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The Placement Position of Hollow Cores in the Ideal Longitudinal Direction on the Reinfoced Concrete Beam

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ABSTRACT
Reinforced concrete beam is a structure that designed to restrain the bending moment, torsional moment, axial force and shear force, made of concrete which functions to withstand compressive strength and reinforcing steel to withstand flexural strength. However, of reality many other utilities as: water supply, sewerage, power lines, telephone cables, air conditioning systems, computer networks and so on, attached to the beam, so that it looks less aesthetic and protected. If the utility is placed in the block space by making a hole in the beam in the compressed area, it will reduce the compression strength. Therefore, it will be investigated the strategic position of the hollow cores longitudinal direction, so that the strength of the beam is not reduced, it can function as a structure that holds and distributes the loads that work on it, and as a support for utility. The purpose of this research was to make a reinforced concrete beam, apart from it has function as a structure that holds and distributes the loads that work on it, it also has function as a utility support by utilizing the space in the structural beam. To achieve the purpose of this research, 10 specimens of 100x150x750 mm beam with 4 variations in placement of hollow cores made of Polyvinyl Chloride with 1 inch diameter, which is compared to a beam without a hollow core. Testing of reinforced concrete beams is carried out based on the standard simple beam with centre-point loading, after curing for 28 days to obtain data: ultimate load, modulus of rupture (MOR) that can be withheld by blocks, modulus of elasticity (MOE) and cracked fields that occurs beam. Based on the results of the research has been undertaken, it indicated that the position of hollow care that is put on the tensile zone in the longitudinal direction of the beam increased the stiffness (MOE) on the beam, ultimate load and modulus of rupture (MOR) which the beam can withstand. However, a reinforced Concrete beam with a hollow core of 100 mm from the top of the beam decreased stiffness. The collapse that occurred in the reinforced concrete beam with a hollow core started from the cracked at the very bottom of the beam, in the middle of the span in the tensile zone.

Keywords: *hollow core, modulus of rupture,*

1. INTRODUCTION

Concrete is a mass made from a mixture of cement, water and aggregate. Aggregate consists of fine aggregate (sand), and coarse aggregate (crushed stone). The structure of beam is made of concrete or other materials are basically planned to accept the bending moment, torsional moment, axial force, shear force or a combination of these forces. Concrete has advantages including high compressive strength, resistance of corrosion and resistance of fire, but it also has disadvantages such as flexural strength is only 10-15% of its compressive strength. Meanwhile, reinforcing steel has high flexural strength. Hence, to withstand the bending moment and force that will work on the beam, reinforcing steel is used so that a building construction method is called as reinforced concrete.

The structure of high-rise buildings, bridges, overpasses that use reinforced concrete as the forming material, it usually requires utility networks such as: water supply, sewerage, power lines, telephone cables, air conditioning systems, computer networks and so on. This network placement is usually only attached to the beam or placed at the top of the ceiling for buildings. In this regard, it certainly seems less aesthetic and less protected.

Creating the holes in reinforced concrete beam can reduce the weight of the beam, which certainly it can save concrete material, so that the cost of making concrete becomes more economical. The lighter weight of the concrete can also mitigate the danger of an earthquake. However, the reduced cross-sectional area of the beam, it has function to withstand the compressive strength that will work together with the reinforcement to restrain the bending moment and certainly it will also decrease.

The position of placing the hollow core on the beam and the material that is used, it will certainly greatly affect the flexural strength that the beam can withstand. If it is put in compression zones (in the compressed area), thus, it will affect on the compressive strength. Whereas, if it is placed in tensile zones, it will not affect the flexural strength. This is due to the flexural strength of the concrete, which is only 10-15% of its compressive strength, it is not optimally utilized. Research [1], by placing holes in compression zones, neutral axes and tensile zones in the direction of longitudinal beams and the diameters of hole that vary, it is found that if the holes are placed in compression zones, it will reduce the flexural strength of beams. Meanwhile, if it is placed in tensile zones, it will not affect the flexural strength of beams. Flexural strength also affects the hole diameter, the larger of the hole diameter, the smaller of the flexural strength that can be resisted by the beam.

