

Effect of Cross Section Dimensions to Stiffness and Deflection on Reinforced Concrete Beams

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ABSTRACT

The strength of reinforced concrete can be planned in various ways, either doing manual calculations, compressive strength testing, or testing using applications. Therefore, an accurate result approach can be obtained, one of which is by using the Response-2000 application program. This research aims to obtain the output results of the Response-2000 program in the form of deflection values, maximum load, crack width, and stiffness. The research was conducted by modeling beam specimens with dimensional variations but the cross-sectional area was the same as the total model of 10 samples. The results of the analysis show that with the same surface area but the shape of the shape and also the different dimensions of the beam greatly affect the deflection value, maximum load, crack width, and stiffness. Test object I1 has the smallest deflection value that is 7.524 mm and test object I2 has the largest deflection value, namely 19.759 mm. Of all the specimens experiencing flexural cracks, specimen I3 had the smallest crack width, namely 1.59 mm and specimen I2 had the largest crack width, namely 14.29 mm. The T2 specimen has the smallest stiffness value, namely 23.5 kN/mm and the I1 test object has the largest stiffness value, namely 91.4 kN/mm.

Keywords: *Deflection, maximum load, crack patterns, reinforced concrete beam, response-2000*

1. INTRODUCTION

Concrete is one of the most widely used construction materials in the world. The advantages of concrete include its strength against compressive loads, economics and good durability. In general, the building blocks of concrete consist of water, cement, coarse aggregate, fine aggregate and reinforcement which is often known as reinforced concrete. Reinforced concrete can be used in various types of infrastructure such as roads, bridges, buildings and various other types of buildings. Beams are one structural element that is quite important in several types of construction, especially buildings. Beams generally serves to to accommodate vertical loads are then transferred to other structures. The types of beam cross-section are quite varied, such as square, I, T, and trapezium. In general, the level of ductility and deflection of the beam is very important, so in designing the beam it is necessary to take into account the moment of inertia and the modulus of elasticity.

Analysis of the capacity of reinforced concrete blocks can be carried out by a variety of methods, ranging from finite element analysis to manual calculations. One application that is quite easy to use in analyzing the performance of reinforced concrete beams is using the Responce-2000 application. Responce-2000 application is a computer program developed

by Evan Bents at the University of Toronto [1]. At this time, this application has been widely used by various researchers in various countries. Several research results using Response-2000, among others, are to determine the response of critical shear forces in reinforced concrete beams [2], calculate the value of stiffness and moment of curvature of reinforced concrete beams [3,4], utilization of waste as recyceaggetae [5, 6].

The shape and size of the cross section is one of the important components of reinforced concrete beams. One of the advantages of concrete material is the shape that can be reduced according to needs. Several studies have been conducted on the cross-sectional shape of reinforced concrete beams, including rectangular beam [7-10], T beam [11-13], I beam [14-16]. In this test, using the Response-2000 program, which is one of the programs used to analyze a beam that is loaded with a certain force. The test object to be tested is beam T and beam I, this study performs a flexural test of the beam. The difference between each beam specimen lies in the dimensions, but the surface area, steel quality, concrete quality, dimensions of reinforcement, spacing, and span length have the same size of the 10 specimens, so the results obtained will determine the deflection, load maximum, crack width, and stiffness.

2. METHODOLOGY

2.1 Experimental Program

The specimens used in this study were beams of T and I shape, with a concrete quality of 30 MPa, and a tensile strength of 392 MPa. In this study consisted of 10 models where 5 models were T-shaped beams and 5 I-shaped beams with the same area but different cross-sectional sizes. The length of the entire beam is 6 m. Reinforced concrete beam design refers to the applicable standards in Indonesia [17, 18] with loading in the form of point loads in the middle of the span. The research implementation starts from looking for references, determining beam design, determining reinforcement design, manual analysis according to SNI-03-2847-2002, SNI-2847-2013 and SNI 1725: 2016 and then analysis using the Response-2000 program.

