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QUICK RESPONSE USING FORENSIC ENGINEERING ON STRUCTURAL BUILDING DAMAGE

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ABSTRACT

Quick response and emergency when buildings are damaged by earthquakes and other situations to determine the causes and ensure that the structure of the building can still be used safely. The additional building of one the heritage buildings in Jakarta currently being used as an office was observed to have suffered damages in the form of torsion of the beams, cracks in beams and walls, as well as the subsidence in floors. Therefore, this research was conducted to investigate these sudden and quick damages using forensic engineering through visual observations, Ultrasonic Pulse Velocity testing, Profometer, Cone Penetration Test, Ground Penetrating Radar, and structural analysis. The visual observation results showed the existence of cracks in the beams, walls, and columns as well as a maximum deformation of 94 mm, especially in the dilation area or the border between the main building and the additional building around the lobby and the floors above it. Moreover, the improper structural system caused the damage as observed with one column having an ultimate axial load of 114 tons while the surrounding columns were only 25-50% of this value. The quick response provided was observed to be the addition of steel columns, beam strengthening with FRP, and zoning of usable space in buildings. The quick response also showed the main damage was caused by the dewatering work of the office construction project near the building and this can be used by the building owner as the basis to submit a claim to the responsible party.

Keywords: *Quick Response, Forensic Engineering, UPV, Georadar, FRP*

INTRODUCTION

The Heritage Building in Jakarta which is the focus of this study is an office complex consisting of three –story building and one basement in the main and annex buildings. Some parts of the structure were observed to have suddenly and quickly collapse causing floor subsidence and damages to the columns, beams, and walls even though there was no earthquake at the time. This damage was also apparently experienced by 8 other buildings in the surrounding, thereby, leading to a disturbance in the building operation as well as anxiety and inconvenience for the users. Therefore, the owners requested a quick investigation to know the anticipatory steps and initial repairs to be implemented. This is expected to be in the form of field investigations and preliminary analysis to generally explain the existing structural conditions and specifically to provide evaluation and recommendations on the conditions and actions required in areas with structural and non-structural damages. However, several obstacles were observed in this process including the non-existence of the building architectural drawing, minimal data on the building, and the need for the structure to be operational during the investigation.

Quick response through forensic engineering is, therefore, needed to overcome and resolve the existing problems. Several researchers have, however, proven that non-destructive tests such as Ultrasonic Pulse Velocity (UPV) and profometer produce good validity, especially for existing structures (Rucka M., Wilde K (2015) and Breysse, D. and Balayssac, J.P (2018)). Moreover, Ground Penetration Radar (GPR) has also been reported to be a technology used in testing several facilities through the use of different applications due to its underground utilities and structural systems as well as high-reliability level. (Zhongming Xiang, et al (2019) and D.G Goulie, et al(2020))

This research a quick investigation to know the anticipatory steps and initial repairs to be implemented and the main cause of building damage. Benefit from this result provide quick solutions to existing problems, temporary repairs so that office activities can continue to run and then provide comprehensive solutions for the damage that occurs.

METHODS

Quick response is carried out through forensic techniques by testing as shown in figure 1: (1) visual observation, (2) investigation of the concrete quality using ultrasonic pulse velocity test, (3) investigation to detect location and size of reinforcements and concrete cover with Profometer test, (4) Cone Penetration Testing (*CPT*) that is used to identify the soil and (5) GPR to measure the dimensions, depth, and thickness of foundations. The results were used to study and analyze the structural system and also to determine the structural behavior in the form of internal force and deformation due to gravity loads and the possibility of failure.

(1) (2) (3) (4) (5)

Figure 1. The test is carried out (1) visual observation. (2) UPV. (3) profometer. (4) CPT (5) GPR

The visual inspection was conducted by tabularizing the existing condition of the local structure and soil while the UPV and Profometer tests were performed on several elements at the Structural Engineering Laboratory of ITB, Bandung using 4 columns with 4 points, beams with 6 points, and slabs with 3 points. Moreover, the Georadar test was conducted by the Binanusa Pracetak & Rekayasa Company, Bandung using a 10 m^2 area on the main and additional buildings foundation while the CPT test was performed on 3 points by Tribina Wahana Cipta Company, Jakarta.

