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The Audit and Assessment of Building Structural Strength (Case Study of Mataram Islamic State University Rectorate Building)

Authors
Rijali Amin*, Suryawan Murtiadi, Akmaluddin
Master of Civil Engineering, Faculty of Engineering, Mataram University, Indonesia
*Corresponding Author
Rijali Amin
Email: *rijaliamin98@gmail.com*

Abstract
Rectorate building of Mataram Islamic State University was designed of four story building and started under construction on 2008. However, the construction was aborted due to lack of administration management and left the building under incomplete condition with only foundation and the first floor erected. Ten years afterward, the management decided to continue construct the building. This study aimed to investigate the condition of existing building whether can be rebuilt properly corresponding to the previous design. The investigation included structural cracks that happened on structural element as well as the deflection of structural beams. The conditions of existing structural column have also been investigated.

The assessment process was conducted both on field and laboratory testing. The field testing was run with Schmidt Rebound Hammer test to know the compressive strength of structural concrete and its quality. The waterpass, theodolite, and tape measurement were used to measure the building geometric. SAP 2000 computer package was used to analyze the structure. Loading test was carried out base on the total measurement test which was required in SNI 03-2847-2002. The total measurement load of 700 kg/m^2 was employed representing U = 85% (1,4D + 1,7L), where D was dead load and L was live load. In this study, the loading test was conducted on 300/700 and 200/500 size beams.

Test result indicated that the qualities and the concrete compressive strengths on the building construction elements were varied. Steel reinforcement of structural columns was good enough to withstand the load, but, the column concrete strength should be improved. On the beam of 300/700 in the first floor, the deflection did not exceed the maximum deflection based on the code. However, the maximum deflection on 200/500 beam was 6.92 mm > 5.85 mm (maximum allowable deflection) and permanent deflection after loading of 2.31 mm > 1.46 mm (maximum allowable permanent deflection). Therefore, rehabilitation and retrofitting of structural columns and 200/500 mm beam are essential.

Keywords: *Structural building, assessment, loading test, non-destructive test, retrofit.*

Introduction

The Rectorate building of Universities Islam Negeri Mataram was designed to be four-story-building with reinforced concrete. Because there was problem in the administration, the construction was stopped in 2008 and it covered the foundation construction to the first floor plate. Since the construction Stage 1, there has been no further activity of the building construction. The condition of the building structure looks bad and abandoned. This can be seen from the cracks on the structure parts such as on the beams and the floor plate. Many rain puddles also cause the load structure become mossy and there are leakages[1]. Many reinforcing steels on the first floor corrode and the steel length does not satisfy the qualification (1/20 L) because mostly of the steel bars were stolen.

Based on the condition, it has been decided that there will be further plan to continue the construction in 2018. Therefore, there should be evaluation on overall strength of the building construction. If there is some doubt about the safety of a constructed building, a study on structure strength can be conducted through analysis, loading test, or the combination of both [2]. Loading test was run based on the procedure in Chapter 22 SNI 03-2847-2002 about the evaluation of the constructed structure. In this study, the evaluation of building structure strength of *Mataram Islamic State University* was run by combining the analysis and loading test. Reanalysis of the structure was performed by using loading data which had been obtained from the field study and loading test was conducted on floor plate structure and structure beams[3].

The structure of rectorate building of *Mataram Islamic State University* which had been built under Stage 1 Construction Project in 2008 had been stopped. There has not been any further construction since then even though the structure condition shows cracks, porosity, and non-standard iron bars (1/20 L). The structure cracks have spread to almost all of the elements/structure components of the building both on the columns, structure beams, and the floor plate. This study aims to find out the residual strength, the deflection value, and inter-story drift on the structure of rectorate building of *Mataram Islamic State University*, and to know the safety level of the structure of the existing condition of rectorate building of *Mataram Islamic State University*. The result will be used as suggestion in as the result of technical analysis about structure appropriateness of a building structure for *Mataram Islamic State University* to continue construction of the rectorate building based on the plan.

