which have access and high mobility to the CBD Tunjungan Area are Darmo Raya Road, Urip Sumoharjo Road and Basuki Rahmat Road. The high activity and mobility in the CBD area cause several transportation problems, one example is traffic accidents. The traffic accident data by the Directorate of Traffic and City Resort Police of Surabaya show that there are quite a several traffic accidents on these two roads. Traffic accidents are divided into three levels of severity i.e. slight, serious, and fatal injuries. To obtain the probability model of traffic accidents within every accident severity, it is necessary to do an analysis using the multinomial logistic regression method. The independent variables such as vehicle speed, lane width, accident time, and accident type, are considered to affect the equation model. Thus, it can be discovered the variables that affect the probability at the three levels of traffic accident severity.

**Keywords:**
Accident Severity, Multinomial Logistic, Surabaya, Traffic accident

## 1. Introduction

Surabaya is one of the metropolitan cities in Indonesia with fairly advanced development and has many CBD (Central Business District) areas spread throughout the city (Safitri, Budisusanto, Deviantari, & Dediyono, 2016; Walikota Surabaya, 2014). One of the CBD centers located in the middle of Surabaya is the Tunjungan CBD area, and this area is the center of trade and services in Surabaya (I, Kurniawan, & Usman, 2010; Sistyaningsih & Kisnarini, 2017; Walikota Surabaya, 2014). Tunjungan CBD area has very crucial accessibility and is surrounded by secondary arterial roads such as Darmo Raya Road, Urip Sumoharjo Road, and Basuki Rahmat Road (Sistyaningsih & Kisnarini, 2017; Sulistiono, Mawardi, & Arifin, 2016; Syafi'i, Pambagus, & Kartika, 2020). The three roads become access to connect the CBD area with the southern part of Surabaya. The high activity and mobility in the CBD area cause several problems, one of which is a traffic accident (Bagloee & Asadi, 2016; Hermawan, 2016). Traffic accidents should be considered specifically as a safety aspect to facilitate a transportation system (H. Widyastuti & Budhi, 2020). In addition, road safety is also included in one aspect of environmentally friendly transportation (Machsus, Prayogo, Chomaedhi, Hayati, & Utanaka, 2017). Based on data obtained from the Directorate of Traffic and City Resort Police of Surabaya, on Darmo Raya Road, Urip Sumoharjo Road, and Basuki Rahmat Road, there is a reasonably high volume of traffic accidents. This is certainly drawing attention as traffic accidents are one of the highest causes of death in the world (Mathers & Loncar, 2006; Murray & Lopez, 2013; World Health Organization, 2016, 2019). In general, traffic accident severity is divided into three types, i.e. fatal injury, serious injury, and slight injury (Pemerintah Republik Indonesia, 1993).

In analyzing the severity of traffic accidents, various methods have been applied (Savolainen, Mannering, Lord, & Quddus, 2011). One method that can be used is the statistical method by considering the variables and data which will be used (Savolainen et al., 2011). Several statistical methods that can be used are binary logit and multinomial logit, wherein these two methods there are many derivative models (Mannering & Bhat, 2014; Savolainen et al., 2011). Binary logit and multinomial logit methods can be used in statistical analysis related to traffic accident severity analysis (Mannering & Bhat, 2014).

Some previous studies have been conducted by using logistic regression models related to accident severity factors and prediction of accident severity (Ratanavaraha & Suangka, 2014; Shankar, Mannering, & Barfield, 1996). Halim et al. (2018) used a logistic multinomial regression approach to obtain a model of the correlation between the severity of accidents with the independent variables such as gender, day of the accident, age, time of the accident, position of the victim, type of accident, type of vehicle, education, as well as type of collision and location of the accident (Halim, Ramli, Adisasmita, Aly, & Prasetijo, 2018). Ratanavaraha and Suangka (2014) used speed, Annual Average Daily Traffic (AADT), number of lanes, time of the accident,

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weather conditions, accident location, and cause of the accident as independent variables to obtain a multinomial logistic regression equation model of the severity of accident (Ratanavaraha & Suangka, 2014). Meanwhile, Crocco et al. (2010) conducted a logistic regression model analysis using different variable variations such as weather conditions, road surface conditions, pavement maintenance, geometric characteristics, and types of accidents (Crocco, De Marco, & Mongelli, 2010). Several aspects can affect the probability of a traffic accident in Surabaya, i.e. income, age, and the number of children. (Utanaka & Widyastuti, 2019; Hera Widyastuti, Dissanayake, & Bell, 2011; Hera Widyastuti & Utanaka, 2020).

Therefore, in this study, the multinomial logistic regression method is used to obtain an equation model and the probability of a traffic accident for each level of severity. The equation model is formed based on the significant variables. The variables that are considered affecting the equation model are accident time, type of the accident, vehicle speed, and lane width which are categorized as independent variables. These variables were selected based on previous studies and by the availability of data. Thus, this study is expected to figure out the significant variables that affect the probability at each of the three-level of traffic accidents severity.

