

Manufacturing device to investigation of how the steel beam shape effect on deflection magnitude.

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Abstract. This paper describe that how the shape of the beam (hollow, solid rectangle, solid circular beam) influences the magnitude of beam deflection, when it is having the same material and same cross-section area, to measure a horizontal deflection of the beam. Two methods are used, the cantilever-supported and simply-supported beam. By applying the multi-loads from (4.905 to 58.86N) using dial Gauge Indicator (DGI) measurement by the manufactured device as shown in figure 5 (a), and Theoretical measurement (TM). The comparison is made to check the effectiveness and strength of the beam, the experimental and theoretical result proofed that the (Hollow rectangle beam) it has a minimum deflection is (3% TM, 16% DGI and 4% TM, 15% DGI) by cantilever-supported and simply- supported method respectively, compared with a (solid rectangle and solid circular beams). It is noticed logically that the beam that a solid cross-section is less susceptible to deflection from the hollow cross-section. But practical experiments proved the opposite. This accuracy or convergence by measurement proves the effectiveness of the manufactured device in this study despite its simplicity of design and its low cost, which does not exceed (1-2%) if compared to the other devices such as scale of Rockwell or universal hydraulic machine EPP300, wich used for the same purpose.

Keywords: beam deflection, multi-loads, different types of beam, theoretical measurement (TM), experimental measurement (DGI).

1: Introduction

The study of beam loads is complex by the fact that the loading effects vary from section to section of the beams where the loading effects take the form of a shearing force and bending moment (Tariku Achamyeh, et al. 2019). The main aim of this research is to study deflection in different types of beams, which are subjected to all kinds of loading under many supporting cases, and then calculating maximum values of those deflections. The important part of the mechanical engineering responsibility is to select the best metal and shape of the beam from replacements. The best choice of the structural system is significant in effect on the economy and to able on the more of the load in the structural engineering (Nilson. 2003). The maintenance should be taken according to all considerations as important on design and the structure of the building. Actually, in this case, to upgrade requirement a good design and strengthen the structure of structural to be able to withstand extreme stress and enjoy stricter durability (Jones. 1982). The structures of load testing such as (beams, columns) did for both a strength assessment and evaluate the experimental and theoretical elements (T. Whiteman. 1987). When applied the load at anybody or any surface, the body or surface will change size and shape that is known as deflection. This paper proposed to measure different types of beam deflection have the same cross-suction by cantilever-supported and simply-supported beam methods. Using experimental measurement, by Dial Gauge Indicator (DGI), and theoretical measurement(TM), is studied by applied multi-loads from (4.905 to 58.86 N). To know which beam is less susceptible to deflection and effective. The maximum deflection for every section was a calculation by

repetition of the experimental procedure for every section. Comparison (L-D) curve for each section studied.

2. Aims of Study:

This study aims to manufacture device and opting three different sections of steel beams (Hollow, solid rectangle, solid circular section) having the same cross-section area to select which one is less susceptible to deflection of these sections of beams, using the experimental measurements (DGI) and theoretical measurements (TM). By two methods, the simply-supported and cantilever-supported beam, the experimental measurements and theoretical measurements were done by applying multi-loads from (4.905 to 58.86 N).

3: manufactured device.

The manufactured device, made of a strong loading frame with a separate dial gauge indicator (DGI) with suitable size. The manufactured device consists of the following major parts. 1: frame, made of iron the dimensions of the frame are 600 mm length, 400 mm width, and 400 mm height, 2: screw beam stabilizer, with dimensions 250 mm length and 25 mm diameter, use to stabilizer of the beam testing, 3: movement weight base, moving in two direction to determine the test point on the beam, with dimensions 399 mm, and 100 mm width, 4: beam of weight, use to applied of the load on beam, as shown in figure 1. The following tests can be done in the manufactured device (deflection, bending or shear tests on aluminum or iron samples, tensile tests on the metal samples such as standard shapes, springs, screws, elastomeric samples, etc.).

