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The Effect of Structure Performance on RC Strengthening Using Concrete Jacketing Method

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Abstract— *Columns are the primary elements that have the most important role in a structure. Damage columns can occur due to overloading, poor design, poor construction and others. In this case the local reinforcement that needs to be done is in the column element. The selected repairing and strengthening is the concrete jacketing method. The selection of bamboo reinforcement is a form of utilization of natural materials that have a fairly good axial tensile capacity, so that it is expected to increase the ductility of column elements. The test method in this study was carried out based on the Quasi Static Loading Test method on existing specimens and retrofit where axial loading was given in cost and lateral load based on displacement control patterns as a form of simplification of earthquake loads. The results of the study show that reinforcement with concrete jacketing from the initial dimensions of 15x15x90 cm to 21x21x90 cm shows an increase in lateral capacity, ductility, stiffness and dissipation of energy.*

Keywords— *Concrete Jacketing, Damaged Column, Structure Performance, Strengthening.*

I. INTRODUCTION

The column is an RC structural element that has the most important role in a portal structure. The function of this element is to support all the loads above it which are channeled through the plate and beam elements which then rest on the foundation in the soil. Therefore, planning on column elements is a major concern. Safety factors in columns are also very large compared to other elements such as plates and beams. This is to guarantee failure that occurs in the column.

One method that is often used in construction is concrete jacketing. This is because the method is easier to do and costs less. The purpose of strengthening using this method is to increase the performance of the RC in accepting load response by increasing the cross-sectional area. in addition, RC elements are expected to be more ductile because the confinement of the existing RC have improved.

The selection of bamboo is a form of utilization of natural materials that have adequate mechanical capacity for construction needs. According to (Dewi, Munawir, Wisnumurti, & Nuralinah, 2017) bamboo is a non-timber forest product that has a high socio-economic value and can be used widely for architectural needs, permanent and non-permanent construction structures. Bamboo is a natural plant material whose development is very fast, even in a few years (± 2-3 years) bamboo has been able to achieve ultimate mechanical capacity (Ghavami K., 2005).

So in this study we will conduct an experiment on the effect of restraint on longitudinal inter-reinforcement distance on RC concrete jacketing column capacity in accepting axial loads and lateral loads.

II. LITERATURE REVIEW

A. Column RC

Columns are classified into 2 types, namely short columns and slender columns. The column according to the Indonesian concrete regulation code SNI-2847-2013 is a structural component with a ratio of 3 times the sectional height to the lateral dimensions. For structural components with changes in lateral dimensions, the smallest lateral dimensions are smaller up and down dimensions. If the ratio of section height to the smallest lateral dimension is less than three, it is called the pedestal column (short column).

$$\frac{K.L_u}{\sqrt{\frac{I}{A}}} \leq 22$$

B. Ductility

Ductility is the ability of material, elements, and structural systems to undergo large deformations from elastic conditions to plastic and to maintain strength without a significant decrease in strength. Ductility is needed very important by the structure to respond to large earthquake loads that occur in the structure (seismic loading) including its ability to absorb energy (dissipation energy).

$$\mu = \frac{\Delta_u}{\Delta_y}$$

Ductility can be formulated as a comparison between deformations when the ultimate divided deformed when the first yield occur. Several alternatives suggested to determining the yield point. One of that is from (Park R. & T. Paulay, 1974) given suggest to determine yield point. Several researchers have used option D from that or determination of yield points based on the equivalence of yield points at elasto-plastic.

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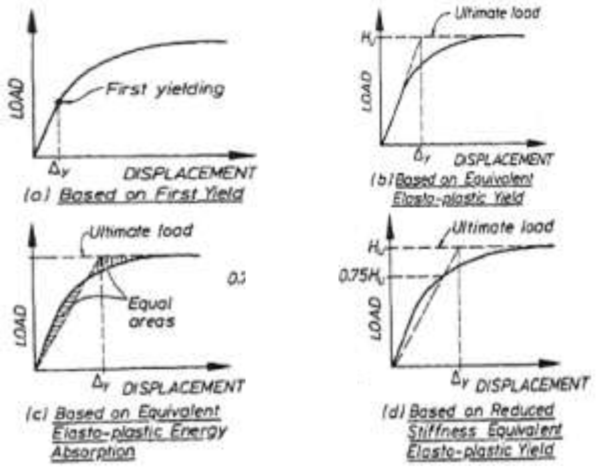


Fig. 1. Alternative for determining yield points (Park R. & T. Paulay, 1974)

C. Stiffness

One concept that is often used in determining the stiffness of an element is the secant stiffness method. In several studies many conducted studies related to these methods, one of them by (Sullivan, Calvi, & Priestley, 2004) states that the character of structural stiffness in the building of dynamic response with DBD (displacement based design) is more effective if using the secant stiffness method.