Theoretical Review

Basically, load types can be categorized into:

1. **Dead load**

   Dead load is the load which is permanent and comes from the structure's weight which includes the walls, partitions, columns, beams, floor, roof, structure finishing, and machines or tools that cannot be separated from the building where the overall value to be exceeded is limited in certain amount of time at a certain percentage. Generally, the load probability can be exceeded in 50 years and it is stated in the standards of building structure loading and it can be considered as nominal dead load (SNI-1726-2002)[3]

2. **Live Load**

   Live load comes from human and the furniture. Live load that is caused by human is usually determined 100 kg standard of strength and serviceability. Necessary strength U on a structure components are the strength because the load is multiplied by load factor. Load factor is a safety number that calculates overloading that is generated by the function of the building. Based on *SNI* (the Indonesian National Standard) 03 – 2847 – 2002 Phrase 11.2[3-8], necessary strength U and load factor are: Necessary strength U to bear dead load *D* at least must equal with

   $U = 1.4\,D$ .... (2.1)

   Necessary strength U to bear dead load D, live load L, roof load A of rain load Rare at least equal with the equation:

   $U = 1.2\,D + 1.6\,L + 0.5\,(A \text{ or } R)$ .... (2.2)

   If the structure endurance towards wind load *W* must be calculated in the planning, the influence of load combination of *D*, *L*, and *W* has to be reviewed to determine the highest *U* value that is:

   $U = 1.2\,D + 0.5\,L + 1.6\,W + 0.5\,(A \text{ or } R)$.(2.3)

   Where the load combination must consider the probability of full and empty live load *L* to know the most harmful condition, and

   $U = 0.9\,D + 1.6\,W$ ....(2.4)

   If the structure endurance towards earthquake (*E*) must be calculated in the planning, the necessary strength *U* value can be calculated with:

   $U = 1.2\,D + 1.0\,L + 1.0\,E$ ....(2.5)

   Or $U = 0.9\,D + 1.0\,E$ ....(2.6)

Method

1. The Location of the Research

This study took place in the neighborhood of *Mataram Islamic State University* which was located in *Jl.* Gajah Mada, Jempong Baru Village, Sekarbela Sub District of Mataram City. This construction was planned to be four-story building.

Figure 1 Existing Condition of *Mataram Islamic State University*

2. The General Data of the Building

a. The Name of the Construction : Rectorate Building
b. Address : Jl. Gajah Mada, Mataram
c. Function : Head Quarter of Rectorate Administration
d. The amount of floors : Planned to be four-story building
e. The base ground : Solid ground
f. Earthquake area : 3 (three)
g. Owner : Islamic State University of Mataram
h. Time of the Construction : 1st floor structure in 2008

3. Construction Test

a. Field Test

NDT (Non Destructive Test) on concrete surfaces have been done using hammer test. The aim of the test is to get the quality and compressive strength of the existing concrete. The positions of hammer test equipment and The *Schmidt Rebound Hammer Test* tool are presented in Table 1 and Figure 2, respectively.

Table 1 The Position of Schmidt Rebound Hammer Test

Angle Taking	Position of the Test
0°	Horizontally upright
-90°	Vertically upwards
+90°	Vertically downwards
45°	Incline plane 45°

Figure 2 The *Schmidt Rebound Hammer Test* tool

Theodolite and Waterpass: The geometrical measurement is needed not only during the construction but also during the investigation process. After it is being constructed, the structure can undergo changes because of the nature or other technical things. Degradation of the components or the overall buildings are measured to find out the level of damage. *Theodolite* is used to know the level of slant related with the *story drift* of the building on the exterior parts. *Theodolite* is also used to measure the site plan and dimension of the building components. *Waterpass* is used to measure flatness level of the second floor plate and deflection value of the second floor structure beam.

Micro-crack meter: This tool quite light and is easy to operate. This is useful to measure the width and the depth of the cracks on the concrete. This tool is also equipped with light and lines to help the reading with up to 0.01 mm of accuracy level.

Tape Measure: In order to measure the column dimension and structure beam, the measurement of cross section was run by using tape measure with 5 meters length. The measurement will be used as an input in the analysis of appropriateness/safety of the structure of the main frame work of the building. The measurement of column dimension and structure beam had been performed by peeling off the plaster first. Thus, the real concrete measurement was obtained. The mesurement of cracks length and the need of the other measurements was run with roll-meter.

