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Structural Performance of Reinforced Concrete Beams with Various Cross-Section

Marwa S. Meteab*, Ahmad A. Mansor and Wissam D. Salman

Department of Civil Engineering, University of Diyala, 32001 Diyala, Iraq

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ABSTRACT

The deflection of reinforced concrete beams with various cross-sections was investigated in this work. The experimental program comprised of four reinforced concrete beams that were simply supported. They were put through a two-point load test. High to width ratio (h/b) was (0.36, 0.64, 1, and1.56), concrete compressive strength was from 27 MPa. The gradual increase in the (h/b) ratio (from 0.36 to 0.64, 1 and 1.56) with (27 MPa) compressive strength of concrete leads to increase the first crack load for the (N2, N3 and N4) by (74%, 111% and 122%) respectively as compared with (N1), the beams (N2, N3 and N4) exhibits an increase in the yielding load by (41.2%, 70.6% and 64.7%) respectively as compared with (N1), increase the ultimate load by (25% - 130%). The ductility index is reduced with gradual increase in the (h/b) ratio (from 0.36 to 0.64, 1 and 1.56) for (27 MPa) concrete compressive strength by (1.2% - 25.5%). For the beams (N1, N2, N3 and N4) it is noticed that the central deflection of the four beams reduced gradually at the same load with increase in the (h/b) ratio from (0.36 to 0.64, 1 and 1.56) with constant (27 MPa) compressive strength concrete. The maximum crack width decreases gradually with gradual increase in the (h/b) ratio (from 0.36 to 0.64, 1 and 1.56) for constant (27 MPa).

1. Introduction

The main text format consists of a two A beam is a structural ingredient that resists the loads, when some external loadings are applied on the beam, it tends to bend and deflect under loading, therefore it is also called flexural member because it behaves as a flexural member in the structure. It is considered one of the significant parts in the structure because it carries the slab load and transfers it to the column. [1,2] Basically, there are two most significantly modes of failure occur in reinforced concrete beams: flexural and shear. For attaining a total flexural ability of reinforced concrete beams under maximum loads, it should be designed to represent a ductile flexural failure mode. [3]. Four significant events are occurring in the beam during the flexural failure, which can be identified it as follows: Cracking of concrete in the tension zone. Yielding of tensile reinforcement. Concrete cover is crushing and spalling in the compression zone. Disintegration of the compressed concrete. [4-5] There are several factors influence the flexural behavior of beam, such as the tensile reinforcement ratio, compressive reinforcement ratio, compressive strength of concrete, height to width (h/ b) ratio, and confinement in the pure flexural zone by closed stirrups. The results of an experimental inquiry of the strength and performance of reinforced concrete beams are presented in this study. Significant parameters that were taken into account in the strength analysis of a beam with various high-to-depth ratios (h/b) under a set compressive strength value. The goal of this

* Corresponding author.
E-mail address: eng.marwasaleem@gmail.com
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research is to look into the strength and behavior of reinforced concrete beams with various (hb) ratios when the compressive strength is fixed.

2. Research significant

The goal of this study was to predict the deflection of reinforced concrete. beams with different cross-sections. The compressive strength ranged between 27 MPa, h/b was (0.36, 0.64, 2, and1.45).

3.Materials and methods

3.1 Description of beams specimens and details

Four simply supported RC beams were built and tested as part of the experimental program. They were 1400 mm long overall, with a 1200 mm clear span. The amount of flexural reinforcement for all specimens was 4Ø16 mm in tension and 2Ø12 mm were used in compression reinforcement. The amount of shear reinforcement for the tested beams was Ø10@100 mm, c/c as shown in the Figure 1 in which all dimensions are in (mm). All beams had the same amount and arrangement of reinforcement.. Normal strength concrete (NSC) used in this work. Ordinary Portland Cement with the trade mark of (Tasloja) and it was discovered to meet ASTM C150-16 [6]. As a fine aggregate, regular sand from the Al-Rahalia region(zone) was used, while crushed gravel from the Al-Nibaey region(zone) was used as a coarse aggregate with a maximum size of (14 mm). The ASTM C33-11 specification limitations were met by both fine and coarse material [7].

3.2 Mixture composition

To achieve the requisite compressive strength, several trial mixes were created. Because the British Standard BS 5328-83 mix design approach generates mixes with a higher strength range than the compressive strength ACI 211 method [8], it was used. The compressive strength of the concrete was 27 MPa. The experiment was carried out in the structural laboratory of the Diyala University's civil engineering department. Table 1 shows the test matrix, and the specimens were N1, N2, N3, and N4 with cross sections 150x416.6) mm, (200x312.5) mm, (250x250)mm, and (312.5x200)mm with compressive strength 27 MPa.