Many previous studies have been carried out, including: research [2], using reinforced concrete beams in the size of (150x150x600) mm with the diameter of tensile steel is 8 mm and the variation of pipe diameter is ½ inch; 1 inch; 1½ inch and reinforced concrete beams without hollow cores. The results of the research on the relationship between flexural strength and variations in pipe diameter indicate that the larger of the diameter of the pipe, the smaller of the flexural strength that can be withstood by the beam.

Research [3], using Polyvinyl Chloride Pipe and Galvanized Iron Pipe vary on 1ø63.5 mm and 2ø31.75, placed in tensile zones (50 mm below the neutral axis) with cross section (150 x 200) mm, it is found that flexural the strength of beams using Galvanized Iron Pipe 1ø63.5 mm is greater when compared to beams without hollow cores and beams with Polyvinyl Chloride Pipe. Beams with hollow core Polyvinyl Chloride Pipe have lower bending strength when it is compared to beams without holes. Beams use the holes for Polyvinyl Chloride Pipe and Galvanized Iron Pipe with holes 1ø63.5 mm and those have a higher flexural strength than those that use holes 2ø31.75 mm.

Research [4], the size of beams is (150x150x1400) mm, with varying pipe diameters ø 32 mm, ø 40 mm and ø 50 mm that placed in compression zones along the beam (longitudinal direction of the beam), it is found that the forces that can be retained, it decreases along with the increase of diameter of the hole when it is compared to a beam without a hollow core.

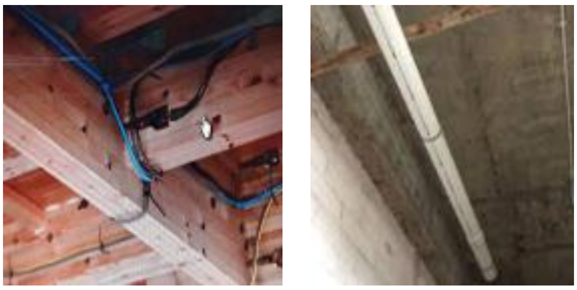
Based on [5], that making holes in reinforced concrete beams is only allowed about 4% of the cross-sectional area of reinforced concrete.

In this research, we will use Polyvinyl Chloride Pipe which is placed in the longitudinal direction of the beam with various placement positions, so that an alternative design will be obtained by utilizing the space in the structural beam. Apart from it has function as a structure that holds and distributes the loads that work on it, the beam can also has function as a utility support.

The main purpose of this research was to obtain the placement position of hollow cores in the ideal longitudinal direction on the reinfoced concrete beam, by way of analyzing the ultimate load and modulus of rupture (MOR) that could be resisted by the beam and also the stiffnees/modulus of elasticity (MOE) and cracked fields that occured in the beam, so that an economical beam structure will be obtained without reducing the function of the beam to carry out the loads, mitigate earthquakes and has aesthetic value.

2. METHODOLOGY

This research was undertaken based on seeing the cases in the field, where the electrical installation is attached to the beam (Figure 1.a) and the sewerage installation is also sticked to the beam (Figure 1.b).



a.Electrical installations b. Sewerage installations

Figure 1. Electrical installations and sewarage installations attached to the beams

Therefore, in order to achieve the objectives of this study, 10 specimens of 100 x150 x 750 mm were made, in which 2 specimens were made for each variation of pipe placement. Testing of reinforced concrete beams was carried out based on the standard simple beam with center-point loading [6], after curing for 28 days. Reinforced concrete beams were planned to have a compressive strength of fc ± 20 MPa. The concrete forming materials consisted of: fine aggregate (sand) is originated from the Musi river. coarse aggregate (crushed stone) comes from Bojonegoro and Portland cement of type I under the brand name of Baturaja. To get the targeted compressive strength, a mix design was carried out first based on [7], the material will be used, it must be tested for physical properties, including: Sieve Analysis of Fine and Coarse Aggregates [8], Relative Density (Specific Gravity) and Absorption of Coarse Aggregate [9], Relative Density (Specific Gravity) and Absorption of fine Aggregate [10], Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing [11], Bulk Density ("Unit Weight") and Voids in Aggregate [12], Organic Impurities in Fine Aggregates for Concrete [13], Determination of aggregate crushing value (ACV) [14], Abrasion and Impact in the Los Angeles Machine [15], Density of Hydraulic Cement [16] and Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate [17]. Concrete compressive strength test specimens were made in accordance with the standard [18], as many as 3 samples were cylindrical with a diameter of 15 cm and a height of 30 cm, tested after being cured for 28 days. Reinforcing steel used to make beam, it has a tensile strength of fy ± 240 MPa. Flexural steel 2 ø 10, compressive steel 2 ø 6, shear steel ø6-50 (Figure 2.a). The placement position of pipe, it varies with distance: reinforced Concrete beam with hollow core 40 mm (Figure 2.b); reinforced Concrete beam with hollow core 60 mm (Figure 2.c); reinforced Concrete beam with hollow core 80 mm (Figure 2.d) and reinforced Concrete beam with hollow core 100 mm (Figure 2.e) from the top of the beam section. Based on calculations, the location of the hole is located below the neutral axis (tensile zone).