## 2. Material and method

### 2.1. Traffic Accident

A traffic accident is an event that occurs on a road that is accessible to public traffic resulting in one or more people being injured or killed, which involves at least one moving vehicle (Dahiya, 2016; Masuri, Isa, & Tahir, 2017). In addition, the classification of traffic accident victims in Indonesia is divided into 3, and those are (Pemerintah Republik Indonesia, 1993):

1. Fatal injury is a victim who is confirmed dead as a result of a traffic accident within a period of no longer than 30 (thirty) days after the accident.
2. Serious injury is a victim who due to their injuries suffered from permanent disability or must be treated for more than 30 (thirty) days since the accident occurred.
3. Slight injury is a victim who due to their injuries suffered from no permanent disability and should not be treated in less than 30 (thirty) days since the accident occurred.

### 2.2. Study location

This study was conducted in Surabaya, specifically on 3 secondary arterial roads located around one of the CBD in Surabaya. These roads include Darmo Raya Road, Urip Sumoharjo Road and Basuki Rahmat Road. These three locations are quite crowded and have different infrastructure characteristics. Details of each of these roads can be seen in Table 1 (Vyolita & Mahardi, 2020; Wijaya, 2015). The table contains road descriptions in the form of road status, road type, road length, and average lane width. The detailed image of The Darmo Road, Urip Sumoharjo Road, and Basuki Rahmat Road can be seen in Figures 1.

Table 8. Condition of Raya Darmo Road, Urip Sumoharjo Road, and Basuki Rahmat Road (Vyolita & Mahardi, 2020; Wijaya, 2015)

| Parameter | Raya Darmo Road | Urip Sumoharjo Road | Basuki Rahmat Road |
|---|---|---|---|
| Road Status | Urban road | Urban road | Urban road |
| Road Type | 6/2D (six lanes, two ways divided) | 6/2D (six lanes, two ways divided) | 4/1 (four lanes, one way) |
| Road Length | 2.7 km | 0.5 km | 1.2 km |
| Average Lane Width | 4.4 m | 3 m | 3.95 m |

IJTI (International Journal Of Transportation And Infrastructure)
Available Online @ http://jurnal.narotama.ac.id/index.php/ijti
ISSN : 2597-4769 (ONLINE) ISSN : 2597-4734 (CETAK)
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Figure 8. Road sections of the study location

## 2.3. Data and Tool

The data used in this study were primary data and secondary data. Primary data were obtained from observations of travel time and road length, so that speed can be obtained in each road condition in real-time. The assistive program used to obtain the data is Google Maps. In addition to primary data, this study also used secondary data in the form of accident data from 2015-2017, as well as geometric data of each road obtained from related agencies.

## 2.4. Multicollinierity test

Multicollinearity is a condition where two or more predictor variables in regression models are highly correlated. (Daoud, 2018). Multicollinearity occurs when two or more independent variables in the regression model are correlated (Daoud, 2018). Multicollinearity can cause information overload, which means it causes overlap between the independent variable and the dependent variable (Wonsuk et al., 2013). In the multicollinearity test, values that need to be seen are Tolerance and Variance Inflation Factor (VIF). If the Tolerance value is more than 0.1 and the VIF value is less than 10, it indicates no multicollinearity in the independent variables. (Ghozali, 2005). The multicollinearity test has the objective to find a correlation between independent variables in a regression model (Denziana, Indrayenti, & Fatah, 2014). The correlation between independent variables should not be in the regression model (Denziana et al., 2014).

## 2.5. Heteroscedasticity test

Heteroscedasticity is a condition where the variance in a regression model is not constant (Mokosolang, Prang, & Mananohas, 2015). Therefore, it is necessary to do a heteroscedasticity test to detect the variance dissimilarity in a regression model (Imam, 2011). Where in a regression model there should be no heteroscedasticity (Pamungkas, Junaidi, & Hardono, 2016). One method that can be used in the heteroscedasticity test is the Glejser Method (Widarjono, 2007). The regression model can be considered that there is no heteroscedasticity if the significance value is above 5% or 0.05 (Imam, 2011).

## 2.6. Multinomial logistic regression

The analysis conducted in this study is to look for independent variables that have an effect or correlation to dependent variables by using the multinomial logistic regression method. This method was chosen because the dependent variable consists of several categories (Ratanavaraha & Suangka, 2014). The average value of dependent variables that are affected by independent variables becomes the key quantity in each regression analysis (Al-Ghamdi, 2002). The multinomial logistic regression equation is as follows (Ratanavaraha & Suangka, 2014).

$$T_{ki} = \propto_k + \beta_k X_{ki} \qquad (1)$$

In which:

αk = constant parameters for accident severity category k

βk = vector parameters that can be estimated for accident severity category k

Xki = represents the explanatory variable vector variables that affect the severity of the accident for i in the accident severity category k

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ISSN : 2597-4769 (ONLINE) ISSN : 2597-4734 (CETAK)
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k = represents the three accident severity levels: slight injury, serious injury, fatal injury