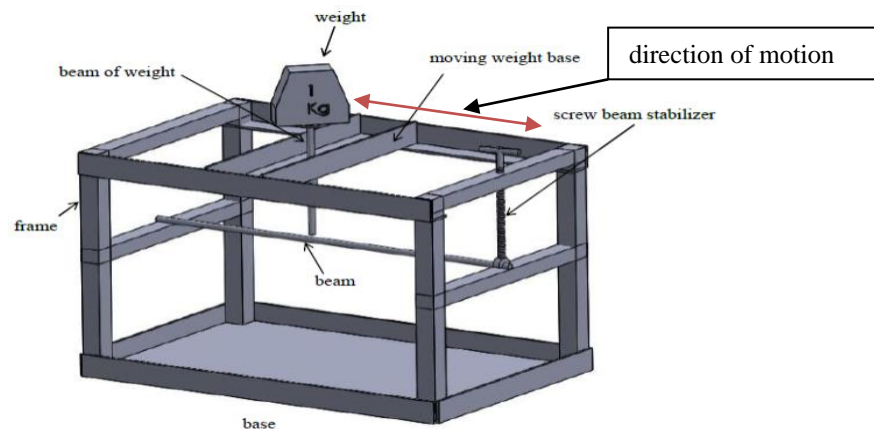


Figure 1: the manufactured device

4: Experimental work

The steel beams deflection measurement was done by theoretical measurement (TM) and experimental measurement by (DGI) using a manufactured device, as shown in figure 1. The dimensions of the cantilever-supported steel beam are 300 mm in length, and the simply-supported steel beam is 500 mm, both have the same cross-section area (961mm²). The loads were applied from (4.905 to 58.86 N) at the free end in case (cantilever-supported) and center of the beam in case (simply-supported). The dial gauge indicator (DGI) is placed under the beam, and the contact point is touching it. Are taking the same test used to get the measurements for all different beams. The setup of the cantilever-supported and a simply-supported steel beam of the experimental measurement is shown in figure 2 (a, b) respectively.



Figure 2: (a, b): Experimental setup cantilever-supported and simply-supported steel beams of deflection measurement by dial Gauge Indicator (DGI) respectively.

5: Experimental Measurements.

5.1: Cantilever-supported beam method

The cantilever-supported beam was experimented with by the dial gauge indicator (DGI). The steel beam dimensions (300 mm) length, cross-section area (961mm²), and applied different multi-loads (p) at the end free of the beam. Where each weight is multiplied by the ground gravity value. All the beams have the same cross-section area. Are taking the same method used to get the readings for all different section. As shown in table 1.

Table 1: Experimental cantilever-supported beam results of three sections of beams by dial gauge indicator (DGI).

Load applied Kg*g = N	Deflection of Hollow rectangle A=961 mm ²	Deflection of Solid rectangle A=961 mm ²	Deflection of Solid circular A=961 mm ²	Maximum deflection of each beam respectively mm	modulus of elasticity of each beam respectively Gpa	Moment of inertia of each beam respectively mm ⁴
4.905	0.26	0.65	0.85	3.38	210	25783.75
9.81	0.56	1.04	1.7	6.2	210	2380.08
14.715	0.86	1.7	2.1	12	210	1401.27
19.62	1.3	1.97	2.4			
24.525	1.46	2.42	4.2			
29.43	1.81	2.88	5.3			
34.335	2.19	3.48	6.1			
39.24	2.62	3.95	7.1			
44.145	2.88	4.49	8			
49.05	2.98	4.93	9.2			
53.955	3.25	5.96	11.1			
58.86	3.38	6.2	12			

5.1.1: Experimental cantilever-supported beams graphs of hollow, solid rectangle and circular section beams by (DGI)