Beam analysis using the Response-2000 program by entering the specimen data specifications from the shape, dimensions, spacing, span, reinforcement ratio, concrete quality, and steel quality. Then after all the inputs are finished running. The results of the Response-2000 program analysis are data, graphics and crack pattern images. The beam is

analyzed manually beforehand to determine the value of its capacity and reinforcement design.

2.2 Model Dimensions

T1 beam specimen with dimensions of flange width (b) 500 mm flange height (hf) 200 mm, beam width (be) 400 mm and beam height (h) 500 mm using a ratio of reinforcement ρ_{min} with stirrup distance 200 mm, span length 6 m. Dimensions of specimen beam I₁ upper and lower flange width (b) 500 mm upper and lower flange height (hf) 190 mm, beam width (be) 350 mm and beam height (h) 700 mm. Dimensions of beam I₂ upper and lower flange width (b) 500 mm, upper and lower flange height (hf) 180 mm, beam width (be) 300 mm and beam height (h) 400 mm with a combination of reinforcement ratio ρ_{min} , spacing 200 mm, and a span length of 6 m. The specifications of the T-beam specimen can be seen in Table 1, for the reinforcement and the span of the T beam can be seen in Table 2. The dimensions and length of the test object beam I can be seen in Table 3 and for variations in the reinforcement of the test object beam I can be seen in Table 4.

Table 1. Dimensional objects test beams T

Test Object	Beam Height (mm)	Beam Width (mm)	Wing Height (mm)	Wingspan (mm)
T ₁	500	400	200	500
T ₂	400	450	200	600
T ₃	450	400	200	600
T ₄	400	400	200	700
T ₅	435	400	180	700

Table 2. Object review and length of test beam T

Test Object	Diameter of the principal reinforcement	Reinforce-ment ratio (ρ)	Reinforce-ment of stirrups (mm)	Beam Length (m)
T ₁	2D25-3D25	ρ_{min}	D10-200	6
T ₂	2D25-3D25	ρ_{min}	D10-200	6
T ₃	2D25-3D25	ρ_{min}	D10-200	6
T ₄	2D25-3D25	ρ_{min}	D10-200	6
T ₅	2D25-3D25	ρ_{min}	D10-200	6

Table 3. Dimensional objects test beams I

Test Object	Beam Height (mm)	Beam Width (mm)	Top wing height (mm)	Lower wing height (mm)	Top wingspan (mm)	Lower wingspan (mm)
I ₁	500	300	150	150	500	500
I ₂	400	300	180	180	500	500

l_3	400	300	200	200	400	500
l_4	400	300	200	200	500	400
l_5	400	300	200	200	450	450

Table 4. Object review and length of test beam I

Test Object	Diameter of the principal reinforcement	Reinforcement ratio (ρ)	Reinforcement of stirrups (mm)	Beam Length (m)
l_1	2D25-3D25	ρ min	D10-200	6
l_2	2D25-3D25	ρ min	D10-200	6
l_3	2D25-3D25	ρ min	D10-200	6
l_4	2D25-3D25	ρ min	D10-200	6
l_5	2D25-3D25	ρ min	D10-200	6