Table 1: Lists the specimens that were tested

Specimens' designation	Dimensions (mm)	f'c (MPa)	b / d
N1	150x416.6	27	0.36
N2	200x312.5	27	0.64
N3	250x250	27	1
N4	312.5x200	27	1.56

3.2 Fabrication of beams test setup, and instrumentation

The wooden moulds were initially filled with reinforcement cages. To accomplish appropriate compaction, beams were cast and immersion-type vibrators were used. Six 150 x 300mm concrete cylinders were produced for each batch of concrete. The beams and control specimens were demolded the next day and cured in a moist atmosphere for 28 days using a damp blanket before being air-dried in the lab. Each beam was bleached before testing to make crack detection easier. The beam test setups are illustrated. in Figure 2. The beams were simply supported over a span of 1400 mm and a 600 kN hydraulically testing machine (Jet materials Ltd. w The loads were applied by Company). Beams were put to the test with two concentrated forces at a distance of 100mm from a support. The deflected form of the beam was measured using an LVDT installation at the midspan and under each concentrated applied force. The crack widths were measured. Using a portable microscope with a resolution of 0.02 mm, measurements were taken.

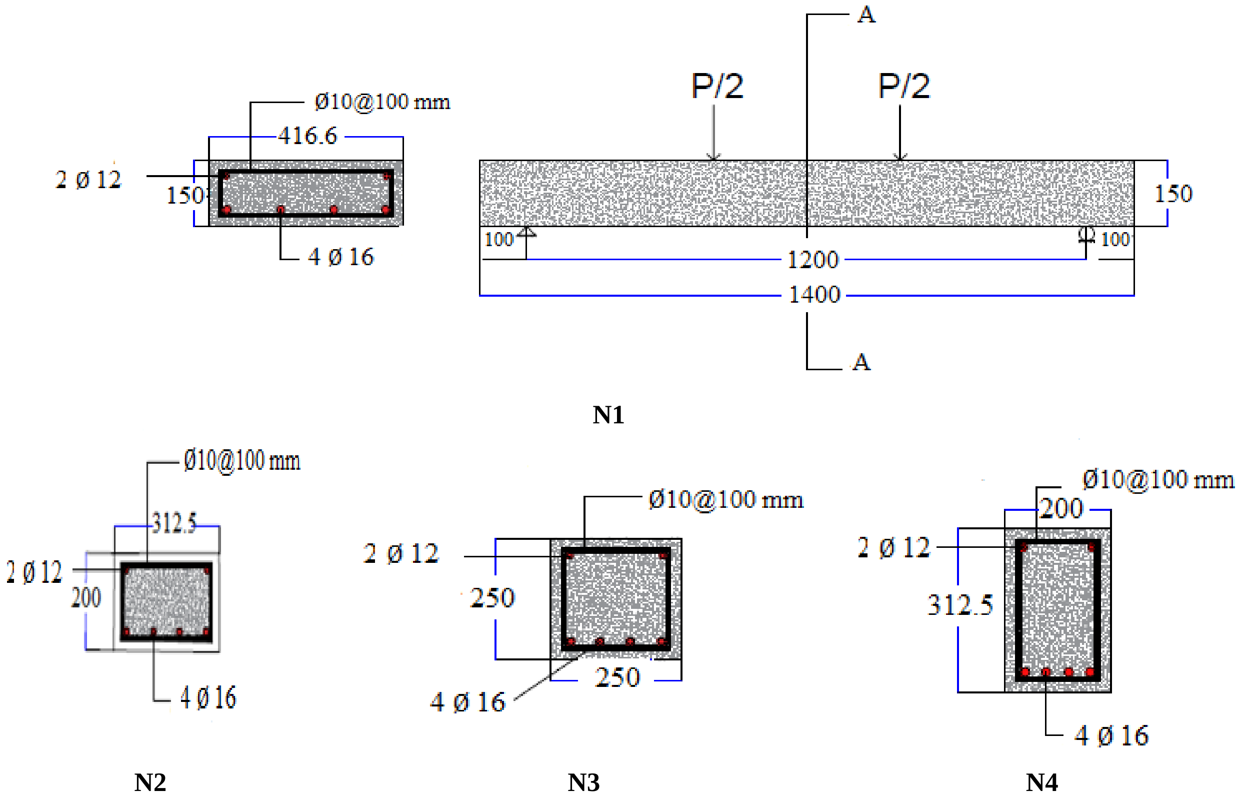