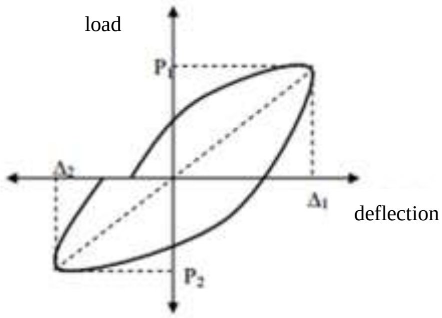


Fig. 2. Stiffness (peak to peak) of member under cyclic lateral loading

$$K = \frac{P1 + P2}{\Delta 1 + \Delta 2}$$

D. Rehabilitation of RC

Damage to the structure can occur locally and globally. Global damage will occur if some structural elements have been damaged locally. Structures that have been damaged will experience a phase where the capacity they have is already unable to withstand the existing load. Damage can occur in 4 conditions, namely poor design, poor quality construction, overloading in service conditions (gravity service load and earthquake load) and conditions in which the latest building planning standards are changed / revised.

Many methods have been used to repair and strengthen RC. one that is often used is the concrete jacketing method. The use of retrofitting the concrete jacketing method has been widely carried out and developed. According to (Chakrabarti et al., 2008), there are several important conditions for use or benefits that can be obtained from the use of this method, as follows:

- Concrete jacketing can improve flexure and shear capacity
- Compatibility and durability between old material and new material it better when compared with other materials besides concrete
- The process is easy to do, doesn't require special skills
- To determine capacity analysis of element, its same with calculation of an ordinary column

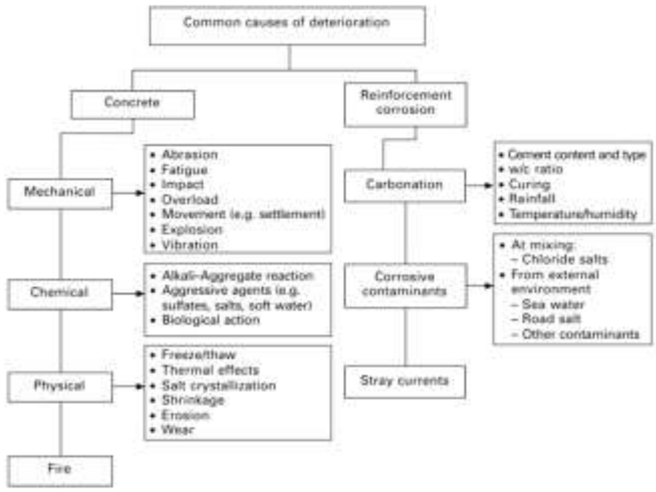


Fig. 3. General problem damaged of RC (Delatte, 2009)

E. Numerical Simulation

Ansys Workbench 14.5 has been used to conducted three dimensional finite element analysis model for existing specimens and retrofitting specimens. As for the consideration in determining the parameters in numerical simulation analysis based on (Cook, 1990), as follows:

- Type of analysis includes geometry stability, geometric and material nonlinearity
- Formulations related to incremental and deformation theories
- Ease of use and mastery of computer software
- Size of numerical problems, computational costs and available storage
- The degree of dominance or non-linearity
- Accuracy desired.

