Study of soil structure interaction on basement wall with variants in distance and depth of the basement on soil class SE

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Abstract. The function of the basement is to carry the weight of the upper structure into the soil and to resist lateral loads around the basement wall. One aspect of geotechnical engineering that often a problem in basement wall planning is the determination of lateral ground pressure in the basement wall due to earthquake which must be held by the basement wall. In this study, an analysis of the effects of local soil conditions due to dynamic loads is done through analysis of soil-structure interaction. The analysis is done by modeling the local soil with variations in basement depth and the adjacent basement distance to get the lateral pressure distribution due to dynamic load. The analyzed soil conditions are considered homogeneous at land sites SE (soft soil) with the dynamic load input from earthquake loads uses a 10% probability of exceedance in 50 years (500 years). The most influential parameter for soil displacement is the distance of the basement and then the depth of the basement. The most influential parameter on lateral forces is the depth of the basement followed by the distance of the basement.

1. Introduction

High-level building structures in general can be divided into two main parts, namely the structure of the building which is above the ground surface and the structure of the building that is below the surface of the land. The structure of the building below the ground surface can be in the form of a basement called a basement. The function of the basement is to carry the weight of the upper structure into the soil and to resist lateral loads around the basement wall. One aspect of geotechnical engineering that often a problem in basement wall planning is the determination of lateral ground pressure in the basement wall due to earthquake which must be held by the basement wall. Indonesia has relatively high potential to stroke by great earthquake, because in the western and southern of this country lay the subduction earthquake zones that known as the zone that can produce the greatest earthquake [1,5,7]. The earthquake can give a high seismic hazard in the vicinity of the zones. Therefore, it is necessary to analyze the interaction of the soil with the basement structure walls on the dynamic response [4,8,9,11-15].
In this study, an analysis of the effects of local soil conditions due to dynamic loads is done through analysis of soil-structure interaction. The analysis is done by modeling the local soil with variations in basement depth and the adjacent basement distance to get the lateral pressure distribution due to dynamic load. The calculation of the effect of soil-structure interaction on surface response amplification factors is done by numerical analysis of finite element methods through the MIDAS GTS NX program.

2. Literature of evaluation seismic earth pressure on basement walls

The method for analyzing dynamic soil lateral pressure on retaining walls was originally developed by linking lateral deformation walls large enough to mobilize the shear strength of the soil so that the soil occurs active and passive soil pressure. The walls that embedded rigidly in the ground (basement, this assumption cannot be applied because in the basement there is not enough deformation to mobilize the shear strength of the soil.

The M-O method assumes that the Coulomb theory of static earth pressures on a retaining wall can be modeled to include the inertial forces due to ground motion (in the form of horizontal and vertical acceleration) in the retained earth as shown in Figure 1.

![Figure 1. The forces acting on the Mononobe-Okabe method [2],[3]](image_url)

The active pressure during the earthquake, $P_{AE}$, is computed by the Coulomb theory except that the additional forces, W.kh and W.kv, are included. For the critical sliding surface, the active pressure is expressed in the following equation:

$$P_{AE} = \frac{1}{2} \gamma H^2 (1 - k_v) K_{AE}$$

(1)

$$K_{AE} = \frac{\cos^2(\phi - \theta - \beta)}{\cos \theta \cos^2 \beta \cos(\delta + \beta + \theta) \left[ 1 + \frac{\sin(\phi + \delta) \sin(\phi - \theta - \delta)}{\cos \delta + \beta + \theta} \right]}$$

$$\theta = \tan^{-1} \left( \frac{k_h}{1 - k_v} \right)$$
Building construction based on its location to the ground surface can be divided into 2 (two) parts, namely the upper structure (upper structure) and the lower structure (substructure). The different analysis methods for the two parts of the structure are caused by differences in environmental conditions around the two parts of the building construction. For the upper structure, the state of the land does not directly influence the process of analysis and design [6].

Soil-structure interaction is the process by which the response of the soil affects movement and the response of the structure affects the movement of the soil. This interaction arises if the structure is located on soft soil because the resulting response is different if the structure is located on hard rock. Soil-structure interaction can be analyzed by 2 (two) methods, namely the direct method and the stepwise method [10].

The stepwise method is based on the principle of superposition so this method is used limited to the analysis of linear systems (linear equivalent). The stepwise method is a combination of kinematic interactions and inertial interactions. The solution to the problem of soil-structure interaction by summing up the kinematic and inertial interaction analysis, i.e.:

\[
[M] \{\ddot{u}\} + [K^*] \{u\} = - [M] \{\ddot{u}_p (t)\}
\]  

(2)

3. Description of the building model, material and method

To find out local soil conditions, 407 SPT test results in Jakarta processed until the land site class is known. Soil conditions based on site class can be determined by using the wave propagation velocity parameters, the average standard penetration resistance \(\overline{N}\) results of SPT or shear strength \(\overline{s_u}\). In this study, to determine local soil conditions, 407 SPT test results in Jakarta were then processed to obtain the land site class. The average standard penetration resistance value \(\overline{N}\) is determined using the following formula (1).

\[
\overline{N} = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{N_i}}
\]  

(3)

where \(d_i\) = soil layer thickness reviewed  
\(N = \) standard penetration resistance 60% measured directly in the field without correction  
\(N_i\) and \(d_i\) applies to non-cohesive, cohesive and rocky soils

From formula (3) and SNI 1726:2012, it is obtained that some of Jakarta’s land including land sites SE (soft soil) with soil properties according to Table 1.