Loading Test: The loading taking of 700 kg/m^{2}based on the total test load regulated in *SNI* 03-2847-2002 was U = 85% (1.4D + 1.7L) where D was the dead load and L was the live load. Dead Load was calculated as D= 266.3 kg/m^2 (mixing weight, sand weight, plafond weight, and brick pairs weight), and live load was planned to be L = 250 kg/m^2. The amount of total test load U=85% (1.4x266.3 + 1.7x250)= 678.147 kg/m^2 ≅ 700 kg/m^2. In this study, the load test was conducted on 300/700 mm and 200/500 mm beams. Loading test was conducted with 7 stages of the same loading which were 100 kg/m^2, 200 kg/m^2, 300kg/m^2, 400kg/m^2, 500kg/m^2, 600kg/m^2, 700kg/m^2 (equal with water height of 70 cm). In every loading, the amount of deflection on the beam was measured.

b. Laboratory Test

The steel tensile strength test was conducted on three twisted steel bars with diameter of 22 mm which was taken from the existing structure. The steel with the tensile yield strength of 400 MPa was used. The tool used for test in Laboratory of building construction material of the Faculty of Technical Engineering of Mataram University was UTM (*Universal Testing Machine*) of Shidmazu brand. The UTM tool can be seen in Figure 3.

Figure 3 UTM (*Universal Testing Machine*) Tool

Result and Discussion

Loading test was performed with water load on floor slab and beam. The component structure which was tested was the structure beam with size of 300/700 cm and 8 m of the length of span and beam with size of 200/500 with 7.65 m of length of span. They were loaded with maximum water height of70 cm (equal with load of 700 kg/m^2).

1. Loading test on Beam 300/700

The deflection on the structure beam was recorded in the Table 2 as follows:

Table 2 The Result of Deflection Measurement on the Structure Beam 300/700 (Dial 1)

Water height (cm)	Load (kg/m^2)	Deflection (mm)	Note
0	0	0	Before Loaded
10	100	0.17	The increase of loading stage
20	200	0.59	
30	300	1.08	
40	400	1.53	
50	500	2.07	
60	600	2.60	
70	700	3.13	Maximum test load
70	700	3.90	After loading was kept for 24 hours
0	0	0.97	After unloading

And, the curve of correlation between load and deflection on the beam is shown in Figure 4.

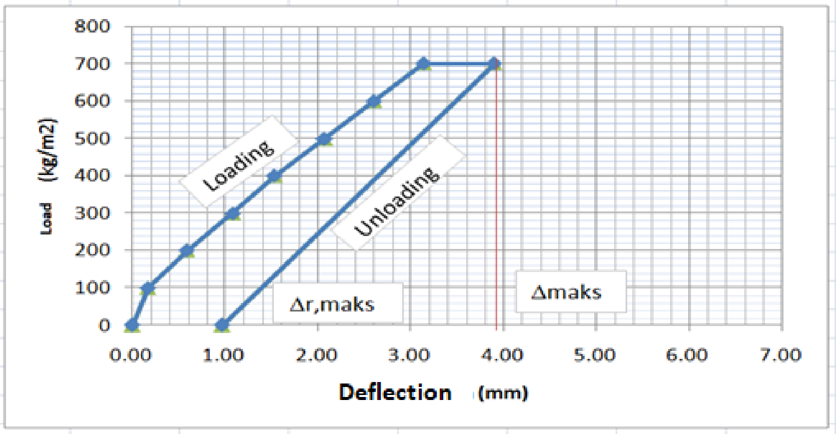

Figure 4 Correlation between load and deflection of the beam 300/700

The deflection on the structure beam was recorded in Dial 2 is presented in the Table 3 as follows:

Table 3 The Result of Deflection Measurement on the structure Beam 300/700 (Dial 2)

Water height (cm)	Load (kg/m^2)	Deflection (mm)	Note
0	0	0	Before loading
10	100	0.02	The increase of loading stage
20	200	0.074	
30	300	0.160	
40	400	0.230	
50	500	0.341	
60	600	0.495	
70	700	0.554	Maximum test load
70	700	0.665	After loading was kept for 24 hours
0	0	0.100	After unloading