Hence, there are three categories of dependent variables, to calculate the probability of each accident severity level can be seen in Equation 2 – Equation 4 (Ari & Aydin, 2015). Where Pi(k) is the probability of an accident for each severity level (Ratanavaraha & Suangka, 2014).

$$P_{i1}(k) = \frac{exp(T_{ki1})}{1+exp(T_{ki1})+exp(T_{ki2})} \quad (2)$$

$$P_{i2}(k) = \frac{exp(T_{ki2})}{1+exp(T_{ki1})+exp(T_{ki2})} \quad (3)$$

$$P_{i3}(k) = \frac{1}{1+exp(T_{ki1})+exp(T_{ki2})} \quad (4)$$

Multinomial logistic regression can estimate the probability of the accident severity that is affected by several factors. The considered factors as independent variables that affect the probability of the accident severity consist of accident time, type of accident, vehicle speed, and road lane width. Therefore, the effect of independent variables on the probability of the traffic accident severity using the multinomial logistic regression method can be identified (Ratanavaraha & Suangka, 2014). Analysis to obtain the multinomial logistic regression model was carried out using SPSS (Statistical Package for the Social Sciences) program because it can be used for various statistical analysis purposes and can process it quickly and accurately (Hasyim & Listiawan, 2015; Zein et al., 2019).

In this study before conducting the multinomial logistic analysis, the independent and dependent variables were categorized. The independent variable categorization is carried out on the accident time variable and the type of accident variable. The accident time variable is divided into 3-time categories, category 1 is 00.00-07.59, category 2 is 08.00-15.59, and category 3 is 16.00-23.59. The types of accidents variable are divided into 5 categories, category 1 is a front collision, category 2 is a rear collision, category 3 is a side collision, category 4 is a vehicle-hit human collision, and category 5 is a single accident. The speed and lane width variables are not categorized because they use the original values.

Table 9. Variables used in the analysis

| Variable | Code | Variable | Code |
|---|---|---|---|
| Severity level | | Accident type | |
| Slight injury | 0 | Front collision | 1 |
| Serious injury | 1 | Rear collision | 2 |
| Fatal injury | 2 | Side collision | 3 |
| Accident time | | Vehicle-hit human collision | 4 |
| 00.00 – 07.59 | 1 | Single accident | 5 |
| 08.00 – 15.59 | 2 | Speed | - |
| 16.00 – 23.59 | 3 | Lane Width | - |

## 3. Result

### 3.1. Multicollinearity and heteroscedasticity test

Before being analyzed by multinomial logistic regression, independent variables were tested statistically to prove the independent variables could be used in multinomial logistic regression analysis. There are 2 types of statistical tests performed, i.e. multicollinearity test and heteroscedasticity test. The results of the multicollinearity test can be seen in Table 3 and the results of the heteroscedasticity test can be seen in Table 4.

Table 10. Multicollinearity test results

| Variable | VIF | Interpretation |
|---|---|---|
| Accident Time | 1.025 | No multicollinearity |
| Accident type | 1.076 | No multicollinearity |
| Speed | 2.509 | No multicollinearity |
| Lane Width | 2.424 | No multicollinearity |

Table 11. Heteroscedasticity test results

| Variable | Sig | Interpretation |
|---|---|---|
| Accident Time | 0.467 | No heteroscedasticity |
| Accident type | 0.229 | No heteroscedasticity |
| Speed | 0.586 | No heteroscedasticity |
| Lane Width | 0.457 | No heteroscedasticity |

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Based on Table 3, shows that the VIF value of the independent variables is above 0.1 and below 10. Thus, this interprets that the independent variables do not experience multicollinearity. Based on Table 4, shows that the significance value of the independent variables is above 0.05 or 5%. Thus, it can be interpreted that there is no heteroscedasticity on the independent variables. With no indication of multicollinearity and heteroscedasticity, the independent variables can be used in multinomial logistic regression analysis.

### 3.2. Multinomial logistic regression

The multinomial logistic regression analysis in this study was carried out using the SPSS program by including related variables. The dependent variables in this analysis are the traffic accident severity (Y), while the independent variables are accident time (X1), the type of accident (X2), vehicle speed (X3), and lane width (X4). The output results of the SPSS analysis can be seen in Table 5.

Table 12. SPSS output results of multinomial logistic regression analysis

| Severity | | B | Sig. |
|---|---|---|---|
| Slight injury | Intercept | 85.122 | .000 |
| | Speed | -1.018 | .000 |
| | Lane width | -14.034 | .000 |
| | [Accident time=1.00] | 12.596 | .991 |
| | [Accident time=2.00] | -1.342 | .277 |
| | [Accident time=3.00] | 0 | . |
| | [Types of accident=1.00] | 14.205 | .993 |
| | [Types of accident=2.00] | -.510 | .689 |
| | [Types of accident=3.00] | .495 | .705 |
| | [Types of accident=4.00] | -2.697 | .066 |
| | [Types of accident=5.00] | 0 | . |
| Serious injury | Intercept | 85.343 | .000 |
| | Speed | -1.023 | .000 |
| | Lane width | -14.309 | . |
| | [Accident time=1.00] | 11.307 | .992 |
| | [Accident time=2.00] | -1.610 | .216 |
| | [Accident time=3.00] | 0 | . |
| | [Types of accident=1.00] | 14.387 | .993 |
| | [Types of accident=2.00] | -1.918 | .266 |
| | [Types of accident=3.00] | .573 | .698 |
| | [Types of accident=4.00] | -1.620 | .317 |
| | [Types of accident=5.00] | 0 | . |

The results of the analysis showed the prediction of accident severity for slight injuries compared to fatal injuries and predictions of accident severity for serious injuries compared to fatal injuries. From the table above, it can be known that there were only two variables that have a significant effect on accidents with the severity of slight injuries and serious injury.