The analyzed soil conditions are considered homogeneous with variations in basement distance and basement depth. The motion input used is synthetic motion input for the Jakarta area. The dynamic load input from earthquake loads uses a 10% probability of exceedence in 50 years (500 years) of SNI
1726: 2012. Modeling variations processed with the MIDAS GTS NX program according to the following Table 2.

**Table 1.** Soil properties used in modeling

| Soil Properties                  | Value           |
|----------------------------------|-----------------|
| Modulus elasticity (E)           | 1000 tonf/m$^2$ |
| Poisson ratio ($\mu$)             | 0.3             |
| Shear modulus (G)                | 384.6 tonf/m$^2$|
| Unit weight ($\gamma$)           | 0.8 tonf/m$^3$  |
| Unit weight saturated ($\gamma_{sat}$) | 1.1 tonf/m$^3$ |
| Cohesion (c)                     | 15 tonf/m$^2$   |
| Friction angle ($\phi$)          | 2º              |
| Damping ratio                    | 0.05            |
| Model type                       | Mohr Coloumb    |

**Table 2.** Modeling variations

| Information                  | Variation Value |
|------------------------------|-----------------|
| earthquake period            | 500 years       |
| Distance to bedrock          | 50m             |
| Distance between basemen     | 10m, 15m, 20m, 25m |
| Basement depth               | 13m, 7m         |
| Depth of basement embedded   | 18m, 10m        |

4. Results and analysis

4.1 Soil Displacement (Dx)
Modeling results on soft soil sites (SE) land distance to bedrock 50m with the variation of distance between basemen (10m, 15m, 20m, 25m), earthquake period 500 years of soil displacement (Dx) presented on Figure 2-3. From the two pictures can be drawn as follows:

- modeling with the same parameters is the site of hard soil (SE), depth of bedrock (50m) and various parameters are the distance of the basement, the depth of the basement gives the results of a pattern of displacement changes that are almost the same.
- surface displacement value ≠ 0, its value increases until the largest displacement value is at 20m depth and shrinks to zero at bedrock depth
- the greatest displacement value is generated by modeling SE 13m JB10m BD50m PG500y which is 0.02998m
- modeling with the same parameters is soft soil site (SE), bedrock depth (50m) and various parameters are basement distance, basement depth gives the result that the most influential parameter is basement distance followed by basement depth

4.2 Lateral Force (Px)
Modeling results on soft soil sites (SE) land distance to bedrock 50m with the variation of distance between basemen (10m, 15m, 20m, 25m), earthquake period 500 years of lateral pressure (Px) presented on Figure 4-5. From the two pictures can be drawn as follows:

- Modeling with the same parameters are soft soil site (SE), bedrock depth (50m), earthquake period (500 years) and varying parameters are basement distance, basement depth and provide almost the same lateral force distribution pattern
- Maximum Lateral force is at a depth of 12m = (2/3 * embedded $H_{basement}$) and the largest lateral force value is produced by modeling SE 13m JB10m BD50m PG500y which is 4.03 tonf
Figure 2. Soil Displacement Value Variation Basement Distance, Basement Depth 13m, Soil SE, Rock Depth 50 years, Earthquake Period 500 years

Figure 3. Soil Displacement Value Variation Basement Distance, Basement Depth 7m, Soil SE, Rock Depth 50 years, Earthquake Period 500 years

- Basement depth variation gives a significant difference in lateral force compared to basement distance as long as it has the same type of soil (in this case SE)
• Modeling with the same parameters is soft soil site (SE), bedrock depth (50m) and varying parameters are the basement distance and basement depth giving the result that the most influential parameter is the basement depth followed by the basement distance.

![Gaya Lateral (tonf)](image.png)

**Figure 4.** Lateral Force Value Variation Basement Distance, Basement Depth 13m, Soil SE, Rock Depth 50 years, Earthquake Period 500 years

5. **Conclusion and recommendation**

5.1 **Conclusion**
Modeling with the same parameters is soft soil site (SE), bedrock depth (50m), earthquake period (500 years) and variable parameters are basement distance, basement depth gives almost the same displacement pattern. Surface displacement value ≠ 0, its value increases until the largest displacement value is at a depth of 20m and decreases to zero at bedrock depth. The greatest displacement value is produced by modeling SE 13m JB10m BD50m PG500y which is 0.02998m. The most influential parameter for soil displacement is the distance of the basement and then the depth of the basement.

Modeling with the same parameters is soft soil site (SE), bedrock depth (50m), earthquake period (500 years) and various parameters are basement distance, basement depth gives the result of almost the same lateral force distribution pattern. Maximum Lateral Force is at a depth of 12m = (2/3 * H embedded basement) and the largest lateral force value is generated by modeling the SE 13m JB10m BD50m PG500y which is 4.03 tonf. The most influential parameter on lateral forces is the depth of the basement followed by the distance of the basement.

5.2 **Recommendation**
To better represent the condition of native soil, variations should be made for hard soil site (SC) conditions and 2500-year earthquake periods. Because with more diverse variations will be obtained a picture of lateral force distribution that is more representative of the original soil conditions. Likewise, soil values reflect the condition of the original soil.
Figure 5. Lateral Force Value Variation Basement Distance, Basement Depth 13m, Soil SE, Rock Depth 50 years, Earthquake Period 500 years

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