And the correlation between load and deflection on beam is presented on Figure 5

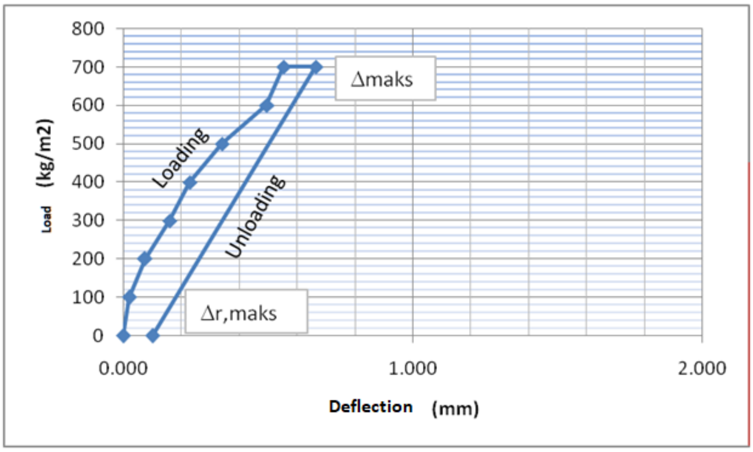

Figure 5 Correlation between load and deflection of the beam 300/700 (dial 2)

2. Loading Test on Beam 200/500

The deflection of the 200/500 mm structure beam obtained from the test is presented in Table 4 in the following:

Table 4 Deflection measurement on beam 200/500

Water height (cm)	Load (kg/m^2)	Deflection (mm)	Note
0	0	0	Before loading
10	100	0.75	The increase of loading stage
20	200	1.60	
30	300	2.60	
40	400	3.55	
50	500	4.65	
60	600	5.66	
70	700	6.92	Maximum test load
70	700	7.98	After load was kept for 24 hours
0	0	2.31	After unloading

From the deflection measurement during the load test on beam 200/500, it was obtained a curve which showed the correlation between the amount of loading and unloading with deflection on structure beam. The curve of correlation between load and deflection on beam is presented in Figure 6.

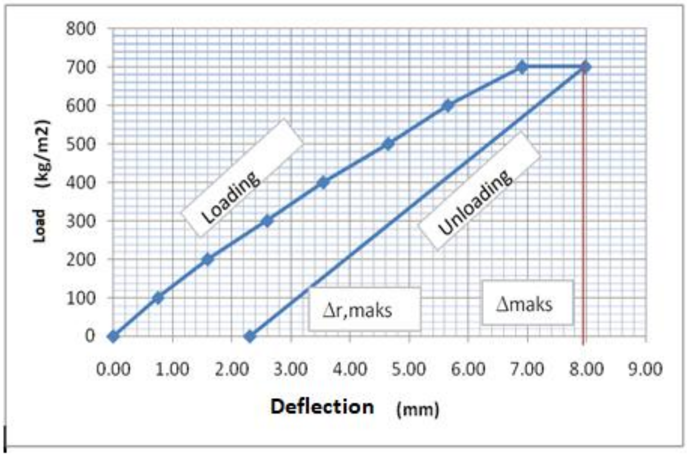

Figure 6 The correlation between load and deflection of beam 200/500

a. The Observation of Crack Width

Based on the observation before running the test, on some beams and floor plates especially beams with span of 8 meter and 7.65 meter, there were early cracks which could be considered as the indication of structure failure. The measurement of crack width was done earlier before the beam loaded, after loaded for 24 hours/permanent load, and after the unloading. The result of the measurement on beams can be seen in Figure 7 and Figure 8.