Two variables that are significant to each model of the equation are the variable of speed (X3) and lane width (X4) because it has a sig value of <0.05. While other variables such as time and type of accident that have a sig value of >0.05 indicate no significant effect on the model. Thus, the equation model is as follows:

$$g_1(x) = \ln \frac{p(slight\ injuries)}{p(fatal\ injuries)} = 85.122 - 1.018(X3) - 14.034(X4)$$

$$g_2(x) = \ln \frac{p(slight\ injuries)}{p(fatal\ injuries)} = 85.343 - 1.023(X3) - 14.309(X4)$$

From those two functions, the obtained probability function for each type of traffic accident severity is as follows:

$$\pi_1 = \frac{\exp g_1(x)}{1+\exp g_1(x)+\exp g_2(x)}$$

$$\pi_2 = \frac{\exp g_2(x)}{1+\exp g_1(x)+\exp g_2(x)}$$

$$\pi_3 = \frac{1}{1+\exp g_1(x)+\exp g_2(x)}$$

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Where $\pi_1$ is the probability function for the accident severity of the slight injury category, $\pi_2$ is the probability function for the accident severity of the serious injury category, and $\pi_3$ is the probability function for the fatal injury accident category. If it is assumed that a motorist drives at 40 km/h on a road that has an average width per lane of 3 meters. This speed of 40km/h is the maximum allowed urban speed (Machsus et al., 2017). Then the probability is as follows:

$$g_1(x) = \ln \frac{p(slight\ injuries)}{p(fatal\ injuries)} = 85.122 - 1.018(40) - 14.034(3) = 2.300$$

$$g_2(x) = \ln \frac{p(slight\ injuries)}{p(fatal\ injuries)} = 85.343 - 1.023(40) - 14.309(3) = 1.496$$

$$\pi_1 = \frac{\exp(2.300)}{1+\exp(2.300)+\exp g_2(1.496)} = 0.646 = 64.6\%$$

$$\pi_2 = \frac{\exp g_2(1.496)}{1+\exp(2.300)+\exp g_2(1.496)} = 0.289 = 28.9\%$$

$$\pi_3 = \frac{1}{1+\exp(2.300)+\exp g_2(1.496)} = 0.065 = 6.5\%$$

The calculation result above shows the probability if a motorist drives at a speed of 40 km/h on a road that has a lane width of 3 meters. The probability of a traffic accident for the severity of slight injuries is 64.6%, serious injuries is 28.9%, and fatal injuries is 6.5%.

## 4. Conclusion and Discussion

The results of this study indicate that there are only two significant variables out of the 4 applied independent variables, consisting of accident time, the type of accident, vehicle speed, and lane width. The two variables are vehicle speed and lane width. This can be seen from the significance values on both variables which are less than 0.05. With the model obtained, it can be interpreted that the higher the vehicle speed, the higher the probability of the accident severity. In addition, the wider the lane, the higher the probability of the accident severity.

Therefore, this study implies that it is important to enforce speed limits on urban roads, by providing related warning signs or the need for socialization to the public. Moreover, stakeholders can consider the aspects of road safety when going to widen the road. Furthermore, to get a better result, further research can be carried out on other variables which are supported by the availability of more adequate data. So that, it is expected that better results can be obtained from further research.

## Acknowledgements

We would like to thank the Directorate of Traffic and City Resort Police of Surabaya and all the stakeholders for supporting us in the development of this study.

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# Comparison Analysis of Cost and Time Forming Conventional Method With Semi-System Method for Column Namira Hotel Surabaya

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## Abstract

In the implementation of project activities, careful steps are needed and the determination of the right implementation method to obtain cost and time efficiency. In general, there are 3 types of formwork, namely conventional formwork, semi-system formwork, and system formwork. The difference between the three types can be seen from the material used. This study aims to determine the comparison of formwork in terms of method, cost and time in the construction of the Namira Hotel project located on Jl. Pagesangan Surabaya which consists of 9 floors. The cost of formwork is usually between 35% to 60% or more of the total construction cost. Material requirements are usually referred to as the calculation of the volume of work. The volume of a formwork work depends on the planned area. The duration needed to complete a job is influenced by the worker. So in order to determine the success of a project, the factors that must be considered are in terms of labor productivity and the number of workers. In the construction of Hotel Namira Surabaya, the cost of conventional column formwork was IDR 376,052,918.80 and for semi-column formwork it was IDR 214.624.700,00 where the duration of semi-system formwork was faster than conventional formwork.

