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Strengthening of Nurul Ilmi Mosque with Concrete Jacketing

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***Abstract*—**Nurul Ilmi moesque is one of building for worship located in University of Andalas. In 2008 the new building of mosques was designed using previous indonesian seismic code, SNI 1726: 2002. The right side of the new mosque was constructied in 2009. Due to the limitation of the budget, the construction of the left side of the mosque was continued on 2014. However, a new indonesian seismic code SNI 03-1726-2012 was established and the designed mosque should be revised based on the new indonesian seismic code. Since the right side of the mosque was designed by using the old seismic code (SNI 1726: 2002), so it is necessary to evaluate the strength of the structure by using the seismic code (SNI 03-1726-2012). Based on the analysis results, it was found that the right side of the building structure is not strong enough to resist the combination loads acting on the structure, especially the earthquake load. Therefore, it is necessary to strengthening (retrofitting) the right side of the building structure before connecting with the left side of the building. In this study, the concrete jacketing method was used to the retrofit the column structure. The results show that the jacketing method is effective to increase the capacity of the column and reduce internal forces and displacements that occur in the structure of the mosque, so the structure can resist the working loads

***Keywords*—**column, concrete jacketing, earthquake, displacement, strengthening.

I. INTRODUCTION

Nurul Ilmi mosque is a building for worship used by students, lecturers, and employees who were in the neighborhood Andalas University campus. As the number of students at the University of Andalas increase every year, the mosque should be expanded which can accommodate more pilgrims. In 2008, the new mosque was designed using old seismic code, SNI 03-1726-2002 [1]. The right side of the mosque was built in 2009 refer to the design. In 2014, the left side of mosque has been planned to be constructed. However, the design of mosque should be revised base on the new seismic code SNI 03-1726-2012. The left side of the mosque was constructed based on the revised design in 2014.

Since the right side of the mosque was designed using old seismic code (SNI 1726: 2002), so it is necessary to evaluate the strength of the existing structure using the new seismic code SNI 03-1726-2012 before connecting with the right side of the mosque (Figure 1)

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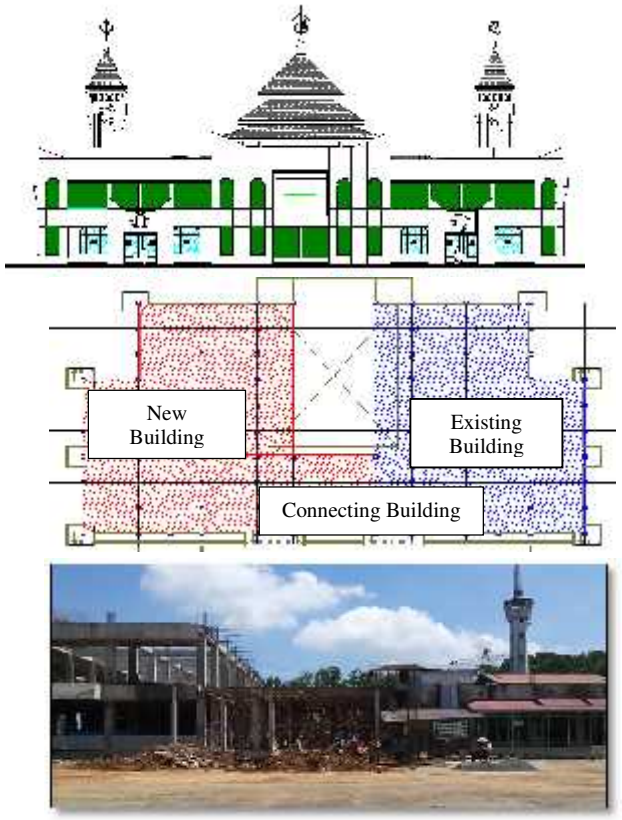


Fig 1. The Plan and View of Nurul Ilmi Mosque Building

II. MOSQUE BUILDING STRUCTURE ANALYSIS

Before analyzing the right side of the mosque building, it is necessary to collect data and information of the building.