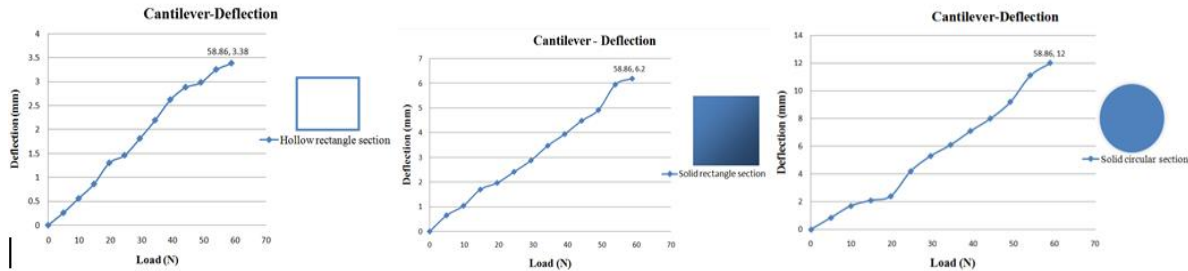


Figure 3: deflection of hollow, solid rectangle and circular section beams.

Figure 3: shown the graph value, The beam exterminated by loads from (4.905 to 58.86 N) using Dial Gauge Indicator (DGI) at the loads observed values as shown in figure 3. The Maximum deflection at (58.86 N is 3.38 mm) hollow, (58.86 N is 6.2 mm) solid rectangle, and (58.86 N is 12 mm) solid circular section. Corresponding load and displacement of Dial gauge indicator (DGI) values.

5.2: Simply-supported beam method

The simply-supported beam was experimented with by the Dial Gauge Indicator (DGI). The steel beam dimensions (500 mm) length, cross-section area (961mm²), and applied different multi-loads (p) at the middle of the beam. Where each weight is multiplied by the ground gravity value. All the beams have the same cross-section area. Are taking the same method used to get the readings for all different section. As shown in table 2.

Table 2: Experimental simply -supported beam results of three sections of beams by Dial Gauge Indicator (DGI)

Load applied Kg*g = N	Deflection of Hollow rectangle A=961 mm ²	Deflection of Solid rectangle A=961 mm ²	Deflection of Solid circular A=961 mm ²	Maximum deflection of each beam respectively mm	modulus of elasticity of each beam respectively Gpa	Moment of inertia of each beam respectively mm ⁴
4.905	0.011	0.60	0.05	3.38	210	25783.75
9.81	0.031	0.100	0.095	6.2	210	2380.08
14.715	0.12	0.140	0.15	12	210	1401.27
19.62	0.16	0.180	0.19			
24.525	0.2	0.220	0.24			
29.43	0.23	0.250	0.29			
34.335	0.26	0.290	0.35			
39.24	0.28	0.310	0.39			
44.145	0.3	0.340	0.43			
49.05	0.32	0.370	0.46			
53.955	0.35	0.410	0.51			
58.86	0.41	0.450	0.57			

5.2.1: simply -supported beams graphs of hollow, solid rectangle and circular section beams by (DGI)

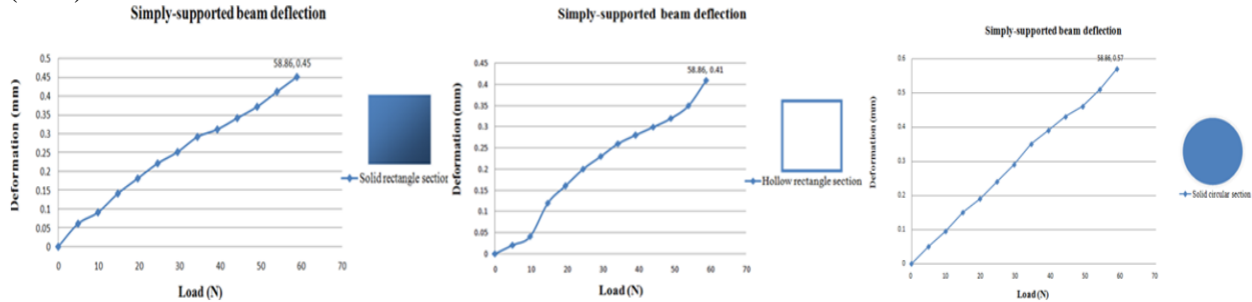


Figure 4: deformation of solid, hollow rectangle and solid circular section beams