**Keywords:**
column formwork, conventional, cost and time, semi-system

## 1. Preliminary

### 1.1. Background

With the rapid development of infrastructure and economic progress, the services required to produce quality, cost and time efficiency are very much needed. One of them is the construction of the Hotel Namira project located on Jl. Pagesangan Surabaya which consists of 9 floors.

According to Kusumawardhani & Noviani, (2018) Formwork is an auxiliary form of molding concrete with the desired size, shape, or position. This means that this formwork work is only carried out temporarily where the formwork construction can be dismantled and reassembled.

In general, there are 3 types of formwork, namely conventional formwork, semi-system formwork, and system formwork. The difference between the three types can be seen from the material used. In general, conventional formwork uses wooden boards and is supported by wooden beams. Semi-system formwork is a formwork method that is made to resemble the shape of the building and for repeated use and the material itself uses steel plates and is supported by wooden beams. In formwork systems, this method is usually used for large-scale construction work and requires high costs.

### 1.2. Problem Formulation

1. How much is the cost of conventional formwork and semi-system formwork in the construction project of Hotel Namira Surabaya?
2. How long does it take to implement the conventional method formwork and the semi-system method for the Hotel Namira Surabaya construction project?
3. What is the cost and time comparison between conventional formwork and semi-system formwork in the Namira Hotel Surabaya construction project?

### 1.3. Scope of Problem

1. The analyzed formwork work is on the 1st floor column to 9th floor.
2. Planning only includes costs and implementation time.
3. The formwork used in the conventional system uses multiplex and wooden scaffolding.
4. The formwork in the semi-system uses hollow beams and tegofilm.
5. Planning does not include the use of heavy equipment methods
6. The strength of the formwork in each method is considered to have met the requirements

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7. The unit prices for labor costs and wages are taken from the Surabaya City Wage Unit Price List

### 1.4. Purpose

With the formulation of the problem, the expected objectives are as follows:

1. Knowing the cost of formwork using conventional methods and semi-system methods in the implementation of the Namira Hotel Surabaya construction project.
2. Knowing the implementation time of formwork using conventional methods and semi-system methods in the implementation of the Namira Hotel Surabaya construction project.
3. Knowing the cost and time comparison of formwork implementation using conventional methods with semi-system methods in the construction project of Hotel Namira Surabaya.

### 1.5. Benefit

The benefits of this final project include:

1. Adding the author's insight regarding the comparison of the cost and time of carrying out formwork work with the conventional method with the semi-system method in the construction of high-rise buildings.
2. As a reference material and reference material in determining the method of implementing formwork work in a construction project.

## 2. Literature Review

### 2.1. General

Formwork is a work item that must exist in concrete work. In the implementation of project activities, careful steps are needed and the determination of the right implementation method to obtain cost and time efficiency. This formwork determines the shape of the concrete structure to be made.

### 2.2. Formwork Type

The quality of the formwork also determines the yield and quality of the concrete form. Broadly speaking, according to Wigbout (1992) formwork is divided into 3 types, namely:

1. Conventional formwork is formwork that has been removed and dismantled into separate parts, can be rearranged into its original shape or other forms.
2. Semi-system formwork is a formwork that is devoted to a particular object or form. In principle, this formwork method can be used repeatedly with an irreversible shape. Usually the sizes are adjusted to the shape of the concrete concerned.

System formwork is a formwork in which the elements are made in the factory and most of the components are made of steel. This formwork can be used repeatedly and besides being able to be purchased directly, it can also be obtained by renting from a formwork equipment provider.

### 2.3. Column Formwork Parts

In general, the formwork parts consist of column shoes, formwork panels, upright reinforcement, flat reinforcement, regulating clamps, supporting beams, holes that clean dirt in the column.

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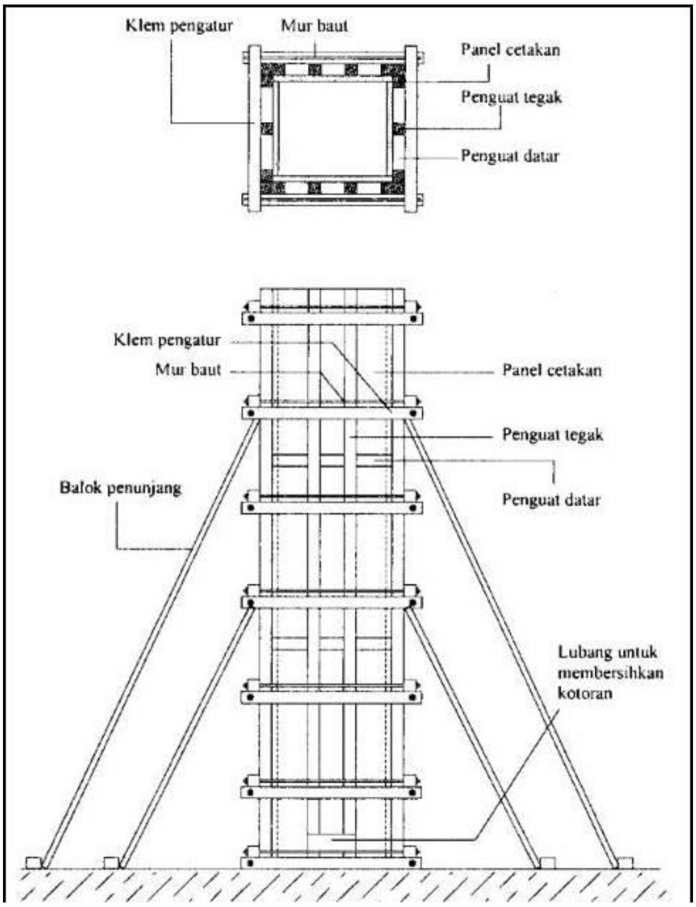