Based on the Indonesian National Standard (SNI 06-0084-2002), the polyvinyl Chloride Pipe used for water supply installations has a diameter of 1 inch, has a modulus of elasticity of ± 3000 MPa, tensile strength of 50-80 MPa and specific gravity of ± 1.4 gr/cm3.

The test results of a simple beam with center-point loading beams without a hollow core and a beam with a hollow core placement position in varying longitudinal directions would be calculated using the formulas (1), (2) and (3), would be illustrated in the form of relation between Modulus of Rupture and modulus of elasticity histogram of specimens and form of relation between load-displacement curves of specimens, it would be analyzed through the ultimate load and flexural strength that the beam can withstand as well as the stiffness and cracked fields that occured in the beam, so that the conclusions of this research will be obtained. The modulus of rupture (MOR) and modulus of elasticity (MOE) of the simple beam test with center-point loading, used the following formula (ASTM C293/C293M-16):

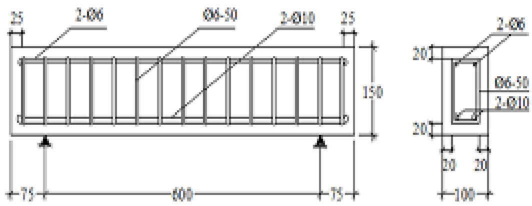
$$\mathrm{MOR} = \frac{3P.L}{2.b.h^2} \quad (1)$$

$$\mathrm{MOE} = \frac{\sigma}{\varepsilon} \qquad \mathrm{MOE} = \frac{\sigma}{\varepsilon} \quad (2)$$

$$\sigma = \frac{P}{A}\ ;\ \varepsilon = \frac{\Delta L}{L_o} = \frac{L_1 - L_o}{L_o} \quad (3)$$

where:

MOR= Modulus of rupture (MPa)
MOE= Modulus of elasticity (MPa)
σ = Stress (MPa)
A = cross sectional area (mm2)
ΔL = is change of the length (mm)
ε = Strain (%)
L = Span length (mm)
P = Maksimum load (N)
b = Average width (mm)
h = Average depth (mm)
Lo = length after elongation (mm)
L1 = original length (mm)



a. Reinforced Concrete beam (RC)

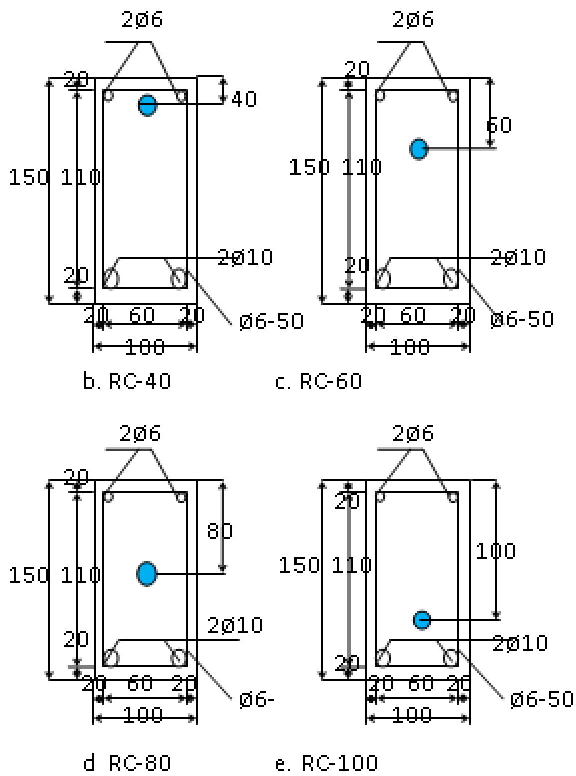


Figure 2. Detail reinforced steel concrete beams with hollow core position.