2.1 Properties of Material

To get the right quality of concrete building mosques, testing was done by hammer test. Hammer test results showed that compressive strength of the concrete for columns is K-250 (fc'=22,5 Mpa). Meanwhile, the number of reinforcement obtained by testing with ferroscan tool. Yield stress of steel reinforcement bar, fy = 350 MPa.

2.2 Structure Analysis

Based on the data that has been described previously as well as by function and location of the building, the structure of the mosque building subsequently modeled and analyzed using commercial structural analysis software ETABS 9.7.4 [3]. The seismic load based on SNI 1726:2012 was used in this study. According to the soil test result, the soil on the building was classified as soft soil. The respon spectra of

mosque location (Padang city) with soft soil category was obtained from the website http://puskim.pu.go.id/ Aplikasi/desain_ spektra_indonesia_2011. After performing the structural analysis, further analysis of the capacity of cross-section beams and columns was carried.

2.3 Load-Carrying Capacity of Beams and Columns

Table 2.1 shows the flexure capacity of beam. From the table, it can be seen the flexure capacity of beam is stronght enough, the Nominal Moment of the beam (Mn) is higher than the Moment ultimate (Mu). Meanwhile, the capacity of column is not sufficient. Based on the analysis capacity of the column cross-section through the P-M interaction diagram (Fig. 2), most axial forces and bending moments exceed the interaction diagram. This means that the structural columns of the mosque is not enough axial and flexural capacity to resist the working loads.

Table 2.2 shows the shear capacity of the column. As seen in the Table, the shear capacity of the column is sufficient, nominal shear is higher than the ultimate shear (Vu).

Table 2.1 The Capacity of Bending Momen in The Beam

Beam Code	Dimension		Reinforcement		Momen		Mu <Mn
	Width	Height	Bottom	Top	Nom	Ult	
B1 30x60	300	600	5 D 19	3 D 19	20,319	15,24	OK

Table 2.2. The Capacity of Shear Force in The Column

Code	Flexure Reinforcement	Shear Reinforcement		Shear Reinforcement Installed		Vu<Vn
		d (mm)	s (mm)	d (mm)	s (mm)	
1st Floor						
K1 40X40	8 D 19	10	17,5	10	10	OK
K1 D45	8 D 19	10	20	10	10	OK
K2 D60	16 D 19	10	27,5	10	10	OK
K2 55X55	16 D 19	10	25	10	10	OK
2nd Floor						
K2 D60	16 D 19	10	27,5	10	10	OK
K2 55X55	16 D 19	10	25	10	10	OK

Table 2.3 Inter Story Drift of Existing Building

Code	Story	UX	High Story	Drift X	X-Direction Δs = (Dx).Cd/Ie	Δa = 0,015 H / ρ	Δs ≤ Δa
X - Direction	2	2,0659	4	0,7531	2,7614	4,6154	OK
	1	1,3128	4	1,3128	4,8136	4,6154	NOT OK
Code	Story	UX	High Story	Drift X	Y-Direction Δs = (Dx).Cd/Ie	Δa = 0,015 H / ρ	Δs ≤ Δa
Y - Direction	2	0,4114	4	0,1770	0,6490	4,6154	OK
	1	0,2344	4	0,2344	0,8595	4,6154	OK