Figure 2.1Column Formwork Parts

(Source :www.siteteknikisipil.com)

### 2.4. Formwork Material

Materials that are generally used in formwork work are:

### 2.5. Wood

The use of wood materials in the construction world is often found in formwork work. The provisions and requirements are regulated in the 1961 Indonesian Timber Construction Regulation (PKKI).

Table 1. Classification of Indonesian Timber

| No | Strong Class | Air Dry Specific Gravity (gr/cm3) | Strong Absolute Bending (kg/cm2) | Absolute Compressive Strength (kg/cm2) |
|---|---|---|---|---|
| 1 | I | >0,9 | >1100 | >650 |
| 2 | II | 0,90 - 0,60 | 1100 – 725 | 650 – 425 |
| 3 | III | 0,60 – 0,40 | 725 – 500 | 425- 300 |
| 4 | IV | 0,40 – 0,30 | 500 – 360 | 300 – 215 |
| 5 | V | <0,3 | <360 | <215 |

Source: Indonesian Timber Construction Regulation (PKKI) 1961

In a good planning calculation, the allowable stress and the modulus of elasticity of the wood material need to be reviewed.

Table 2. Classification of Indonesian Timber

| No | Voltage (kg/cm2) | Wood Grade I | II | III | IV | V |
|---|---|---|---|---|---|---|
| 1 | σ ijin lt | 150 | 100 | 75 | 50 | - |
| 2 | σ ijintk = σ ijintr | 130 | 85 | 60 | 45 | - |
| 3 | σ ijintk | 40 | 25 | 15 | 10 | - |
| 4 | σ ijin | 20 | 12 | 8 | 5 | - |

Source: Indonesian Timber Construction Regulation (PKKI) 1961

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### 2.6. Multiplex

One of the main materials of concrete formwork is multiplex which is plywood. In general, multiplex is divided into 3 types, namely ordinary multiplex, poly resin multiplex, and film face multiplex (tegofilm). In terms of price, ordinary multiplex is much cheaper than tegofilm multiplex.

## 3. Methodology

The research methodology is a series of determining procedures and obtaining data in the process of making the final project. The methodology in writing this final project includes all processes of analysis activities to solve the problems that exist in the final project.

### 3.1. Identification of Problems

The identification stage is one of the initial series before data collection and processing. This stage includes:

1. Determining the Title of the Final Project
2. Making a Final Project proposal
3. Literature study to determine the outline of the Final Project report
4. Determine data requirements
5. Activity schedule planning
6. Job analysis

### 3.2. Research variable

Research variables are useful for collecting data and for analyzing data. In this study there are 2 variables that will be reviewed, namely the cost variable and the time variable

Table 3. Research Variables Cost

| Indicator | Data source | Data collection technique |
|---|---|---|
| Cost<br>Wages | Shop drawing<br>Volume | Secondary Data |

Table 4. Cost Research Variables

| Indicator | Data source | Data collection technique |
|---|---|---|
| Productivity<br>Duration | Schedule<br>Calculation of duration<br>Execution method | Secondary Data |