3. RESULTS AND DISCUSSION

The results of testing the physical properties of concrete forming materials can be seen in Table 1. The materials used are: Fine aggregate (sand) is included in zone 3 (finely graded sand), coarse aggregate has a maximum grain size of 20 mm. Composition of cement: fine aggregate (sand): coarse aggregate (crushed stone) calculation results of mix design concrete obtained a ratio is 1: 1.3: 1.7, with a cement water ratio (w/c = 0.5).

Table 1. Results Testing of physical properties of coarse/fine aggregates and cement

Testing	Result Test			Unit
	Sand	Gravel	cement	
Sieve Analysis	Zone 3	Max 20	-	
Specific gravity Bulk	2.14	2.70	3.0	
Specific gravity saturated-surface-dry (SSD)	2.21	2.74	-	
Absorption	2.79	1.34	-	%
Materials Finer than 75μm	2.51	1,09	-	%
Unit Weight	1302	1401	-	kg/m^3
Aggregate crushing	-	11,52	-	%
Aggregate abrasion	-	15,18	-	%
Fine Modulus	2.98	7.71	-	%
Soundnees Test	-	2.08	-	%
Organic Impurities	non	-	-	%

Compression strength test results for 3 concrete cylinder samples obtained fc = 20.22 MPa and density 2200 Kg/m3. The weight of a concrete beam with a hollow core was reduced by ± 4% from a beam without a hollow core.

Data from the ultimate load test, Modulus of elasticity, Modulus of rupture reinforced concrete simple beam with center-point loading with various pipe placement positions can be seen in Table 2. The results of flexural strength testing on the relationship between displacement and ultimate load can be seen in Figure 3, where the ultimate load and flexural strength/modulus of rupture that can be detained by the beam, it has the highest increase in RC-80 (Fig. 2.d) beams by 74%, RC-60(Fig. 2.c) beams are 61%, RC-40 (Fig. 2.b) beams are 50% and RC-100 (Fig. 2.e) beams are only 5 % compared to reinforced concrete without holes(Fig. 2.a). This can occur because the position of the pipe placement is located in the tensile zone (below the neutral axis), so that the reduced cross-sectional area of the concrete, it does not affect the compression strength that will work together with the reinforced steel in carrying the load and bending moment.

Table 2. Summary of Ultimate Load, MOR and MOE

No. specimen	distance from the top of the beam		Ultimate Load (N)	MOR (MPa)	MOE (MPa)
	mm	Fig.			
RC-1	0	2.a	28,000	11.20	12,89
RC-2			26,880	10.75	23,57
RC-40A	40	2.b	41,330	16.53	39,09
RC-40B			40,848	16.34	41,61
RC-60A	60	2.c	49,243	19.70	48,81
RC-60B			39,258	15.70	39,99
RC-80A	80	2.d	50,283	20.11	17,92
RC-80B			45,024	18.01	39,49
RC-100A	100	2.e	22,440	8.98	27,98
RC-100B			35,113	14.05	35,28

Based on the Whitney stress block, that: compression concrete under the neutral axis does not really affect the ultimate strength of a beam, because the strength below the neutral axis is dominated by the tensile strength which is fully accepted by reinforced steel. Although compression concrete under the neutral axis is neglected, it also plays a role as a medium for transferring stress between the compression zone to the tensile zone. The installation of polyvinyl Chloride Pipe, which replaces this role, it can increase Flexural strength due to polyvinyl Chloride Pipe has a modulus of elasticity of ± 3000 MPa and tensile strength is 50-80 MPa, where the tensile strength of concrete used in this research is merely ± 2 MPa. The stiffness of the beam can be seen from the slope of the curve in relation to the load and beam displacement (Figure 3). The steeper the slope of the curve, so then the beam is more likely to be the stiffness, or vice versa. Inertia moment is the tendency of an object to rotate about its axis while carrying a load. The inertia moment of a section greatly affects flexural strength, shear strength and torsion strength.