III. RESEARCH CONCEPT FRAMEWORK

A. Research Conceptual Framework

Based on the problems, so an algorithm was made to facilitate problem solving. The following is an overview of the conceptual framework in this research:

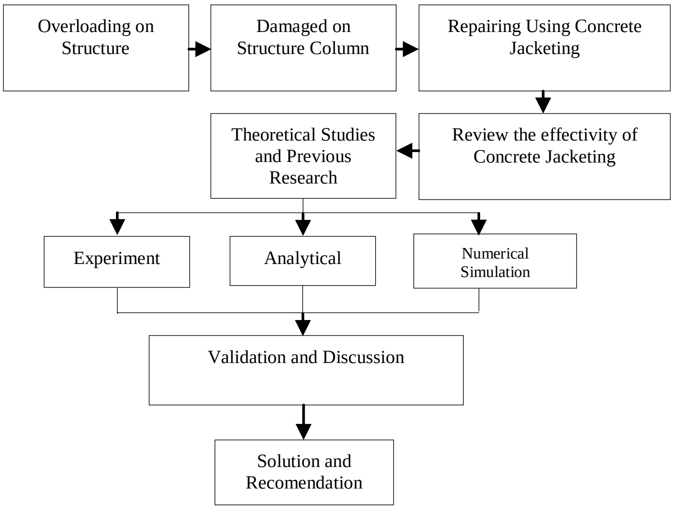


Fig. 4. Alghoritm conseptual framework of research

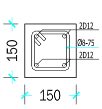
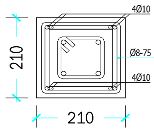
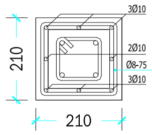
B. *Research Hypotesis*

- Axial, lateral, ductility and stiffness behavior in RC columns reinforced by concrete jacketing with bamboo reinforcement will provide a fairly effective improvement.
- Bamboo material that has good quality can be used as reinforcement in retrofitting concrete. The aim is to increase the confinement capacity on retrofitting concrete.

IV. Research Method

A. *Detail of Specimens*

TABLE I. Detail of Specimens

	Existing	Retrofitting-A	Retrofitting-B
Dimension	150 mm x 150 mm	210 mm x 210 mm	210 mm x 210 mm
Cross-Section			
Amount of Specimen	4	2	2
Label of Specimen	• Pre A-4-75 • Pre B-8-75	• S1 A-4-75	• S2 B-8-75
Longitudinal rebar	• 4Ø12 • Deform steel rebar • Rebar ratio, ρ = 2,01%	• 8⊠10 • Bamboo rebar • Rebar ratio, ρ = 2,45%	• 8⊠10 • Bamboo rebar • Rebar ratio, ρ = 2,45%
Transversal, Ties	• ø8–75 mm • Plain steel rebar	• ⊠6–75 mm • Bamboo rebar	• ⊠6–75 mm • Bamboo rebar

B. *Material Testing*

- f'c , concrete existing = 20,05 MPa
- f'c , concrete retrofitting = 25,84 MPa
- fy, steel reinforcement = 411,65 MPa
- fu, steel reinforcement = 658,64 MPa
- fu, bamboo reinforcement = 256,05 MPa
- fs, bamboo reinforcement = 74,03 MPa

V. Results and Discussion

A. *Lateral Load Capacity*

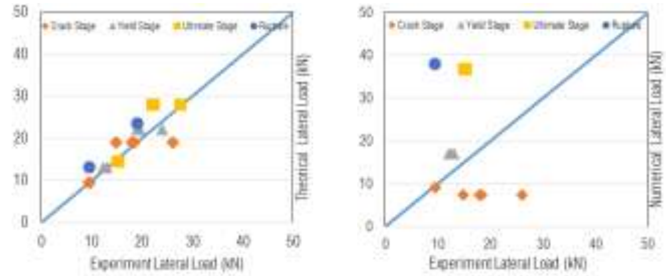


Fig. 5. Envelope Curve of Specimen Lateral Load Capacity

In this study, the results of the experimental tests are then validated with the results of the analysis based on theoretical and numerical simulations. Theoretical analysis using moment curvature analysis and showing results that are close enough to the experimental results. But in numerical simulation analysis, the results show that there is a considerable difference in the results of the ultimate stage and rupture. This is because in numerical simulations with ansys workbench 14.5 it has not been able to show the inelastic effect on concrete and reinforcement.