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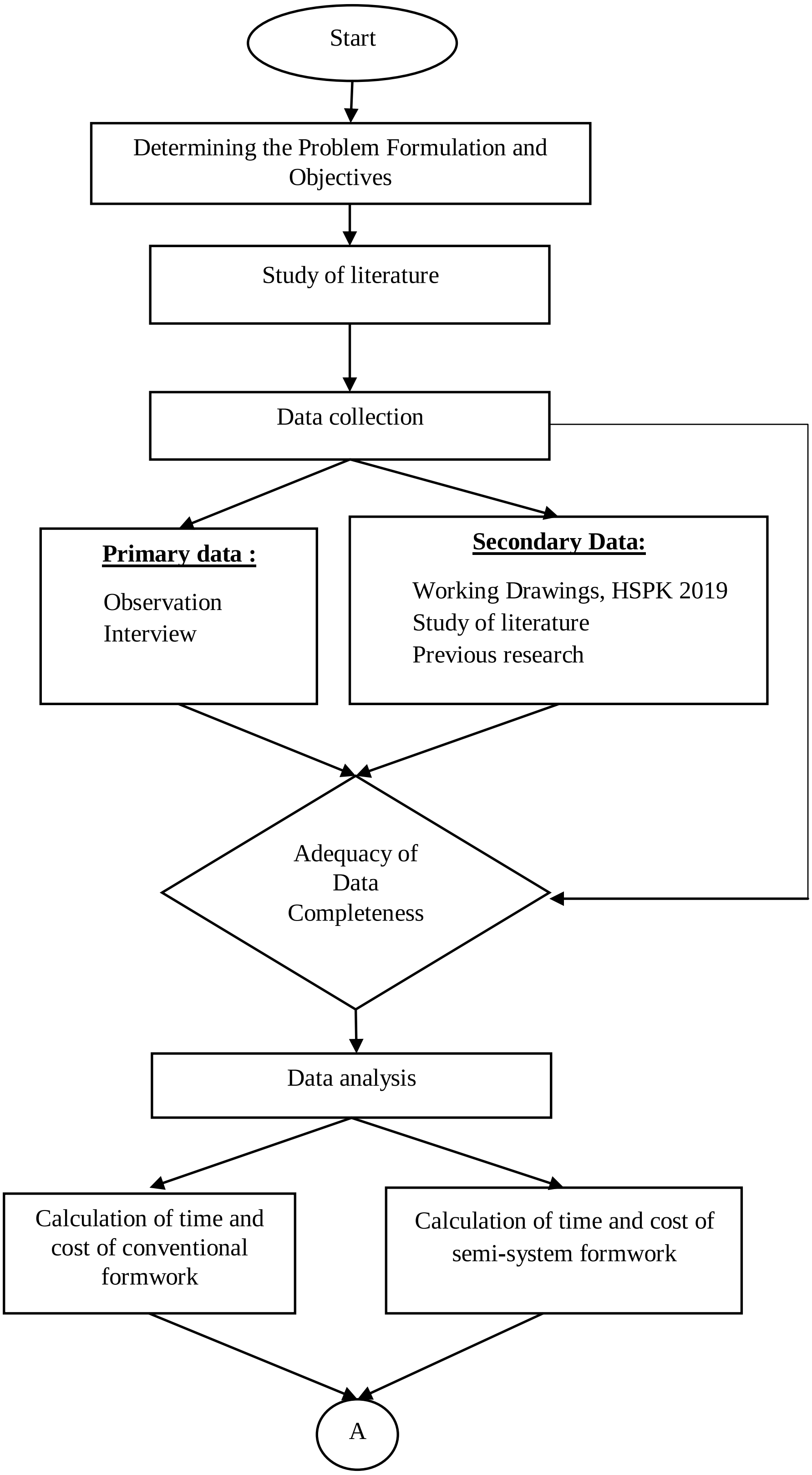

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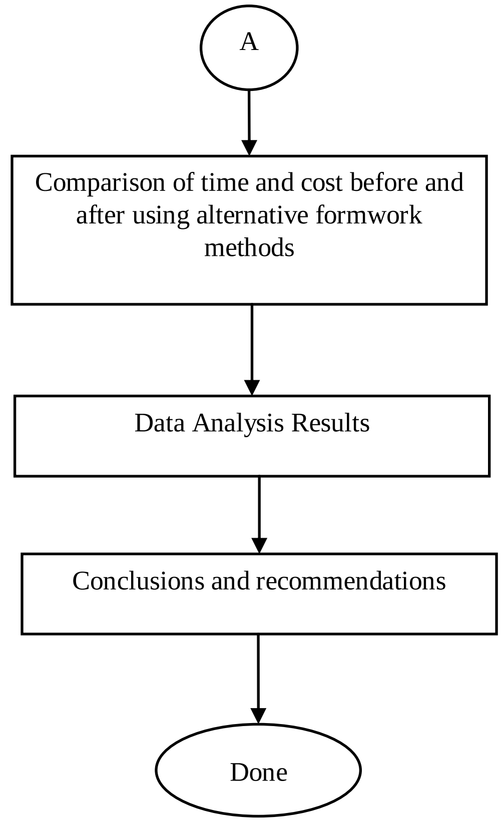


Chart 1 Research Methodology Flowchart

### 3.3. Data Collection

To get optimal results, data which includes primary and secondary data are needed. The method used in data collection using the method of observation and interview with informants to obtain data which will be reviewed later in the calculation.

## 4. Results and Discussion

### 4.1. Data

The column data needed in the calculation of the Namira Hotel column formwork are as follows:

Table 5 Recapitulation of Column Dimensions

| Column Details | Number of Columns | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lt. Base | K1 | K2 | K3 | K4 | K5 | K6 | K7 | K8 | K9 | |
| K1 (70/70) | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 4 | 112 |
| K1a (70/70) | | | | | | | | | | 8 | 8 |
| K2 (50/50) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 |
| K3 (40/60) | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 40 |

### 4.2. Calculation of Productivity and Duration of Forms

In column formwork starting from the ground floor, 1 group with 1 foreman, 3 carpenters and 7 workers for fabrication work and 3 carpenters and 5 workers for installation work. In a working day for 7 hours.