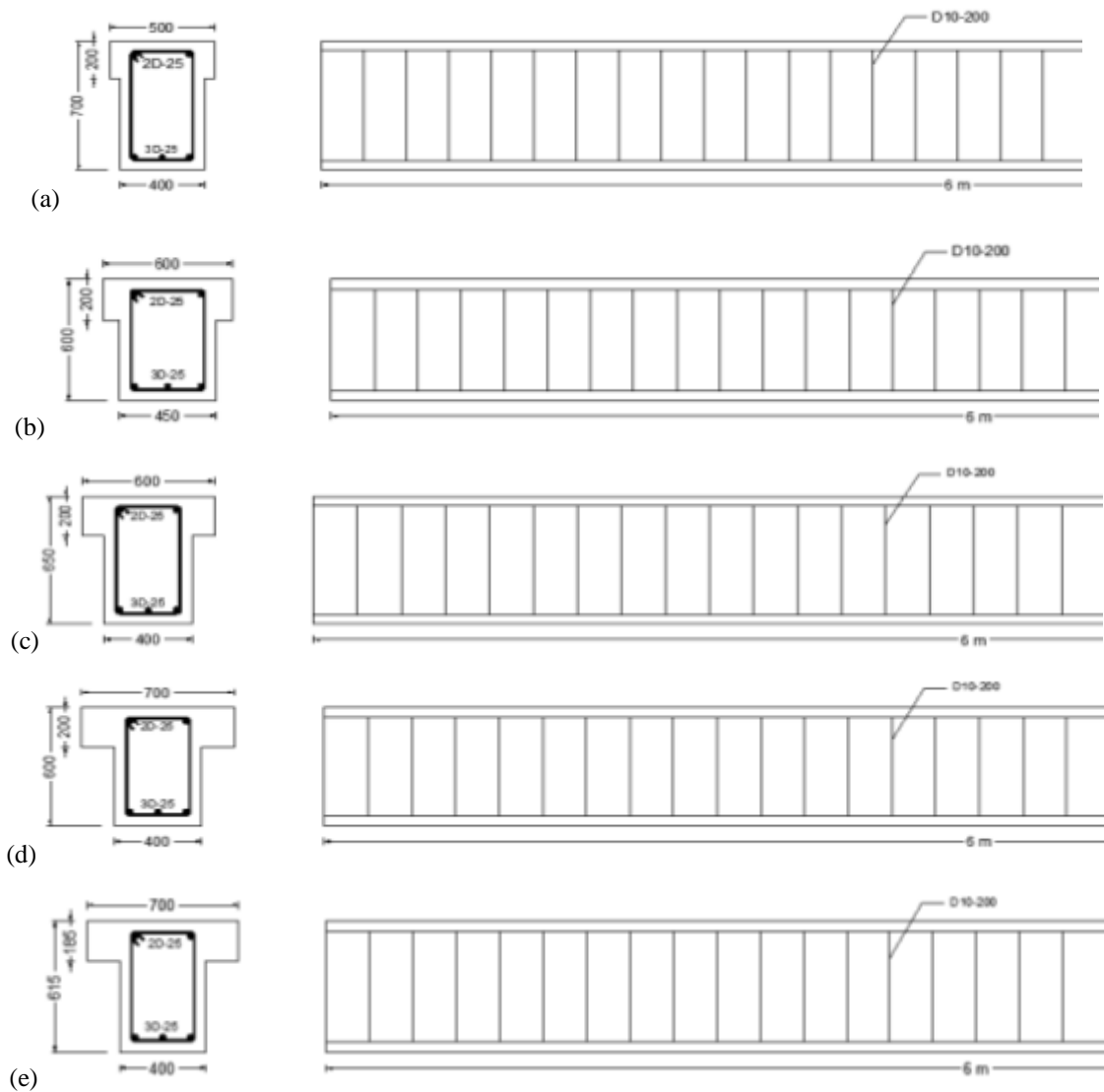


Figure 1 Geometry of beams T (a) T1; (b) T2; (c) T3; (d) T4; (e) T5

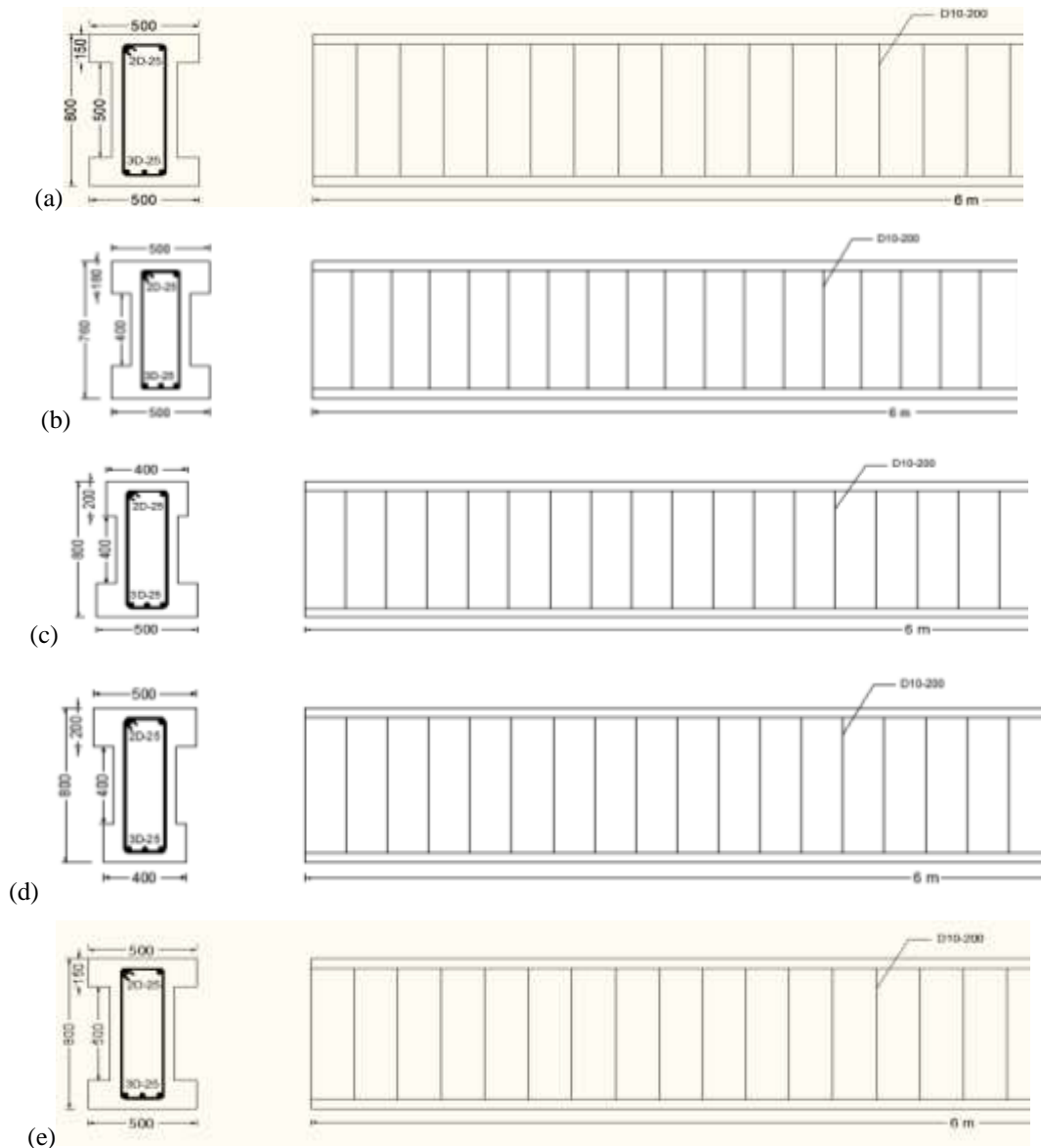


Figure 2 Geometry of beams I (a) I1; (b) I2; (c) I3; (d) I4; (e) I5

3. RESULT AND DISCUSSION

The results of the analysis using the Response-2000 program resulted in deflection values, maximum load, Crack Pattern, and Stiffness.

3.1 Defection

Deflection is a change in the shape of the block in the y direction due to the vertical loading applied to the beam or rod. From the results of the Response-2000 analysis can compare the deflection value of concrete beam specimens with the same surface area and the same span but different dimensions. In Table 5, it can be seen that the T₁ beam test object has the smallest deflection value with a value of 10.604 mm, while the T₄ test object has the largest deflection value with a value of 15.685 mm. T₁ test object having the smallest deflection for the test object has a size dimension, height 500 mm, width 400

mm, height 200 mm wings, wingspan 500 mm with ρ_{min} principal reinforcement and stirrups distance of 200 mm. T₄ specimen has the smallest deflection because this specimen has dimensions, 400 mm high, 400 mm width, 200 mm wingspan, 700 mm wingspan with ρ_{min} main reinforcement and 200 mm stirrup spacing.