Figure 1. Specimens' reinforcement details

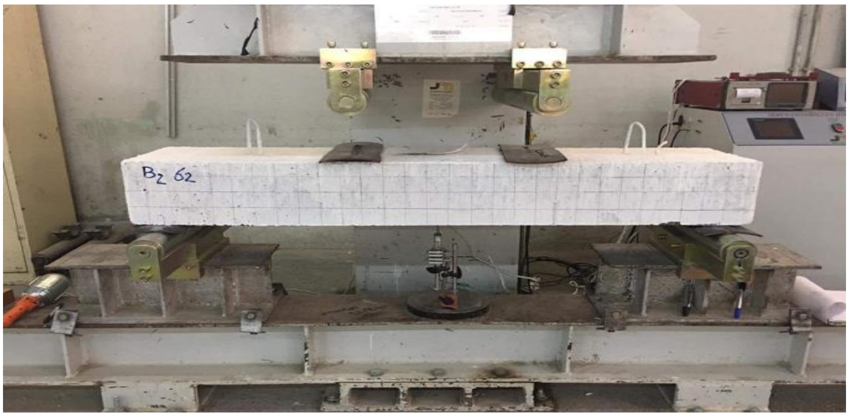


Figure 2. Hydraulic machine used to test all specimens

3.4 Test procedure

The specimens were prepared for testing by placing supports and loading points in the proper positions. The dial gauges were attached to the test specimen's bottom face in the middle and at the loading locations. Bearing plates measuring 20mm x 100mm x 450mm were utilized at loading and supporting points to avoid local direct load concentration on concrete. The specimens were exposed to monotonic-static stresses in sequential steps till failure. The load was paused at each step until it reached the required level. The measurements were taken (progress of cracks, crack width, strain readings, and deflection at the midspan and under the loading points of the tested specimen). The testing procedure was completed when the total load on the specimen began to decrease.

4. Experimental results and discussion

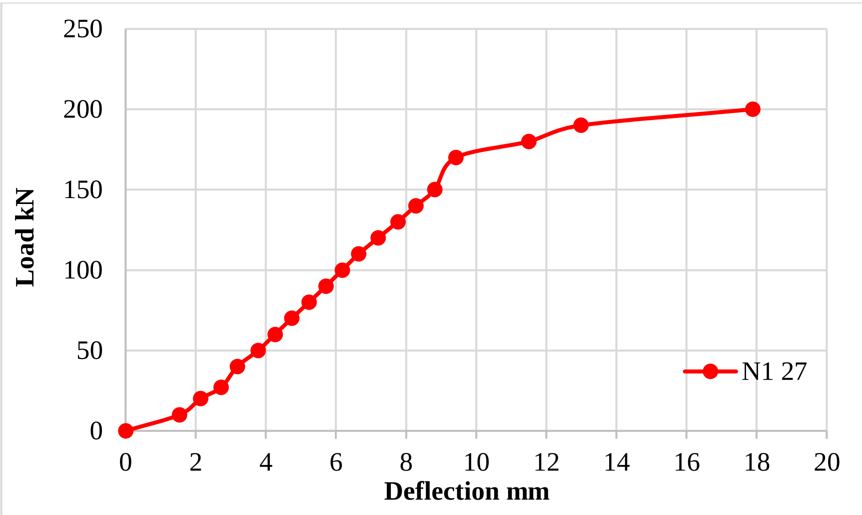
Table 2 shows the ductility index and all experimental data for four specimens, including concrete compressive strength, yield and ultimate loads with defections in two stages, and yield and ultimate loads with defections in two stages.