Figure 4: shown graph value, The beams exterminated by loads from (4.905 N to 58.86 N). Using dial gauge indicator (DGI) at the loads observed values as shown in figure 4. The Maximum deformation at (58.86 N is 0.45 mm) solid, (58.86 N is 0.41 mm) hollow rectangle and (58.86 N is 0.57 mm) solid circular section. Corresponding loads and displacement of dial gauge indicator (DGI) values.

6: Theoretical Measurements (TM).

When applied the loads (P) on the beam the beam is bend and takes a different shape, the deflection at any point on the beam determination by the following methods.

❖ *cantilever-supported steel beam method.*

The deflection at the free end of the beam: $y = -\frac{PL^3}{3EI}$ Eq. 1

❖ *simply-supported beam with a point load at the middle method.*

The deflection at the middle of the beam: $y = -\frac{PL^3}{48EI}$ Eq. 2

Abbreviations:

- I: is the second moment of area about the centric.
- E: is the modulus of elasticity.
- L: is the length of the beam.
- P: is the load on the beam.
- y: is the deflection of the beam.

6.1: Cantilever-supported beam method.

The cantilever-supported beam is evaluated by theoretical measurements (TM). The steel beam dimensions (300 mm) length, cross-section area (961mm²), and applied different multi-loads (p) at the end free of the beam. Where each weight is multiplied by the ground gravity value. All the beams have the same cross-section area. Are taking the same method used to get the readings for all different section. As shown in table 3.

Table 3: Cantilever-supported beam results of three sections of beams by theoretical measurements (TM).

Load applied $Kg * g = N$	Deflection of Hollow rectangle A=961 mm²	Deflection of Solid rectangle A=961 mm²	Deflection of Solid circular A=961 mm²	Maximum deflection of each beam respectively mm	modulus of elasticity of each beam respectively Gpa	Moment of inertia of each beam respectively mm ⁴
4.905	0.0081	0.088	0.149	0.0967	210	25783.75
9.81	0.0163	0.176	0.298	1.056	210	2380.08
14.715	0.0244	0.264	0.447	1.788	210	1401.27
19.62	0.0325	0.352	0.596			
24.525	0.0406	0.44	0.745			
29.43	0.0488	0.528	0.894			
34.335	0.0569	0.616	1.043			
39.24	0.065	0.704	1.192			
44.145	0.0732	0.792	1.341			
49.05	0.0813	0.88	1.49			
53.955	0.0894	0.968	1.639			
58.86	0.0976	1.056	1.788			

6.1.1: Cantilever-supported beam graph of hollow, solid rectangle and solid circular sections by theoretical measurements (TM).

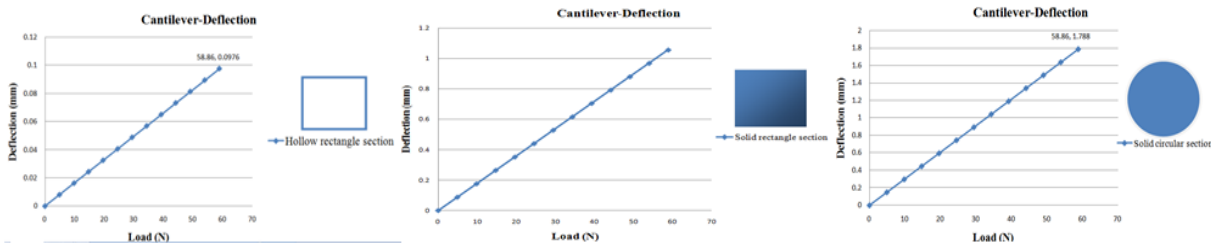


Figure 5: deflection of hollow, solid rectangle and solid circular section beams respectively.