Table 5. Beam deflection T

Test Object	Span (m)	Surface area (mm ²)	Deflection (mm)
T ₁	6	300000	10.604
T ₂	6	300000	14.655
T ₃	6	300000	13.565
T ₄	6	300000	15.685

T ₅	6	300000	14.955
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Table 6. Beam deflection I

Test Object	Span (m)	Surface area (mm ²)	Deflection (mm)
I ₁	6 m	300000	10.546
I ₂	6 m	300000	19.759
I ₃	6 m	300000	10.414
I ₄	6 m	300000	10.791
I ₅	6 m	300000	17.347

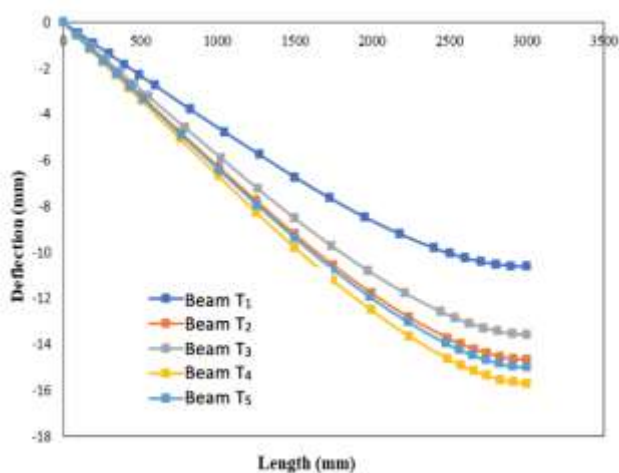


Figure 3 Result of deflection of specimen beam T

Beam I₃ having the smallest deflection value with the value of 10.414 mm deflection, while the test objects I₂ has the greatest deflection value with the value of 19.759 mm deflection. Test object I₁ has the smallest deflection because this specimen has dimensions, 400 mm high, 300 mm width, 200 mm upper wing height, 200 mm lower wing height, 400 mm upper wingspan, 500 mm lower wingspan with ρ_{min} and basic reinforcement. stirrup distance 200 mm. Test object I₂ has the largest deflection value because this specimen has dimensions of height 400 mm, width 300 mm, upper wing height 180 mm, lower wing height 180 mm, upper wing width 500 mm, lower wing width 500 mm with principal reinforcement ρ_{min} and stirrup distance 200 mm. The results of the deflection comparison can be seen in Table 5 and Table 6, while the relationship between span length and deflection can be seen in Figure 3 and Figure 4.