Table 2: Summary of test results for group one specimens

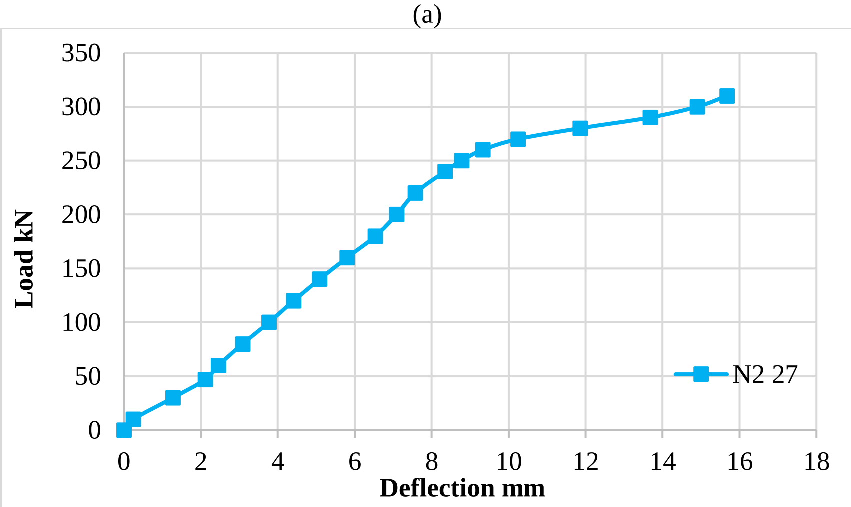
Specimen designation	Dimensions Width× depth (mm)	h / b	f'c (MPa), cylinders *28 days*	1st cracking load Pcr (kN)	Py (kN)	Pu (kN)	Pcr/Pu	Δy (mm)	Δu (mm)	Δcr/Δu	Ductility $\frac{\Delta u}{\Delta y}$
BN1	416.6 × 150	0.36	27	27	170	200	0.135	9.423	17.889	0.152	1.9
BN2	312.5 × 200	0.64		47	240	310	0.152	8.345	15.676	0.135	1.878
BN3	250 × 250	1		57	290	320	0.178	8.002	12.655	0.151	1.581
BN4	200 × 312.5	1.56		60	280	460	0.13	7.782	11.022	0.139	1.416

4.1 Load-Deflection behavior

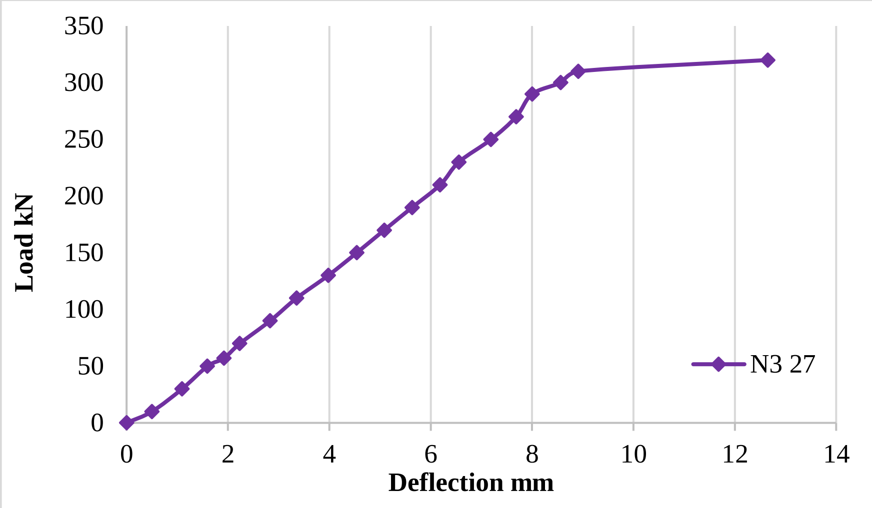
Figure 3 Shows the load-deflection behaviors of the four examples. The deflection increases linearly as the load applied increases in the pre-cracking stage. The first crack load is increased for the (N2, N3, and N4) by (74%, 111% and 48.1%) respectively as compared with (N1), this is attributed to the increase in the gross moment of inertia by increasing the depth of the specimen cross section and the increase in depth of compression zone.



(a)



(b)



(c)