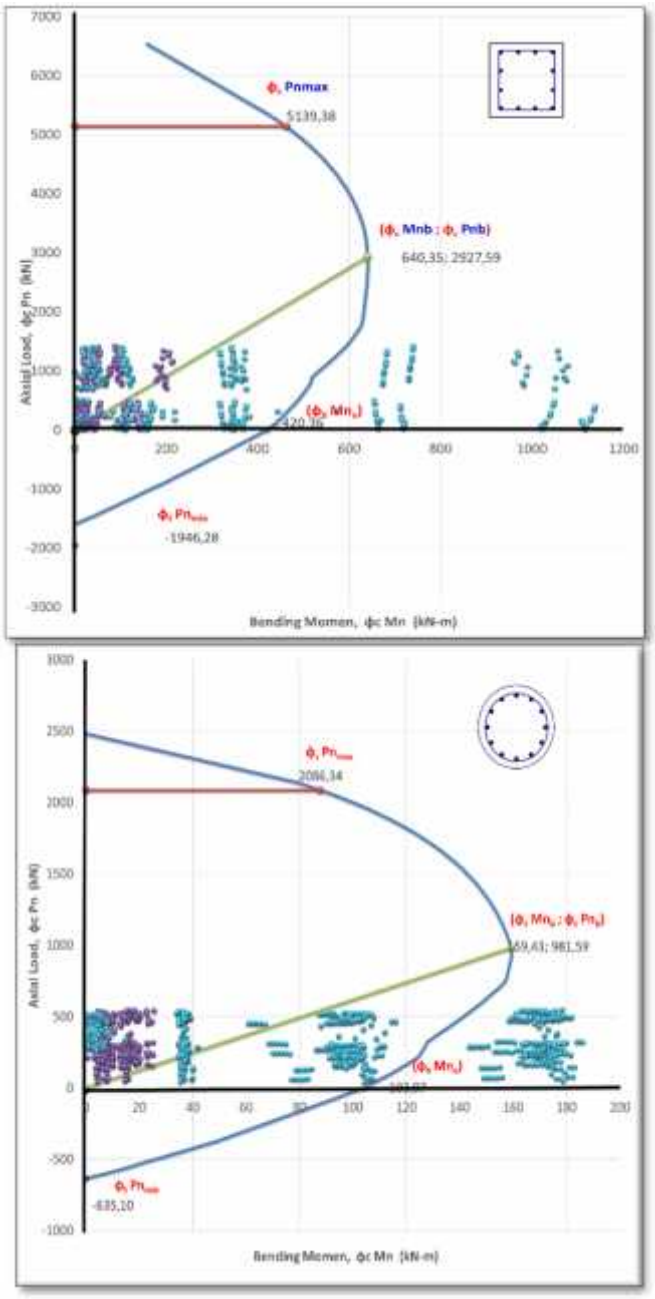


Fig 2. Interaction Diagram P-M of Column in The Right Side of Mosque

2.4 Inter Story Drift

The values of inter story drift of the building on all stories in X and Y directions can be seen in Tables 2.3. As seen in the tables, the inter story drift of the buildings not meet the requirement based on standard code SNI 1726 2012, especially in X direction. This means that the structure is not capable to resist the working loads and the right side of Nurul Ilmi mosque building should be strengthened first before connecting to the left side one.

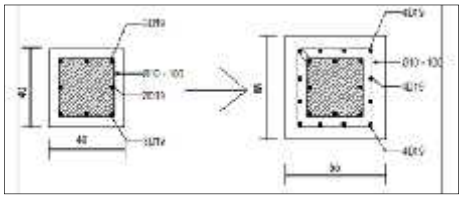
III. STRUCTURE STRENGTHENING WITH CONCRETE JACKETING

Concrete jacketing is one of retrofitting structures used to the columns of the building. The demand for using concrete jackets to strengthen or repair reinforced concrete columns has been increasing in the past few decades [4]. Reinforced concrete jacketing is a common method for retrofitting existing columns with poor structural performance [5].

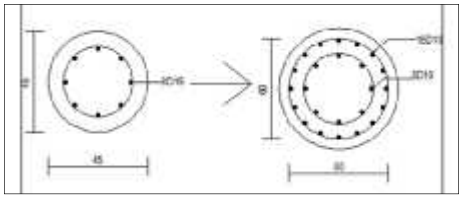
Jacketing implemented by enlarging the column section and increase the amount of reinforcement [6]. Retrofitting column with an effective jacketing can increase flexural, shear and axial strength column. Based on the results of research conducted by Fauzan et al [7,8], an increase in the capacity of a column in the round-jacketing on the building significant both flexural and shear capacity of the column by around 60%.

