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Experimental investigation of reinforced concrete column embedded with the angle steel shapes

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Abstract

Column is an important structural element in a building, because it carries some loads from the beams and the floors connecting to the column. Sometimes it needs to strengthen the existing column for some reasons. For example the load capacity of the column must be increased due to the compressive strength of the concrete column does not comply with the specified requirement. Investigation of the reinforced concrete column with angle steel shapes embedded at the corner of the column is limited. Therefore, it needs to investigate before developing the analysis for practical purpose design. This research conducts the experimental program of the reinforced concrete column with equal-leg angle steel shapes embedded at corner of the column. Eight specimens were tested in this experimental program. Four columns were subjected to the concentrically load and the other were subjected to eccentrically load. The specimens which embedded with angle steel shapes have various stiffeners spacing of 50 mm; 100 mm, and 150 mm. The column has length of 750 mm with sectional dimension of (75 mm x 75 mm). The column has four longitudinal reinforcements of 8 mm and stirrup of 5 mm. The equal-leg angle steel shape has size of (22.1 mm x 22.1 mm x 2 mm). The results of the experimental program show that compare to the reference specimen, the increment load of concentrically loaded column embedded with angle steel shape with stiffener spacing 50 mm, 100 mm, and 150 mm were 210.4447 %, 235.5426 %, and 185.6640 %, respectively. While the increment load of eccentrically loaded column embedded with angle steel shape with stiffener spacing 50 mm, 100 mm, and 150 mm were 85.5607 %, 34.6697 %, and 42.9479 %, respectively

Keywords: reinforced concrete column; equal-leg angle steel shapes; stiffeners spacing; capacity of column; concentric and eccentric load.

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1. Introduction

Column is a structural element of building that transfers loads from roof, slab, beam and others non structural element to the foundation of the building. It can be said that column is a very important element in structural building. So, it must be careful in designing column of high rise building. In a construction of high rise building made of concrete, sometimes the compressive strength of concrete does not comply with specified strength. Insufficient concrete strength can be occurred due to lack of quality control in making of concrete in the construction building. When an element of structure has insufficient strength, it needs to strengthen for safety reason.

There are some methods to strengthen the existing reinforced concrete columns. One of the methods is adding the existing column with an angle steel shape. Generally, the angle steel shape usually used for tension or compression members in roof structure. Now, the angle steel shape was used not only for roof structure members, but also for others element of structures. Research on the reinforced concrete columns embedded with angle steel shape were limited. Basuki [1] conducted a research on utility of angle steel shape as a compression member or column with the couple plat subjected to concentric load. His research showed that the closer spacing of the couple plat on the column, the stiffer the column. However, if the spacing of the couple plat on the column was un-uniform spacing, the column strength will decrease. Suwanto [2] conducted the research on composites column where the angle steel shape used as the reinforcement. His research showed that the angle steel shape can increase the column strength up to 13.85 % compare to the reinforced concrete column which has the same area reinforcement bars with angle steel shape.

Basuki [1] and Suwanto [2] conducted the research on utility of angle steel shape for structural element and reinforcement of the column, not for retrofitting an existing column. Therefore, it needs to conduct an experimental program of reinforced concrete column embedded with angle steel shape at the corner of the column.

2. Experimental program

Eight specimens were tested in this experimental program. Four columns were subjected to the concentrically load and four columns were subjected to eccentrically load. The column has length of 750 mm with the sectional dimension of (75 mm x 75 mm). The reinforced concrete column has four longitudinal reinforcements bar of 8 mm and stirrup of 5 mm with spacing of 50 mm. The equal-leg angle steel shape has size of (22.1mm x 22.1mm x 2mm) which was installed at the corner of the reinforced concrete column as a composite column (see Fig. 1) with couple plates as stiffeners (see Fig. 2). The couple plates as a stiffener were welded at the angle steel shapes with various spacing of 50 mm; 100 mm, and 150 mm (see Fig. 2). The average compressive strength of concrete f_c' at 28 days = 32.29 MPa, the average yield stress of longitudinal bar f_y = 266.8 MPa. While the average yield stress of angle steel shape f_y = 247.01 MPa.
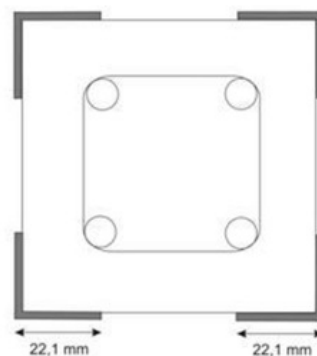
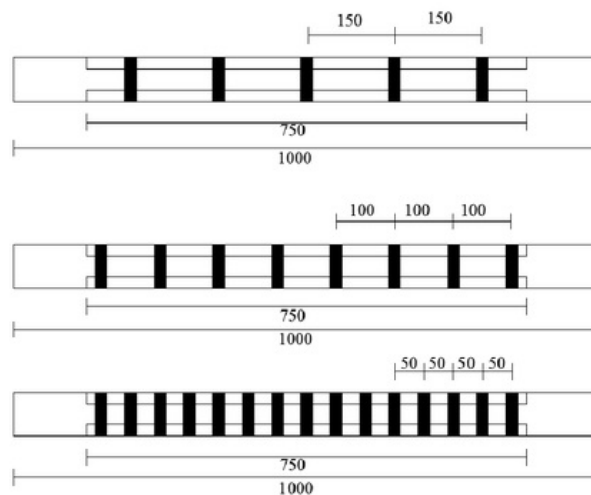Fig. 1. Position of angle steel shapes