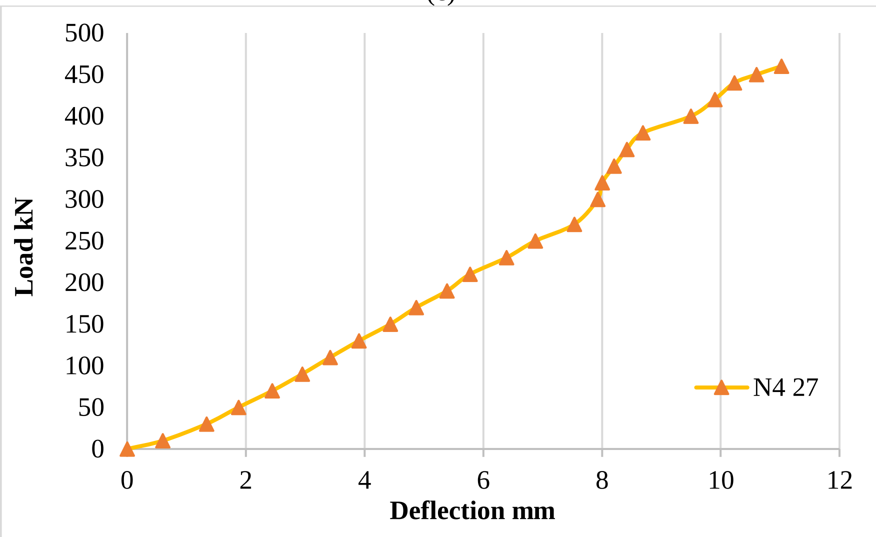


Figure 3. Load- central deflection curve for beams (a): Load- central deflection curve for beam N1(b): Load- central deflection curve for beam N2 (c): Load- central deflection curve for beam N3 (d): Load- central deflection curve for beam N4

4.3 Ductility indix

In this study the ductility of beams is taken as in Eq .(1) below:

$$\text{Ductility} = \frac{\Delta_u}{\Delta_y} \quad (1)$$

where Δ_u is the member deflection at yielding of the tension in steel reinforcement and Δ_y is the member deflection at ultimate load.

The stage beyond which the specimen would not be able to bear further deformations at the same load strength is known as the ultimate. Table 2 summarizes the test findings, including the load and deflection during the yield and ultimate stages. The ductility index is also included in the table. The ductility index of the four examined beams is also shown in Table 2.

4.4 Crack pattern and crack width

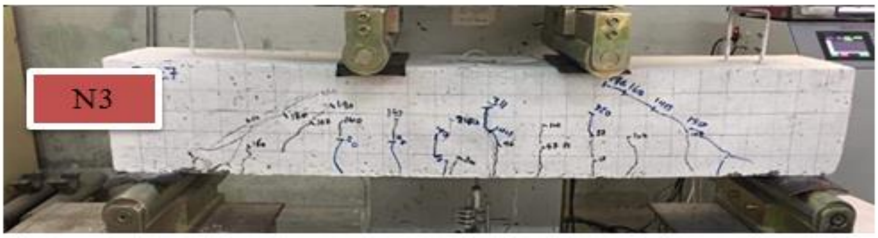
Table 3 illustrates the cracking details for the group one specimen. As can be observed that the maximum crack width decreases gradually for (N2, N3, and N4) by (37%, 44.4% and 55.6%) respectively, as compared with (N1). This is belonging to the clear gradual increase in the (h/b) ratio that increases the stiffness in term of increases the moment of inertia. However, this reduction in the maximum crack width accompanied by an increase in the cracks number for (N2, N3, and N4) by (71.4%, 14.3% and 57.1%) respectively, as compared with (N1). However, this increase is non gradual i.e., unlike the reduction in crack width. The beam (N3) exhibits disagreement, this may attribute to the equalize between (width b and depth h) of the specimen cross section. Thus, the distribution of the stresses is different. Figure 1 (1- (a, b, c and d)) show the crack pattern for beams.

Table 3: Crack details for specimens

Specimen designation	Dimensions Width× depth (mm)	Maximum Crack Width (mm)	Number of flexural cracks at failure
N1	150×416.6	0.54	7
N2	200×312.5	0.34	12
N3	250× 250	0.3	8
N4	312.5×200	0.24	11

a

b



c

d

Figure 4. (a, b, c and d) Crack pattern for beams

5. Conclusion

Based on the results obtained from testing the beams, the following conclusions can be drawn:

1. The gradual increase in the (h/b) ratio (from 0.36 to 0.64, 1 and 1.56) with (27 MPa) compressive strength of concrete leads to increase the first crack load by (74%, -122%),

increase yielding load by (41.2% - 70.6%), increase the ultimate load by (25% - 130%)

2. The ductility index is reduced with gradual increase in the (h/b) ratio (from 0.36 to 0.64, 1 and 1.56) for (27 MPa) concrete compressive strength by (1.2% - 25.5%)
3. The maximum crack width decreases gradually with gradual increase in the (h/b) ratio (from 0.36 to 0.64, 1 and 1.56) for (27 MPa) concrete compressive strength by (11.11% - 25.9%)
4. The increase in the (h/b to 1.56) leads to change the mode of failure of beams from flexural to shear due to the increase in the bending capacity with no increase in the shear strength.

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