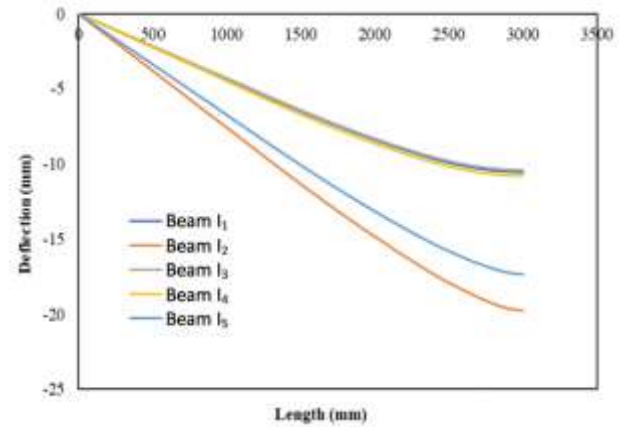


Figure 4 Result of deflection of beam specimen I

3.2 Maximum Load

As a result of the vertical loading from the y direction on the beam specimen, it will cause deflection. Results of the Response-2000 program analysis, the load is shown in Table 7. Based on Table 7 it can be seen that beam I₅ has the largest maximum load value with a value of 136.406 kN, while beam T₂ has the smallest maximum load value with a value of 95.153 kN. The I₅ beam has the largest maximum load value because the I₅ beam specimen with a span of 6 m has dimensions with a height of 400 mm, a width of 300 mm, an upper flange height of 200 mm, a lower flange height of 200 mm, an upper flange width of 400 mm, a lower flange width. 500 mm with principal reinforcement ρ_{min} and stirrup 200 mm, while the T₂ beam has the smallest maximum load because the test object T₂ beam with a span of 6 m has dimensions of 400 mm high, 450 mm wide, 200 mm wing height, 450 mm wingspan with reinforcement principal ρ_{min} and 200 mm stirrup distance.

Table 7. Maximum deflection value and maximum load

Test Object	Span (m)	Maximum Deflection (mm)	Maximum Load (kN)
T ₁	6	22.252	118.250
T ₂	6	15.388	95.153
T ₃	6	14.243	104.803
T ₄	6	16.469	96.476
T ₅	6	15.745	99.303
I ₁	6	11.073	132.638
I ₂	6	20.747	129.817
I ₃	6	10.935	130.198
I ₄	6	11.331	132.636
I ₅	6	18.214	136.406

3.3 Crack Patterns

Based on the results of the T and I beam crack pattern testing using the Response-2000 program, it can be seen from

Figure 5 to Figure 6. Based on Figure 5 to Figure 6, it can be seen that from the test object beam I, beam I₃ shows the smallest maximum crack width value with a value of 1,59 mm, while beam I₂ shows the maximum value of the maximum crack width with a value of 14.29 mm. As for the T-beam specimen, T₂ beam shows the smallest maximum crack width value with a value of 2.09 mm, while the T₁ beam shows the largest crack width value with a value of 11.23 mm. In general, flexural cracks occur in beams in the form of fine cracks starting from the lower side in the middle of the span, then spreading towards the support and propagating towards the load until the specimen collapses. The crack pattern that occurs in the test object can indicate the type of collapse that occurred in the test beam. The following is a graph comparing the crack width between beam T and I, with the value of the smallest fracture width in beam I₃ and the largest crack width in beam I₂. In Figure 7 is the maximum overall crack result.