Figure 5: showing the graph value, The beams evaluated by theoretical loads from (4.905 to 58.86N). By Theoretical measurements (TM), at the loads observed values as shown in figure 5. The maximum deflection at (58.86 N is 0.0976 mm) hollow, (58.86 N is 1.056 mm) solid rectangle section, and (58.86 N is 1.788 mm) solid circular. Corresponding loads and moment of inertia values.

6.2: Simple-supported beam method.

The simply-supported beam is evaluated by the theoretical measurements (TM). The steel beam dimensions (500 mm) length, cross-section area (961mm²), and applied different multi-loads (p) at the middle of the beam. Where each weight is multiplied by the ground gravity value. All the

beams have the same cross-section area. Are taking the same method used to get the readings for all different section. As shown in Table 4.

Table 4: Simply-supported beam results of three sections of beams by theoretical measurements (TM).

Load applied Kg*g = N	Deflection of Hollow rectangle A=961 mm ²	Deflection of Solid rectangle A=961 mm ²	Deflection of Solid circular A=961 mm ²	Maximum deflection of each beam respectively mm	modulus of elasticity of each beam respectively Gpa	Moment of inertia of each beam respectively mm ⁴
4.905	0.00235	0.0255	0.043	0.0280	210	25783.75
9.81	0.00471	0.051	0.086	1.306	210	2380.08
14.715	0.00707	0.0765	0.132	0.521	210	1401.27
19.62	0.00942	0.102	0.1736			
24.525	0.0117	0.1275	0.217			
29.43	0.01404	0.153	0.261			
34.335	0.01638	0.1785	0.303			
39.24	0.01872	0.204	0.347			
44.145	0.02106	0.2295	0.391			
49.05	0.0234	0.255	0.433			
53.955	0.02574	0.2805	0.477			
58.86	0.02808	0.306	0.521			

6.2.1: Simple-supported beam graph of solid, hollow rectangle and solid circular sections by theoretical measurements (TM).

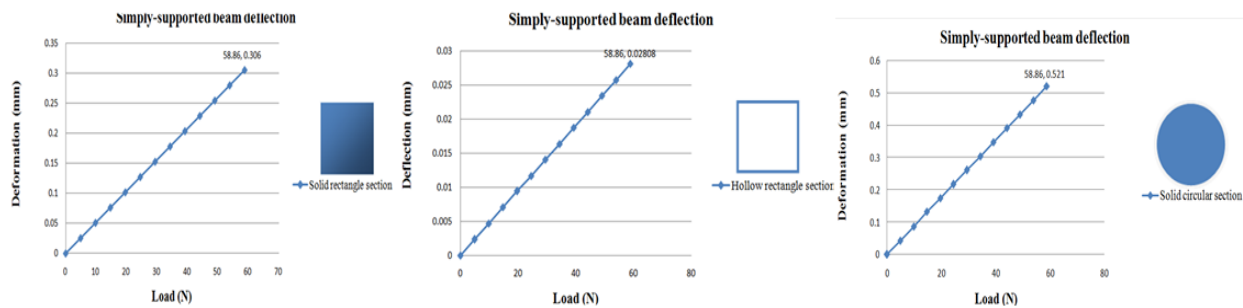


Figure 6: deflection of solid, hollow rectangle and solid circular section

Figure 6: shown the graph value, The beams evaluated by theoretical loads from (4.905 to 58.86 N). By Theoretical measurements (TM), at the loads observed values as shown in figure 2. The Maximum deflection at (58.86 N is 0.306 mm) solid, (58.86N is 0.02808 mm) hollow rectangle and (58.86 N is 0.521 mm) solid circular section. Corresponding loads and moment of inertia values.

7: Result and discussion.