Fig. 2. Various spacing of the stiffeners (in mm)

The concentrically loaded column were tested using Universal Testing Machine as shown in Fig. 3(a). While the eccentrically loaded column were tested using hydraulic jack which was setup at the loading frame as shown in Fig. 3(b) and have eccentricity = 75 mm. The loading was monotonic with load control.

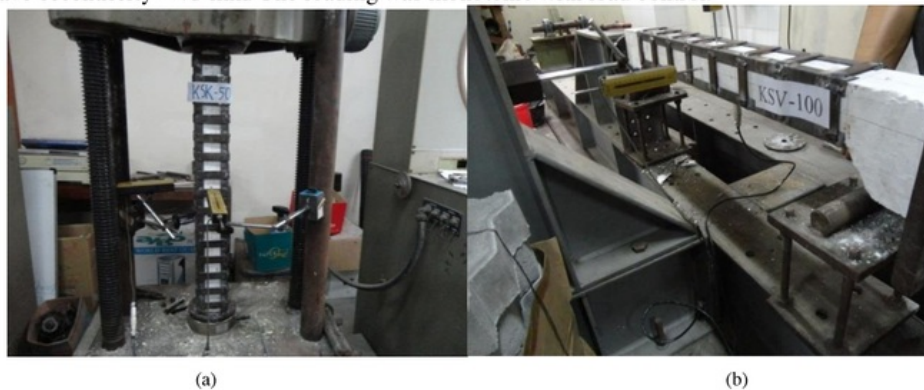(a)   (b)

Fig. 3. (a) Setup of concentrically loaded column; (b) Setup of eccentrically loaded column.

Linear Variable Differential Transformers (LVDT) was used to measure deflection at the mid span of the specimen. The deflections were measured with respect to both principal axes. Measured data both deflection and load were read through a computer driven data acquisition system by data logger. The surface of the column was whitewashed first and then square grids of 50 mm were drawn to facilitate the observation of crack propagation.

3. Results and Discussions

3.1. E Concentrically loaded column

There were four specimens of concentrically loaded column. The first specimen, KN, was reinforced concrete column without adding angle steel shape as the reference specimen. The second specimen, KSK-50, was reinforced concrete column embedded with angle steel shape and stiffener spacing of 50 mm. The third specimen, KSK-100,

was reinforced concrete column embedded with angle steel shape and stiffener spacing of 100 mm. The fourth specimen, KSK-150, was reinforced concrete column embedded with angle steel shape and stiffener spacing of 150 mm.

Comparing the maximum load among the concentrically loaded column specimens can be seen in Table 1.

Table 1. Maximum load of concentrically loaded column specimens [3].

Specimen	Maximum load (kg-f)
KN	6603.2388
KSK-50	20499.4020
KSK-100	22156.6780
KSK-150	18863.0780

Table 1 shows that compare to the reference specimen (KN), the increment load of specimen KSK-50, KSK-100, and KSK-150 were 210.4447 %, 235.5426 %, and 185.6640 %, respectively. Among KSK-50, KSK-100 and KSK-150, it can be seen that the specimen of KSK-100 gave the highest increment load. As Basuki [1] stated that the closer spacing of the couple plates on the column, the stiffer the column. It means that it would gave better confinement if the spacing of couple plates as close as possible. So KSK-50 would gave better strength than KSK-100. However, in this research KSK-100 gave a little bit higher strength than KSK-50, it might be due to the compressive strength of concrete of KSK-100 was a little bit higher than KSK-50.