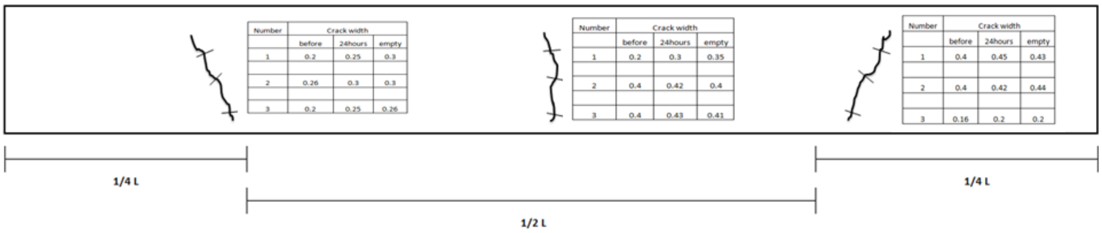

Figure 7 The Result of Measurement of Crack Width on Beam 300/700

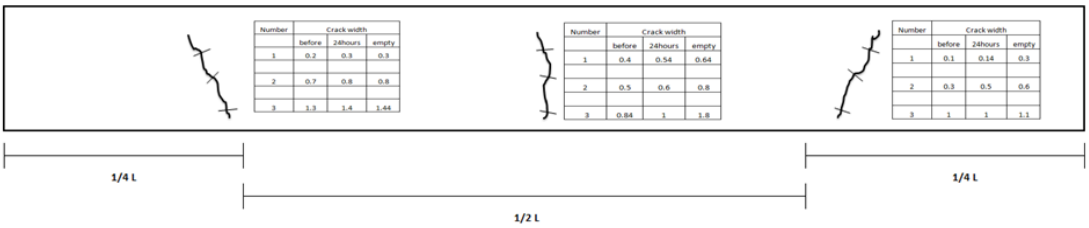

Figure 8 The result of measurement of crack width on beam 200/500

Based on the measurement, the result showed that the crack width increased along with the loading and it decreased when unloading. Therefore, it could be concluded that the cracks were permanent cracks and it needed to be covered with pressing injection. Therefore, the corrosion on steel bars could be prevented[9-11].

b. The Evaluation of Load Test Result

From the result of load test, it was obtained the measured maximum and permanent deflection.

(a). Beam 300/700

For beam with size of : b= 300 mm and height : h = 700 mm, with length of span Lt = 8000 mm, based on the regulation in Chapter 22 *SNI* 03-2847-2002[3], the amount of maximum deflection and maximum permanent deflection allowed were: maximum deflection:$\Delta = Lt^2 / (20000.h)$ $=(8000)^2/(20000.700)=$ 4.57 mm, maximum permanent deflection :$\Delta r = \Delta/4 = (4.57)/4 = 1.143$ mm.

Because the amount of maximum deflection (Δmax) measured on beam 30/70 (dial 1) (Table 7. < Δ = 4.57 mm, and the amount of permanent deflection (Δr, max) < Δr = 1.143 mm, it could be concluded that the structure beam met the strength requirements.

(b). Beam 200/500

For beam with size, width : b= 200 mm and height : h = 500 mm, with span length Lt = 7650 mm, based on the regulation in Chapter 22 *SNI* 03-2847-2002, the amount of maximum deflection and maximum permanent deflection allowed was: maximum defclection :$\Delta = Lt^2 / (20000.h) = (7650)^2/(20000.500)=5.85$ mm, maximum permanent deflection:$\Delta r = \Delta/4 = (5.85)/4 = 1.463$ mm. Because the amount of maximum deflection (Δmax) measured on beam 200/500 (table 7. > Δ = 5.85 mm and the amount of permanent deflection (Δr, max) > Δr = 1.463 mm, it could be concluded that the structure beam did not meet the requirements.

Conclusion

Based on the result and the analysis, it can concluded that:

1. From the structure analysis, it was obtained the ratios of jacketing width on the existing column with the jacketing width of analysis result. For columns which had reinforcement ratios which were smaller than 1 (<1), column strengthening was needed by adding the column size and the amount of jacketing. From the structure analysis, it was obtained the result of jacketing ratios from the existing columns K1-1, K2-1, K3-1, K4-1were higher than 1 (>1). Thus, the columns were remained capable to bear load on the structure even though it was predicted that the concrete quality was lower than the previous designed.
2. In the test load of 700 kg/m^2, on some beams and floor plates especially beams with span of 8 meters and 7.65 meters, there were early cracks which could be stated as the indication of structure failure. On the beam of 300/700 in the first floor, the deflection did not exceed the maximum deflection based on the code. The maximum deflection of the beam $\Delta = 4.57$ mm < 5.85 mm (maximum allowable deflection) and permanent residual deflection after loading of $\Delta r = 1.143$ mm < 1.46 mm (maximum allowable permanent residual deflection).
3. For the beam with size b= 200 mm and h = 500 mm, with span length Lt = 7650 mm, the maximum deflection on 200/500 beam $\Delta = 6.92$ mm > 5.85 mm (maximum allowable deflection) and permanent deflection after loading of Δr =