RESULTS AND DISCUSSION

Visual Observation

The damage to the existing building structure is presented visually in Figure 2 and torsion is observed in the boundary beam between the old and new buildings due to the fact that the steel beams of the new buildings are connected to the old buildings beams instead of the columns. This has the ability to cause cracks in the slabs around the beams in the border area while the upper bolts at the steel beam joints in the new building as well as the old beams experience tension and look uneven as shown in Figure 2.

Figure. 2. Damage to the upper structure

The visual results also showed shear cracks in the beams due to lack of connection to the column as well as the occurrence of non-uniform subsidence in the foundation as observed with the deformation in the basement floor, damage to brick walls, and broken slabs in the dilated area between the main and annex buildings.

The cause of the damage was triggered by a new project in dewatering work, near the building being investigated.building. the evidence is that there are eight buildings that suffered similar damage.

UPV test

The UPV test which was carried out randomly on the existing structural elements showed that the compressive strength of the concrete in the columns and slabs was 25 MPa according to the As built drawing, while the results of the test of the compressive strength of the concrete beams were found to be + 10% lower. This means that the beam requires special attention and immediate repair.

Profometer Test

The thickness of the concrete cover for beam and column elements was observed to generallymeet > 40 mm required by SNI and the same was observed for > 20 mm required for slab concrete. Therefore, this means that the reinforcement is sufficiently protected..

Cone Penetration Test (CPT)

CPT results show a depth of 24 m filled with embankment soil while hard soil at a depth of 30 meters, while based on the As built drawing the existing foundation depth is 20 meters.

Georadar Test

The foundation of the main building has 4 piles with 300 mm diameter and 20 m depth while the foundation slab was found to be 3.5 x 3.5 m with 1 m thickness. Meanwhile, the foundation of the additional building is in the form of 2 piles with 250 mm diameter and 20 m depth while the foundation is 1.8 m x 1.5 m with 0.5 m thickness.

Upper Structure Evaluation

The structural components were calculated using the ETABS program with reference to the SNI Calculation Procedure for concrete structures in buildings and the type of the moment-bearing frame structure. Moreover, the data on concrete quality, diameter and configuration of reinforcing bars, damaged columns, and slabs were based on the investigation results while the data on concrete quality, reinforcement quality, and dimensions of structural elements in other places were based on the information on the As-built drawing. Moreover, the structural analysis only considered the gravity load as shown in Figure 3 and was conducted to model the structural behavior when the building experiences ultimate loads in order to show the possibility of failure in the structural elements. The maximum deformation at the highest service load condition was found to be 9.4 mm, especially in the dilation area which is the border between the old and new structures around the lobby and the floors above it.

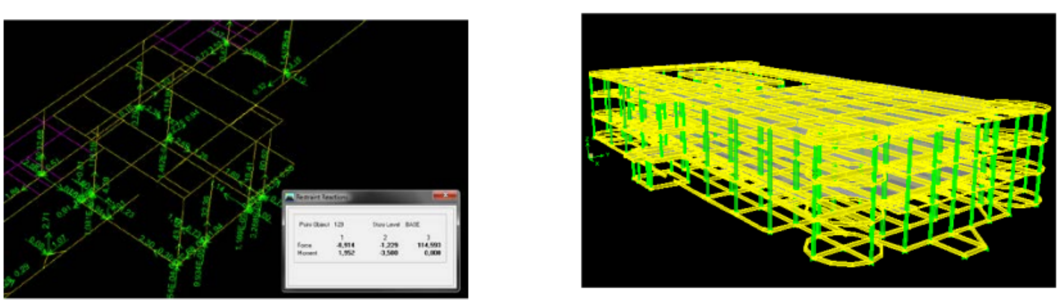

Figure 3. Modeling of the building structures due to gravity loads

The ultimate torsion load condition on the boundary beam due to the mounting of the new building's steel beam on the old building's concrete beam was observed to have led to the twisting which caused the cracks in the slabs. Moreover, an improper structural system was observed to have caused an uneven load distribution mechanism and this made certain columns to be heavy while others are much lighter. In this case, one column has an ultimate axial load of 114 tons while the surrounding columns are only half or one-third. These results, therefore, led to the need to implement the following quick responses.