In Figure 4 can be seen that: the biggest of the increase in stiffness/modulus of elasticity occurs in RC-60 (Fig. 2.c) beams are 144%, followed by RC-40 (fig. 2.b) beams of 121%, RC-80(Fig. 2.d) beams are 57%, while in RC-100(Fig. 2.e) beams experience the decrease of stiffness and it gains 57%. The stiffness of the beam which decreases, it can be caused by reduced moment of inertia and tension stiffening in the beam section. If there is a hollow core in the beam, then the stiffness tensile zone (stiffness in the tensile area) of the concrete, it will decrease so that the modulus of elasticity will also decrease when compared to a beam without a hollow core.

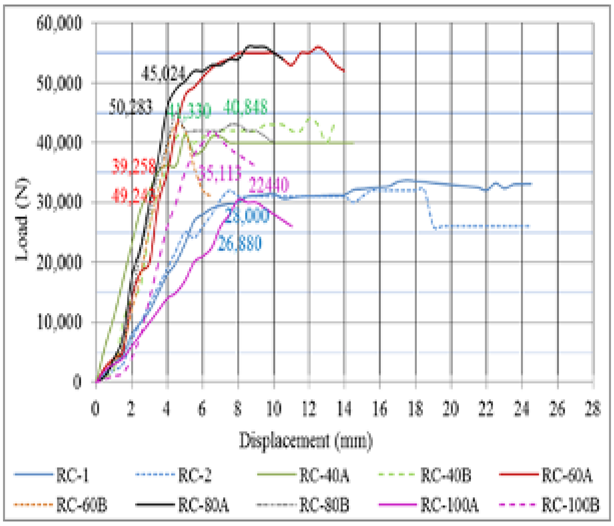


Figure 3. Relation between load-displacement curves of specimens

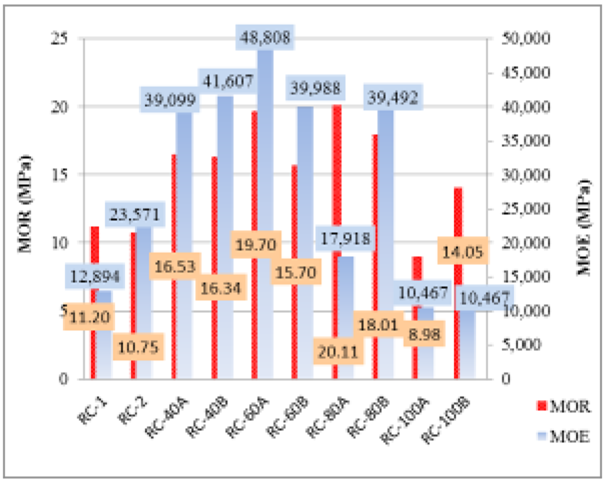
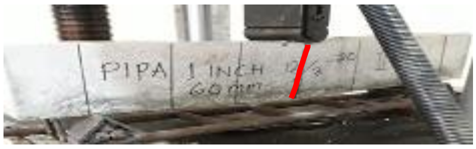


Figure 4. Modulus of Rupture and Modulus of elasticity

Dealing with the observations when testing the flexural reinforced concrete beam until the load has been decreased, it can be observed that the crack pattern that occurs in the reinforced concrete beam with the placement of the hollow core in the longitudinal direction varies in the beam can be seen in (Figure 2.a, 2. b, 2.c, 2.d and 2.e), where the crack patterns that occur can be seen in (Figure 5.a, 5.b, 5.c, 5.d and 5.e). The crack pattern that occurs in all specimens is tensile crack (flexural crack). Flexural cracks occur in the tensile strees starting from the very bottom of the beam in the middle of the span and spreading upwards, followed by other cracks, it is still in the tensile area.

a. RC beam

b. RC-40 beam



c. RC-60 beam

d. RC-80 beam

e. RC-100 beam

Figure 5. Failure modes and crack patter ns of specimens

4. CONCLUSION

Based on the research that has been conducted, it can be concluded that: The placement position and the hollow core material used, it greatly affected on the ultimate load and modulus of rupture (MOR) that could be held by the beam and the value of stiffness (MOE) on the beam. It is better, if the position of the hole placement is in the tensile area below the neutral axis, because it does not reduce the strength of the beam.

The collapse that observed in reinforced concrete beams and reinforced concrete beams with hollow cores, starting from the cracked at the very bottom of the beam, in the middle of the span in the tensile area.

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