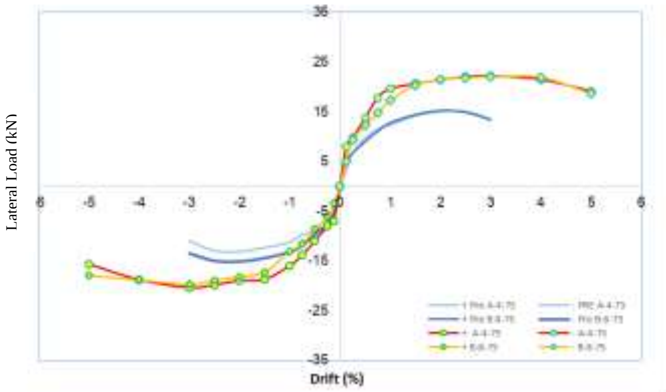


Fig. 6. Envelope Curve of Specimen Lateral Load Capacity

If seen on the figure about the confinement effect of column test specimens on longitudinal reinforcement points, it can be seen that the column with 8 reinforcements spread over 4 mounting points (there are 2 reinforcement in one bundle in 4 reinforcement points) shows better lateral load capacity performance compared to 8 reinforced columns retrofitting is spread in 8 installation points (there is 1 reinforcement in one reinforcement point).

So confinement just not affects about distance between longitudinal reinforcement but also the shape and size of the reinforcement can affect the value of confinement. The larger size of the longitudinal reinforcement, the more confinement that can be given. This is in accordance with the factors that influence confinement, namely the influence of the shape and

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size of longitudinal reinforcement (Park R. & T. Paulay, 1974).

B. Curvature Distribution

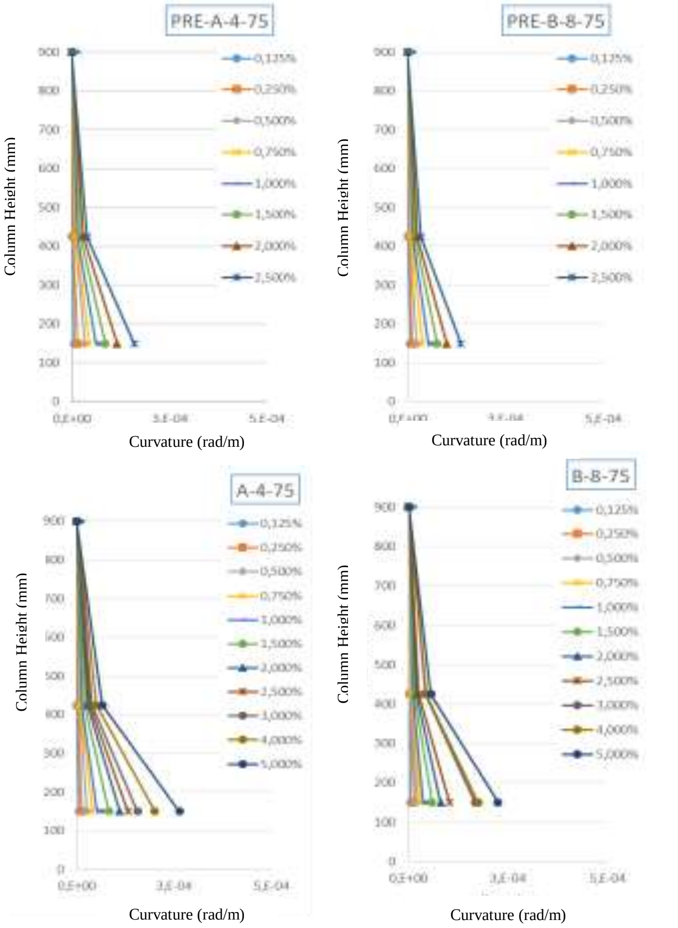

Fig. 7. Distribution of cutvature

From the above graph, it can be seen that the column with longitudinal reinforcement retrofit laying evenly distributed on all side in retrofit's cross section has a smaller curvature compared to the column whose retrofit reinforcement is only spread over several reinforcement points. This can indicates that confinement with a more tight reinforcement distance can better control damage to the plastic hinge zone in the column.

So that in some concrete regulations, including the Indonesian regulation SNI 03-2847-2013, it states that every 35 mm maximum distance must be given a hook of transversal reinforcement which is bound to longitudinal reinforcement, this is to ensure the column restraint level against column curvature.