Addition of steel columns

These were placed in the basement at the lobby area as well as the right and left wings of the lobby as shown in Figure 4.

Figure 4. Temporary strengthening of the basement floor

Strengthening with Fiber Reinforced Plastic

The beams in the basement are cracked as a result of the transfer due to the lack of support from the column as shown in Figure 5. Therefore, FRP was used as the strengthening material due to its lightness, high stiffness, corrosion resistance, fast installation, and low maintenance costs.

Figure. 5. FRP strengthening of beam on first floor.

The foundation repair using the Underpinning System

In principle, this system creates a new foundation as indicated in Figure 5 to support the old foundation. This is in the form of a bore pile with 30 m depth which was designed and implemented using an underpinning system as indicated in Figure 6 based on several considerations such as the limited workspace, not being noisy, and not disturbing the operation of an office building. This makes it possible for the structure to protect the old foundation and the structure it carries from the subsidence damage due to changes in soil conditions. Moreover, all the points of the foundation were reinforced but the repairment cannot be quickly conducted due to the limited field conditions which led to a longer period of work.

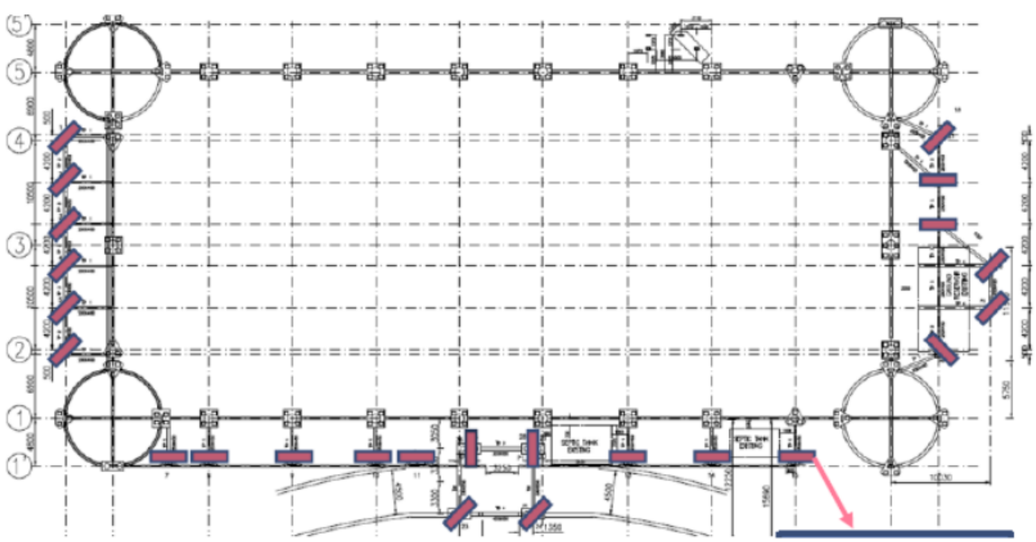

Figure 6. Strengthening with a new foundation

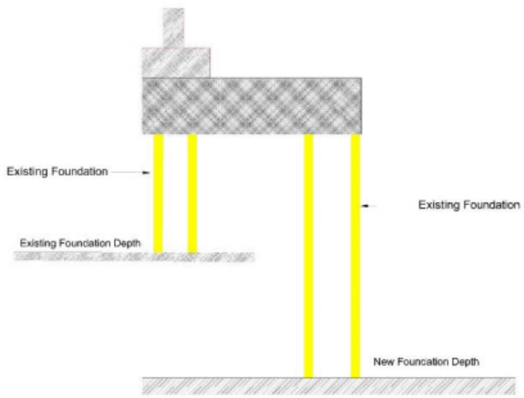

Figure 7. Underpinning method for strengthening existing foundations

CONCLUCION

The conclusions obtained based on the analysis conducted are as follows:

1. Structural damage occurs in the area between the main building and annex buildings
2. The subsidence occurs due to changes in soil conditions under the building due to dewatering activities in the around the building
3. The structure and detail of the lobby area are not in accordance with the existing structure system
4. Strengthening of the foundation structure must be carried out immediately

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