The crack propagation of the concentrically loaded column can be seen in Fig. 4(a). The first crack will be occurred at the near both supports. After that, the crack propagated to the mid span of the specimen until the specimen was failure. Local buckling of the angle steel shape also occurred at the near support as shown in the Fig. 4(b).

Fig. 4. (a) Crack propagation of concentrically loaded column; (b) Local buckling of angle steel shape of concentrically loaded column.

3.2. Eccentrically loaded column

Four specimens of eccentrically loaded columns were tested in this experimental program. The first specimen, KN, was reinforced concrete column without adding angle steel shape as the reference specimen. The second specimen, KSV-50, was reinforced concrete column embedded with angle steel shape and stiffener spacing of 50 mm. The third specimen, KSV-100, was reinforced concrete column embedded with angle steel shape and stiffener

spacing of 100 mm. The fourth specimen, KSV-150, was reinforced concrete column embedded with angle steel shape and stiffener spacing of 150 mm.

The maximum load and deflection of each specimen can be seen in Table 2.

Table 2. Maximum load and deflection of eccentrically loaded column specimens [4].

Specimen	Maximum load (kg-f)	Deflection (mm)
KN	1714.010	8.3192
KSV-50	3180.529	8.4002
KSV-100	2308.252	7.0146
KSV-150	2450.141	11.3284

Table 2 shows that compare to the reference specimen (KN), the increment load of specimen KSV-50, KSV-100, and KSV-150 were 85.5607 %, 34.6697 %, and 42.9479 %, respectively. Among KSV-50, KSV-100 and KSV-150, it can be seen that the specimen of KSV-50 gave the highest increment load. This can be explained that KSK-50 had the closest spacing of couple plates. It means that the KSK-50 had better confinement compare to others, therefore it gave higher capacity. The relationship of load and deflection of specimen KSV-50 can be seen in Fig. 5.
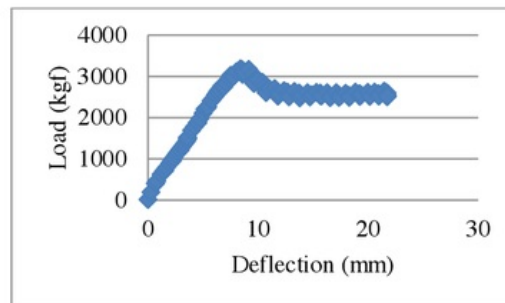
Fig. 5. Load-deflection relationship of specimen KSV-50.

Fig. 5 shows that the curve was increasing almost linearly until reaching the maximum load, after that the curve was decreasing nonlinearly with increasing deflection, and proceed with a section of horizontal curve prior to collapse. The crack propagation of the eccentrically loaded column can be seen in Fig. 6(a) and (b). Generally, the first crack was occurred at the outer tension fiber of column near to the support. As the load increased, the crack propagated to across the column up to compression fiber, then failure.

(a)   (b)

Fig. 6. (a) Crack pattern of the specimen KSV-50; (b) Crack pattern of the specimen KSV-150.

4. Conclusions

Based on the obtained experimental results, the following conclusions can be drawn:

1. Angle steel shapes embedded to the reinforced concrete column with plate stiffeners can increase the strength, both for concentrically loaded column as well as eccentrically loaded column.
2. Compare to the reference column the increment load of concentrically loaded column embedded with angle steel shape with stiffener spacing 50 mm, 100 mm, and 150 mm were 210.4447 %, 235.5426 %, and 185.6640 %, respectively.
3. Compare to the reference column the increment load of eccentrically loaded column embedded with angle steel shape with stiffener spacing 50 mm, 100 mm, and 150 mm were 85.5607 %, 34.6697 %, and 42.9479 %, respectively.
4. The relationship of load-deflection curve was increasing almost linearly until reaching the maximum load, after that the curve was decreasing nonlinearly with increasing deflection, and proceeded with a section of horizontal curve prior to collapse.
5. The concentrically loaded column embedded with angle steel shape was failure initiated with crack at the near support together with local buckling of the angle steel shape. While eccentrically loaded column embedded with angle steel shape was failure initiated with crack at the outer fiber near to the support, then it propagated across the column up to compression fiber.

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