C. Ductility

TABLE II. Ductility Specimen

Specimen		δy (mm)	δu (mm)	Ductility μ	Improved Ductility
S1	Pre-A-4-75	0,93	2,00	2,14	*(Control)*
S2	Pre-B-8-75	1,07	2,00	1,88	*(Control)*
S1	A-4-75	0,93	3,00	3,21	150%
S2	B-8-75	1,27	3,00	2,37	126%

The increase in ductility when viewed from the effect of the longitudinal reinforcement configuration in this study shows that the retrofitting A configuration is that the distance between the longitudinal reinforcements is farther than that of configuration B which results in different ductility closer. The effect that arises in this study that causes differences in the level of column ductility is caused by other parameters, namely, the difference in the size of retrofitting longitudinal reinforcement. In configuration A the size of bamboo reinforcement on retrofitting is 2 pieces of size 10x10 mm while in configuration B the size of bamboo reinforcement on retrofitting is 1 size 10x10 mm. This is certainly in accordance with the factors that influence confinement based on (Park R. & T. Paulay, 1974).

D. Stiffness

TABLE III. Stiffness Specimen

Specimen		P (kN)	Δ (mm)	Stiffness (kN/mm)	Improved Stiffness
S1	Pre-A-4-75	14,085	15,0	0,83	*(Control)*
S2	Pre-B-8-75	15,18	15,0	0,90	*(Control)*
S1	A-4-75	21,295	22,5	0,95	113%
S2	B-8-75	20,885	22,5	0,93	103%

In principle, the theory that stiffness (k) of material, elements and structure is directly proportional to the max load (P) which is held back and inversely proportional to the deformation that occurs (Δ).

If you look at the effect of the longitudinal reinforcement configuration in this study, it can be seen that configuration A, which is more tenuous between longitudinal reinforcements than the B configuration, results in better stiffness. This is seen from the configuration of reinforcement on the specimen that has been loaded at the beginning (Pre-loading) until it is damaged and the specimen that does not experience loading at the beginning. Surely the effect of bridle variation due to the difference in distance between longitudinal reinforcement in this study is less influential.

E. Dissipation Energy

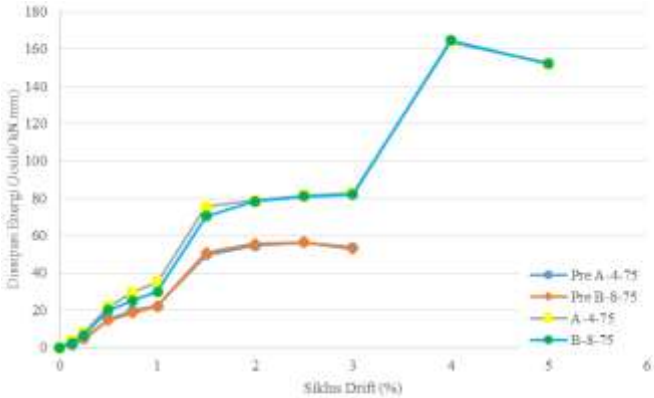

Fig. 8. Dissipation Energy of Specimens

There is energy dissipation in retrofit A column specimens and retrofit B specimens. It is seen that reinforcement in retrofit A specimens produces better energy dissipation ability than retrofit B specimens. From this it can be seen that if a structural element has good ductility, the element is also will emit energy well through energy dissipation capabilities.

VI. CONCLUSION

From the research result and analysis that has been done, the conclusion are as follows:

1. Concrete jacketing can increase the lateral capacity of the damaged column. while the increase that can be obtained is around 146%.
2. Columns with main reinforcements that are more closely spaced will produce better curvature and are distributed in plastic hinge area.
3. Ductility is important to the structure in the inelastic period. Ductility in existing damaged columns can be increased by concrete jacketing repair and strengthening. The ductility that can be increased is 126% - 150%.
4. If viewed in terms of stiffness of the test object, it can be seen that in the configuration of reinforcement points variation A gives more stiffness. On a retrofit of a damaged column the stiffness capacity rises to 113%.
5. Retrofit columns can increase energy dissipation in the column. This is also related to the area under the load deflection curve.

VII. SUGGESTION

From the research result and analysis that has been done, the conclusion are as follows:

1. It is necessary to conduct a review regarding more varied configuration of reinforcement points with different longitudinal reinforcement ratios.
2. It is necessary to review the surface treatment between old concrete and new concrete.
3. Need a more detailed review of nonlinear parameters in Numerical simulation analysis using the Finite Element method in the software.

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