2.31 mm >1.46 mm (maximum allowable permanent residual deflection). Therefore, rehabilitation and retrofitting of structural columns and 200/500 mm beam are essential.

Suggestions

1. On disintegrated parts of beams and floor slabs, pressing injection process is needed in order to build a strong permanent bond.
2. The column reinforcement connection needs to use Coupler Fujibolt Type M and Type RII, Coupler Type M (grout injection). They are used for bar connection where the condition of existing reinforcement height from the floor is under 5 cm, the minimum size bar that is put into the coupler Type MT22 (rebar 22/19/16) was 11 cm with surrounding cut up diameter is at least 5 cm. Coupler Type M (press) is used for bar connection where the condition of existing reinforcement is more than 10 cm from the floor. Coupler Type RII is a coupler with system of clamping on both connected iron ends.
3. Construction of the stairs should be changed with construction of steel WF, since there are no adequate reinforcing bars to connect the stairs reinforcement. Based on the loading test, beam with dimension of 200/500 does not meet the qualification. Therefore, it needs additional reinforcement where the reinforcement can be fixed with method of jacketing. The ideal is that the dimension of the beam is 300/600 or by decreasing the load on the second floor by using light material as partition wall.

References

1. O. Ortiz, F. Castells, and G. Sonnemann, “Sustainability in the construction industry: a review of recent developments based on LCA,” Construction and Building Materials, vol. 23, no. 1, pp. 28–39, 2009
2. A. Haapio and P. Viitaniemi, “A critical review of building environmental assessment tools,” Environmental Impact Assessment Review, vol. 28, no. 7, pp. 469–482, 2008
3. SNI 03-2847-2002 , Tata Cara Perhitungan Struktur Beton untuk Bangunan Gedung, Perhitungan Struktur Beton untuk Bangunan Gedung, Jakarta 2002
4. SNI 03-1726-2002, Tata Cara Perencanaan Ketahanan Gempa Indonesia untuk Bangunan Gedung, Jakarta 2002.
5. SNI, Tata Cara Perhitungan Struktur Beton untuk Bangunan Gedung SNI 03-2847-2002, Bandung, Direktorat penyelidik Masalah Bangunan, Direktorat Jendral Cipta Karya Departemen Pekerjaan Umum, 2002
6. SNI, Standar Nasional Indonesia Peraturan Pembebanan Indonesia untuk Rumah dan Gedung SNI 03-1727-19, Jakarta, Dewan Standarisasi Nasional, 1989.
7. SNI 1727-1989F, Pedoman Pembebanan Indonesia untuk Rumah dan Gedung, Jakarta 1989.
8. SNI 03-1726-2002, Tata Cara Perencanaan Ketahanan Gempa Indonesia untuk Bangunan Gedung, Jakarta 2002.
9. K. Narmashiri, M. Z. Jumaat, Comparison Between 2D and 3D Computer Modeling for Flexural Rehabilitation of Steel Structures With HM-CFRP and Steel Sheets, Proceeding of 1st International Conference on Rehabilitation and Maintenance in Civil Engineering (ICRMCE), Solo, Maret 2009.
10. Imran, S. Darmawan, I. Sulaiman, C. Lie, Aryantho, Assessment and Repair/ Strengthtening of a Settlement Damaged Office Building, Proceeding of 1st International Conference on Rehabilitation and Maintenance in Civil Engineering (ICRMCE), Solo, Maret 2009.
11. T. Norris, H. Saadatmanesh, Shear and Flexural Strengthening of Reinfor Concrete Beam With Carbon Fiber Sheet, Journal of Structural Engineering, July 1997/903