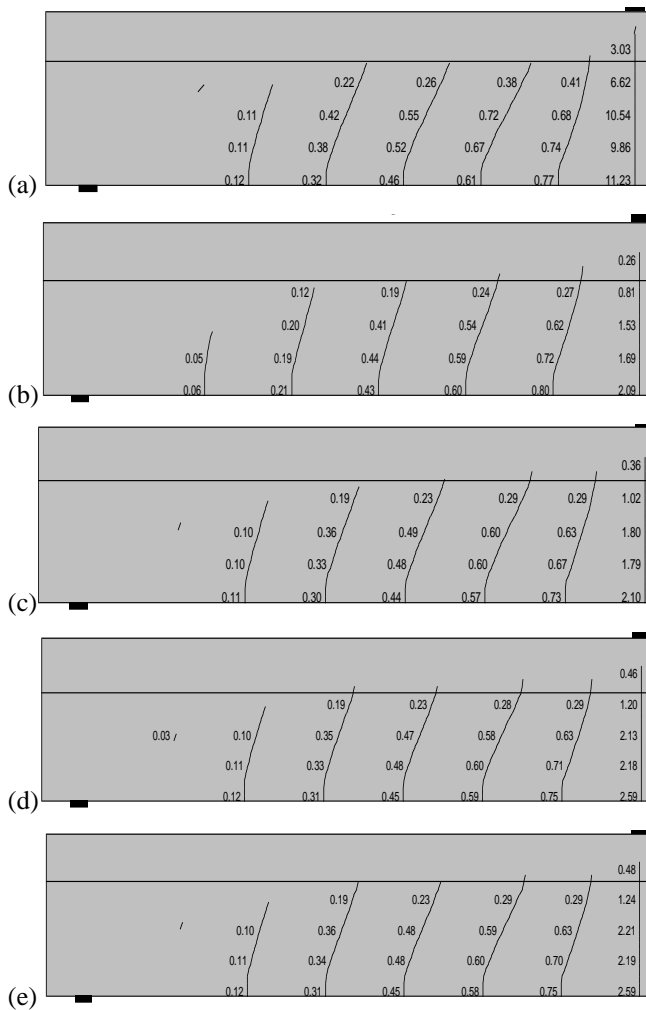


Figure 5 Crack Pattern Beams T (a) T1; (b) T2; (c) T3; (d) T4; (e) T5

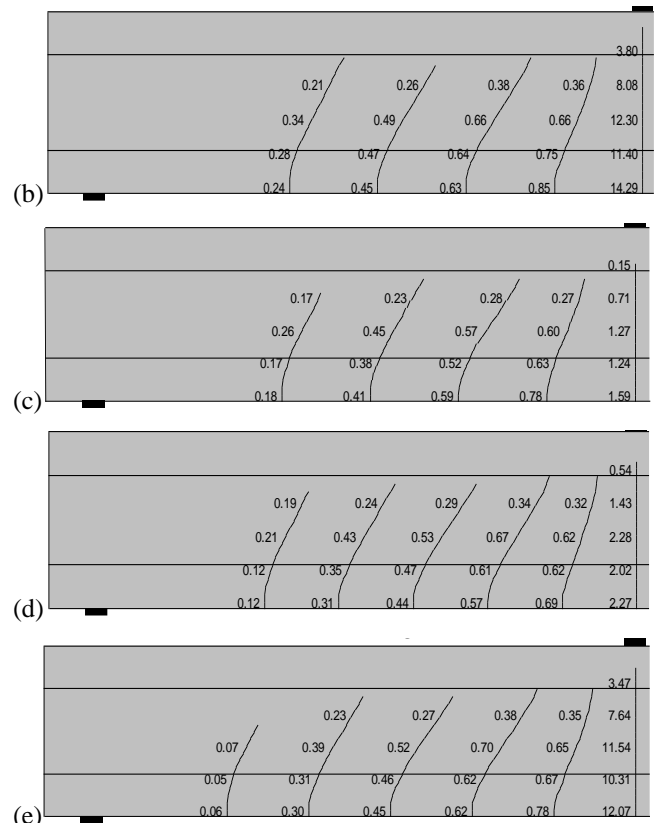
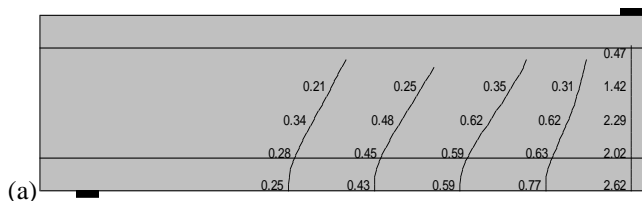