After completing the experimental part related to measuring the deflection of steel beams by two methods, the first is the cantilever-supported method and the second is the simple-supported beam, using theoretical and experimental measurements by the device that was manufactured in this study. It was noticed that the maximum deflection for the three steel beams (Hollow, Solid rectangle, and Solid circular) in both measurement methods (DGI, TM) was somewhat close. observed the maximum deflection value is (0.57,0.521 mm at the load 58.86N) solid circular section, (0.45,0.306 mm at the load 58.86N) solid rectangle and (0.41,0.02808 mm at the load 58.86N) hollow rectangle section respectively. As shown in figures 7-8. The magnitude beam deflections of experimental and theoretical measurements during cantilever-supported and simply-supported beam methods are shown in Figure 9.

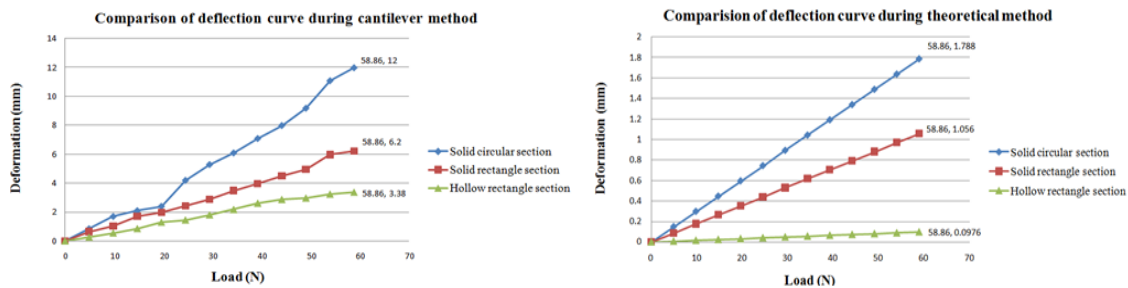


Figure 7: Comparison of deflection between three steel beams sections.

Figure 7: showing the graph values, the deflection of the above cases from three different sections using dial gauge indicator (DGI) and theoretical measurements (TM), from these graphs are observed that the maximum deflection is (12,1.788 mm at load 58.86 N) solid circular section, (6.2,1.056 mm at the load 58.86 N) solid rectangle and (3.38, 0.0976 mm at the load 58.86 N) hollow rectangle section respectively.

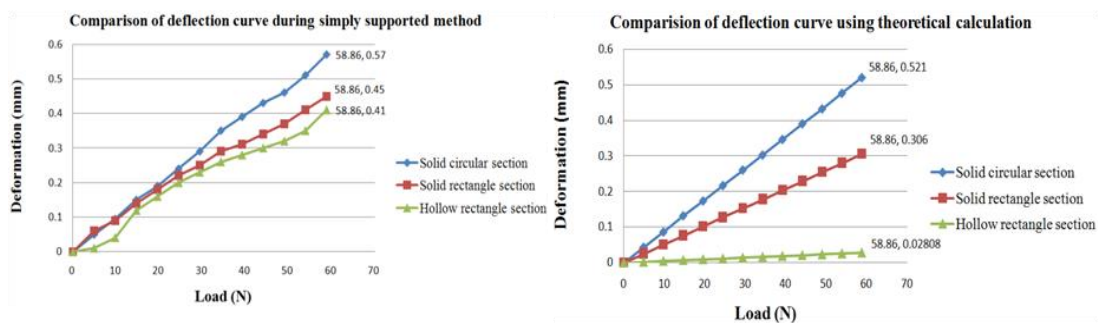


Figure 8: Comparison of deflection for three different sections curves.

Figure 8: showing the graph values, the deflection of the above cases from three different sections using dial gauge indicator (DGI) and theoretical measurements (TM), from these graphs are observed that the maximum deflection is (0.57,0.521 mm at the load 58.86N) solid circular section, (0.45,0.306 mm at the load 58.86N) solid rectangle and (0.41,0.02808 mm at the load 58.86N) hollow rectangle section respectively.

7.1: Magnitude Beams Deflections of Experimental and Theoretical Measurements during Cantilever-Supported and Simply-Supported Beam Methods.