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Table 6 Needs of Working Hours in Implementation

| Coefficient | | Labor | Max quantity | Number of Wear (person) | | | Working Hours (hours/day) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Total | Manufacturing | Install | Manufacturing | Install | Demolish |
| 0.660 | Oh | Worker | 20 | 12 | 7 | 5 | 49 | 40 | 49 |
| 0.330 | Oh | Carpenter | 10 | 6 | 3 | 3 | 21 | 21 | 24 |
| 0.033 | Oh | Foreman | 1 | 1 | 1 | | 7 | | |
| | | Total | | 19 | 11 | 8 | 77 | 61 | 73 |

The productivity of each job in one day is:

$$- set = \frac{number\ of\ hours\ worket\ bu\ workers}{working\ hours\ 10m^2} x10m^2$$
$$= \frac{77\ hours}{6\ hours} x10m^2$$
$$= 128.33m^2/day$$
$$- Install = \frac{number\ of\ hours\ worked\ by\ workers}{working\ hours\ 10\ m^2} x10m^2$$
$$= \frac{61\ hours}{3\ hours} x10m^2$$
$$= 203.33\ m^2/day$$
$$- Disassemble = \frac{number\ of\ hours\ worked\ by\ workers}{working\ hours\ every\ 10m^2}$$
$$= \frac{73\ hours}{3{,}5\ hours} x10m^2$$
$$= 243.33m^2/day$$

For conventional formwork, the 6th floor column uses 20% of the 4th floor, the 7th floor column uses 40% of the 3rd floor formwork and the 8th floor column uses 40% of the 4th floor formwork. The calculation results will be tabled with the same calculation. So that the repairs are carried out with productivity:

$$Repair = \frac{number\ of\ hours\ worked\ by\ wokers}{working\ hours\ every\ 10m^2} x10m^2$$
$$= \frac{77\ hours}{3.5\ hours} x10m^2$$
$$= 220m^2/day$$

## 4.3. Calculation of Form Costs

Cost of wages for manufacturing workers in one day

| | | | |
|---|---|---|---|
| a. | Foreman | @ IDR 158,000.00 x 1 person | = IDR 158,000.00 |
| b. | Carpenter | @ IDR 121,000.00 x 3 people | = IDR 363,000.00 |
| c. | Worker | @ IDR 110,000.00 x 7 people | = IDR 770.000,00 |

Material analysis for 1m2 conventional column formwork

| | | | |
|---|---|---|---|
| Wood | | = 0,059 x IDR 3,3500,000.00 | = IDR 197,673.60 |
| a. | nail | = 0.387 x IDR 19.000,00 | = IDR 7,343.50 |
| b. | Oil | = 0.288 x IDR 29,600,000 | = Rp. 8,510.00 |
| c. | Plywood 9 mm | = 0.018 x Rp 121.4000.00 | = 2221.62 |

Material price for semi-column system formwork

Table 7 Semi-system Column Formwork Material Prices

| Material name | Unit | Unit price |
|---|---|---|
| Tego film 15 mm | Sheet | 328,000 |
| Hollow 50x50x1.6 | stem | 238,500 |
| Screw | Fruit | 950 |
| Tie Rod | Fruit | 5,000 |
| Wing Nut | Fruit | 3000 |
| Push Pull Prop | Fruit | 100,000 |
| Kicker Brace | Fruit | 75,000 |

In semi system formwork, support materials and other components are planned to be rented, so the cost of formwork material is the rental fee per month.

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### 4.4. Comparison of the Duration of Conventional Formwork and Semi-System Formwork

In each formwork method using the same productivity, number of groups, and number of workers. With the same volume of work, the duration of the work is as follows:

Table 8 Duration Calculation Results

| Work Sub-Item | Conventional Formwork | Semi-System Formwork |
|---|---|---|
| Set | 20 | 10 |
| Install | 10 | 10 |
| Open | 10 | 10 |
| repair | 3 | 0 |

### 4.5. Cost Comparison of Conventional Formwork and Semi-System Formwork

Table 9 Cost Calculation Results

| | |
|---|---|
| Conventional Formwork | Rp 376.052.918,80 |
| Semi-system Formwork | Rp 214.624.700,00 |

In conventional formwork, the material is used 3 times and for semi-system formwork, the material can be reused 5 times. In conventional formwork there are repair costs and additional materials, while in semi-system formwork for floors 3-8 only one fabrication is carried out. Based on the analysis from Table 9, the difference between the cost of conventional formwork and semi-system formwork is IDR 376,052,918.80 - IDR 214.624.700,00 =IDR 161.428.218,80

## 5. Conclusion

1. Calculation of the cost of conventional formwork of IDR 376,052,918.80 and on semi-system formwork of IDR 214,624,700.00
2. In the calculation of the duration of the work, the duration of fabrication on conventional formwork for 30 days and for semi-system formwork for 20 days is faster.
3. Conventional formwork is more expensive at IDR161,428,218.80 than semi-system formwork. And the duration of conventional formwork is 10 days longer than that of semi-system formwork. In terms of time and cost, the most optimal formwork method is the semi-system formwork method.

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