Figure 6 Crack Pattern Beams I (a) I1; (b) I2; (c) I3; (d) I4; (e) I5

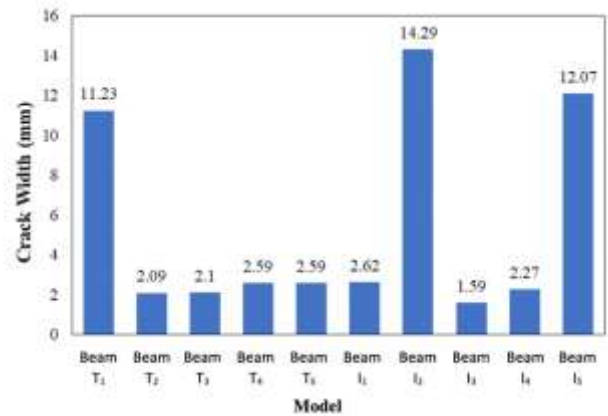


Figure 7 Comparison of the crack width of the test object

3.4 Stiffness

Based on the results of the stiffness analysis, in Figure 7, the T₁ beam experienced the largest decrease, while the T₃ beam had the smallest decrease. In beam I₂, the largest decrease while beam I₁ has the smallest decrease. When compared as a whole of the 10 specimens, it can be concluded that beam I₁ has the greatest stiffness value, which is 91.4 kN/mm and beam T₂ has the smallest stiffness value, which is 23.5 kN/mm. The value of the stiffness in beam I is due to the height of beam I which is more able to accommodate large loads when compared to other beams. In Figure 8 and Figure 9 is the relationship between load and deflection, from this

result the stiffness value is obtained in Table 8. Table 8 shows that the results of the stiffness of the tub are quite varied even though the cross-sectional area and volume of the concrete used are the same. Through this analysis, it can be concluded that the beam section has an important role in determining the stiffness of a reinforced concrete beam.

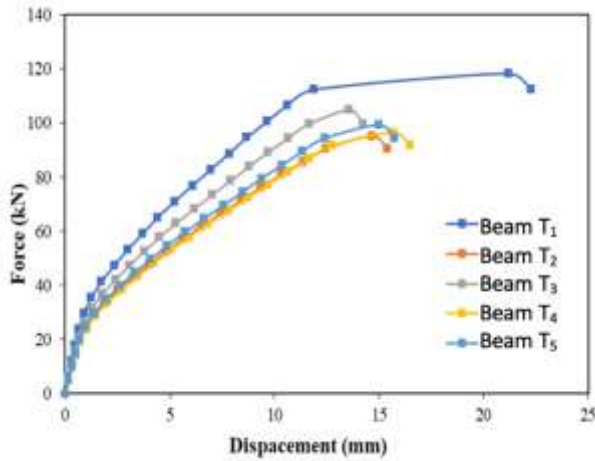


Figure 8 Load Deflection relationship with the test object beam T

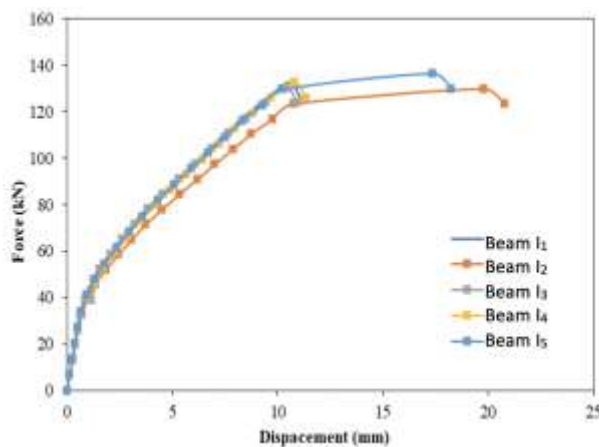


Figure 9 Relation of Load and Deflection of beam specimen I

Table 8. Result of stiffness calculations

Test Object	Stiffness (kN/mm)
Beam T ₁	31.1
Beam T ₂	23.5
Beam T ₃	28.9
Beam T ₄	25.0
Beam T ₅	25.9
Beam I ₁	48.6
Beam I ₂	37.6

Beam I ₃	42.5
Beam I ₄	42.5
Beam I ₅	42.7

4. CONCLUSION

Based on the analysis and discussion that has been carried out, it can be concluded that the comparison of the amount of deflection based on the experimental results with Response-2000 for 10 specimens of T₁-T₅ and I₁-I₅ beams, the largest deflection is in beam I₂ with a value of 19.759 mm and the smallest deflection is in the beam. I₃ with a value of 10.414 mm. In the test, the resulting crack was a flexible crack with the smallest crack in beam I₃ with a value of 1.59 mm and the largest crack in beam I₂ with a value of 14.29 mm.

The dimensions made determine the maximum stiffness that can be accepted by the T and I beam specimens. By testing using the Response-2000 beam I1 has the greatest stiffness level with a value of 48.6 kN /mm.

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