3.1 Detail of Column Cross Section

Concrete jacketing is done by enlarging the cross-sectional dimensions and increase the amount of reinforcement column as can be seen in Figure 3. Jacketing the column is done by installing reinforcement enveloped the existing column [9].
In this study, the dimensions of rectangular columns were enlarged from 40x40 cm^2 to 55x55 cm^2 and for circular columns from ϕ 45 cm to ϕ 60 cm. While, the steel reiforcement was added, 12 D 19 for rectangular columns and 16 d 19 for circular columns. Shear reinforcement (strirrup) ϕ10-100 was installed to the added reinforcement. The concrete with compressive strenght of K-250 (fc'=22,5 Mpa) was used for this jacketed column.



Column K1 (55X55)		
	Existing	Retrofitting
Dimension	40 x 40 cm	55 x55 cm
Reinforcement	8 D 19	20 D 19
Stirrup	Ø10 – 100	Ø10 - 100



Column K2 (Ø60)		
	Existing	Retrofitting
Dimension	Ø45 cm	Ø60 cm
Reinforcement	8 D 19	24 D 19
Stirrup	Ø10 – 100	Ø10 - 100

Fig 3. Dimensions and Cross Section of Existing and Retrofitting Column

3.2 Analysis after jacketing

Figure 4 shows P-M interaction diagram of column after strenghtening (retrofitting). As seen in the figure, the axial forces and bending moments are not exceed the interaction diagram, that means the capacity of column is strong enough to resist the working loads.

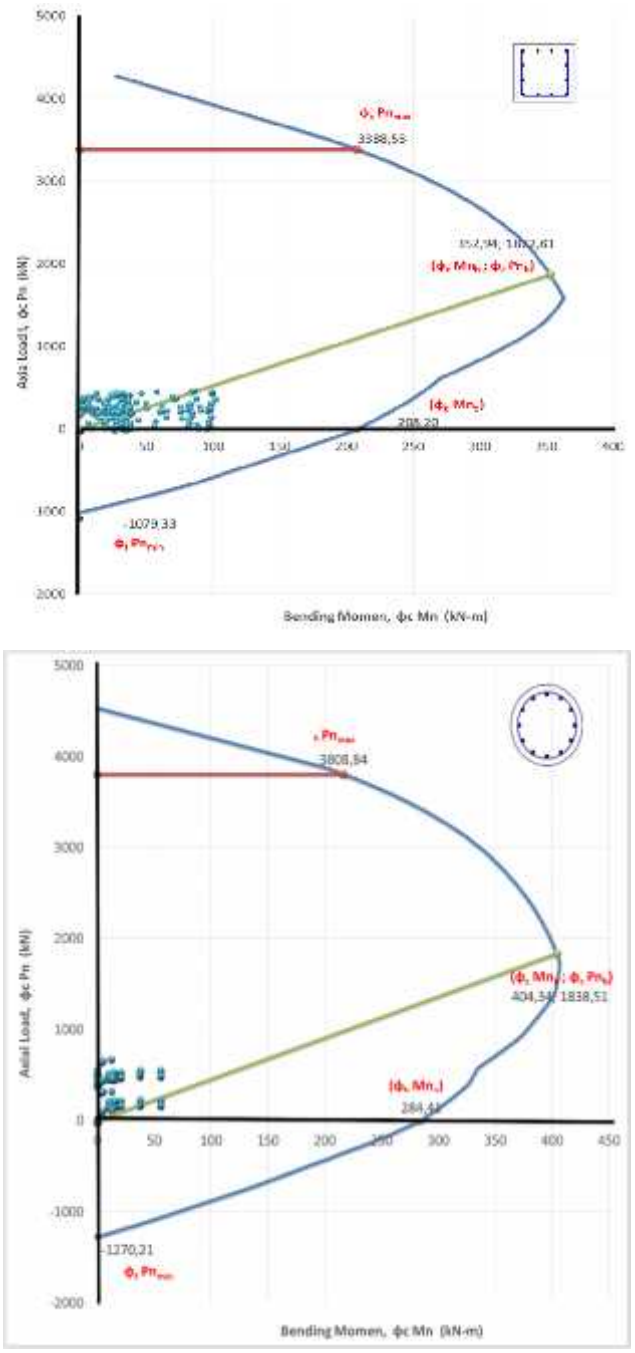


Fig 4. Interaction Diagram of Column After Retrofitting by Concrete Jacketing

Table 3.1 shows the comparation of column capacity on the first floor between existing and jacketted columns. As seen in the table, there is an significant increase on the column capacity after jacketing. The increased of moment capacity reached 70% compared to the existing condition, while for axial and shear forces reached 51 % and 38 %, respectively.