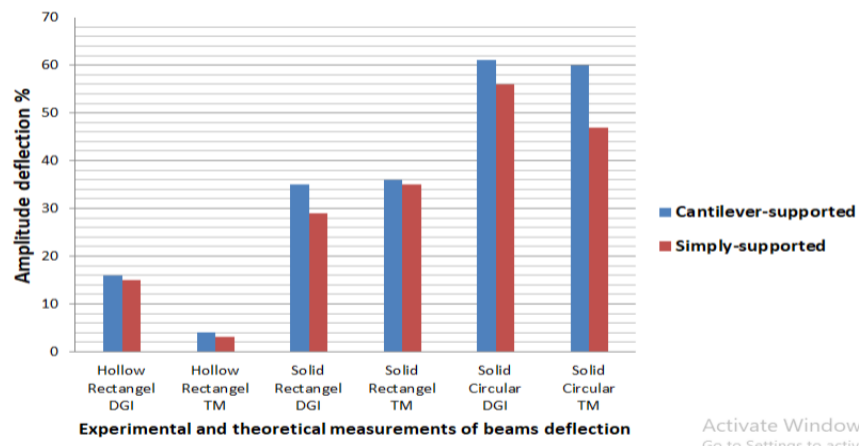


Figure 9: Experimental and theoretical measurements of beams deflection

Figure 9: shown the amplitude of deflection of steel beams by cantilever-supported and simply-supported beam methods, using experimental measurement (DGI) and theoretical measurement (TM). Where the theoretical and experimental results showed the maximum deflection is (61% DGI, 60% TM at load applied 58.86 N) in the steel beam (Solid Circular) respectively, the minimum deflection is (4% TM, 16% DGI, at load applied 58.86 N) in the steel beam (Hollow rectangle) by cantilever-supported method respectively. Ana the maximum deflection is (56% DGI, 47% TM at load applied 58.86 N) in the steel beam (Solid Circular) respectively and the minimum deflection is (3% TM, 15% DGI, at load applied 58.86 N) in the steel beam (Hollow rectangle) by simply-supported method respectively. Are taking the same method used to get the readings for all different beams. As shown in table 5.

Table 5: shown magnitude of beams deflection parsantage (%)

Type of beam	Type of method (TM)	Type of method (DGI)	Deflection parsantage %	
			(TM)	(DGI)
Hollow rectangle	Cantilever-supported	Cantilever-supported	4%	16%
Solid rectangle			36%	35%
Solid circular			60%	61%
Hollow rectangle	Simply-supported	Simply-supported	3%	15%
Solid rectangle			35%	29%

Solid circular			47%	56%
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Conclusions:

This study observed that the method of experimental measurement for the magnitude of steel beams deflection using the manufactured device is very accurate when compared to theoretical measurement, despite there are some slight differences between the two readings, the difference between the experimental and the theoretical measurements due to the presence of a mistake in the composition of the metal or some of the physical changes that occurred to the metal. Where the theoretical measurements give a precise description of cases of ideal for metals (ASTM), as tests have shown that the values of the deflection readings of steel beams using the manufactured device for both methods (cantilever-supported and simply-supported beam) were close to the theoretical readings, and this indicates the effectiveness of the manufactured device, despite the simplicity of design and its low cost that does not exceed (1-2%) compared to other measuring devices manufactured for the same purpose such as the scale of Rockwell or hydraulic machine EPP300. The cantilever-supported beam is a higher deflection than the simply-supported beam. duo to apply the load at the free end of the beam. Also, the deflection results showed that the hollow rectangle section beam less susceptible for the deflection and effectiveness than (solid rectangle and solid circular beam) as shown in figure 9.

Summary:

In this study, the manufactured device has many advantages, as it consists of a simple iron structure and few parts, weightiness, low cost, and easy to install, as it does not require programming or laboratory settings as it can be used by researchers to measure the amplitude of beams deviation, using the DGI or any other device used to measure the deflection of the beam.

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