The inter story drift of the building after retrofitting can be seen in table 3.2. From the table, it can be seen that the structure of the building after retrofitting has met the applicable requirements in seismic code SNI 1726 2012.

Table 3.1 The Capacity of Column

Code	Column Capacities	Existing Condition	Jacketing Condition	Increase of Rasio (%)
Column K1	Momet (kNm)	123,01	400,21	69,26
	Axial (kN)	1743,5	3584,75	51,36
	Shear (kN)	223,27	361,26	38,20
Column K2	Momet (kNm)	159,43	542,51	70,61
	Axial (kN)	2086,34	4257,84	51,00
	Shear (kN)	254,63	386,24	34,07

Table 3.2. Inter Story Drift of Bilding after Jacketting

Code	Story	UX (cm)	High Story (m)	Drift X (cm)	X-Direction Δs = (Dx).Cd/Ie	Δa = 0,015 H/ρ	Δs ≤ Δa
X – Direction	2	1,5597	4	0,7595	0,7595	4,6154	OK
	1	0,8002	4	0,8002	0,8002	4,6154	OK

Code	Story	UX (cm)	High Story (m)	Drift X (cm)	Y-Direction Δs = (Dx).Cd/Ie	Δa = 0,015 H/ρ	Δs ≤ Δa
Y – Direction	2	0,4000	4	0,1798	0,1798	4,6154	OK
	1	0,2202	4	0,2202	0,2202	4,6154	OK

3.3 Retroftting Implementation Method

The first step of the retrofitting on the mosque was by eliminating the concrete cover of the existing column. Then, a reinforcement was added to the column. The concrete was cast after the formwork were installed. Concrete bond of SIKACIM was used to connect between the old and new concrete.

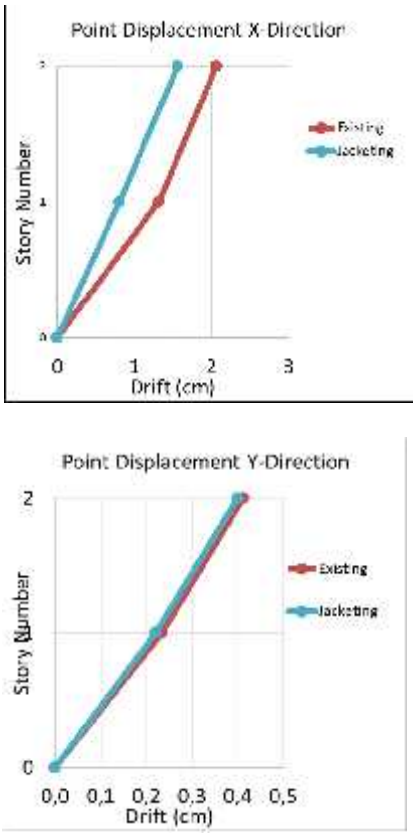


Fig. 5. Point Displacement

Implementation of the jacketing carried out on Nurul Ilmi Mosque building can be seen in Figure 6.

a. b. c. d.

a. Eliminate concrete column shelled approx 5 cm b. Installed the added reinforcement b. Installed formwork on enlarging of column dimensions and casting cocrete d. Column after jacketing

Fig. 6. Jacketing Method of Column

IV. CONCLUSION

1) The right side of Nurul Ilmi mosque is unable to resist the working loads based on SNI 03-1726-2012 and should be retrofitted before connecting it to the left side one.
2) Concrete Jacketting was recommended to Strengthening the mosque structure
3) Retrofitting with concrete jacketing increase the capacity of the column with a percentage increase for Moment, axial and shear are 69-70%, 51% and 30-40%, respectively.
4) Retrofitting of the building using jacketing reduces displacements of the building structure.
5) The retrofitted mosque building meet requirement of the new seismic code, SNI 03-1726-2012 and has adequate capacity to resist the working loads.

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