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Behavior of Hybrid Concrete Beams Containing Two Types of High Strength Concrete (HSC) and Conventional Concrete

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Abstract: ***This paper is a port of a study experimental investigating the behavior of hybrid reinforced concrete beams using two types of high strength concrete (HSC). Twelve test beams with (100 X 200 X 1100)mm dimension have been divided into four groups, each of which consisted of three beams specimens sames in size and gross section but different in concrete type and steel bar .All beams were tested to failure under two point loading to investigate the structural behavior . experimental results show that the use of high strength concrete improves the beam capacity are increasing (10.41% - 48.80)% with conventional concrete in compression . the use of hybride concrete increased the beam capacity (14.28% - 42.30%)% with conventional amerd in compression.***

Keywords: Shear strength, Hybrid Concrete, High Strength Concrete.

1. Introduction

The use of high strength concrete leads to the design of smaller sections, there by reducing the dead weight and that is very useful for longer spans in building[(1)].

High strength concrete can be make by adding super plasticizers (high range water) redcing admixtures to mixture. It is sensible to merge high strength concrete and conventional concrete in hybrid members in order to make use of the advantages of the two materials in best ways. The main goal of this research is to investigate the shear behavior of hybrid concrete beams containing high strength concrete and normal concrete. the preceding studies show that increased shear strength by using high strength concrete. Aamer [(2)] Make an experimental investigation an shear behavior of hybrid rectangular cross section reinforced concrete beams strengthened with high strength concrete on the zone of compression in the beams. Mohammed [(3)] study presents experimental and theortical investigation of flexural behavior (strength and deflection characteristics) of hybride rectangular beams combining convertional concrete and reactive powder concrete. Husain[(4)] and B.,A., presents theoretical and experimental investigation of shear behavior of hybride reinforced concrete T. beams cast monolithically. but , the web is made with concrete differing from concrete of tension and compression flanges. Conventional concrete has limited low impact, ductility and little resistance to cracking and abrasion resistance, where for we tend to the hybrid concrete due to advances in concrete technology . it is simple in relation make combined section which has high ductility, high compressive strength, high tensile strength and high ability absorption.

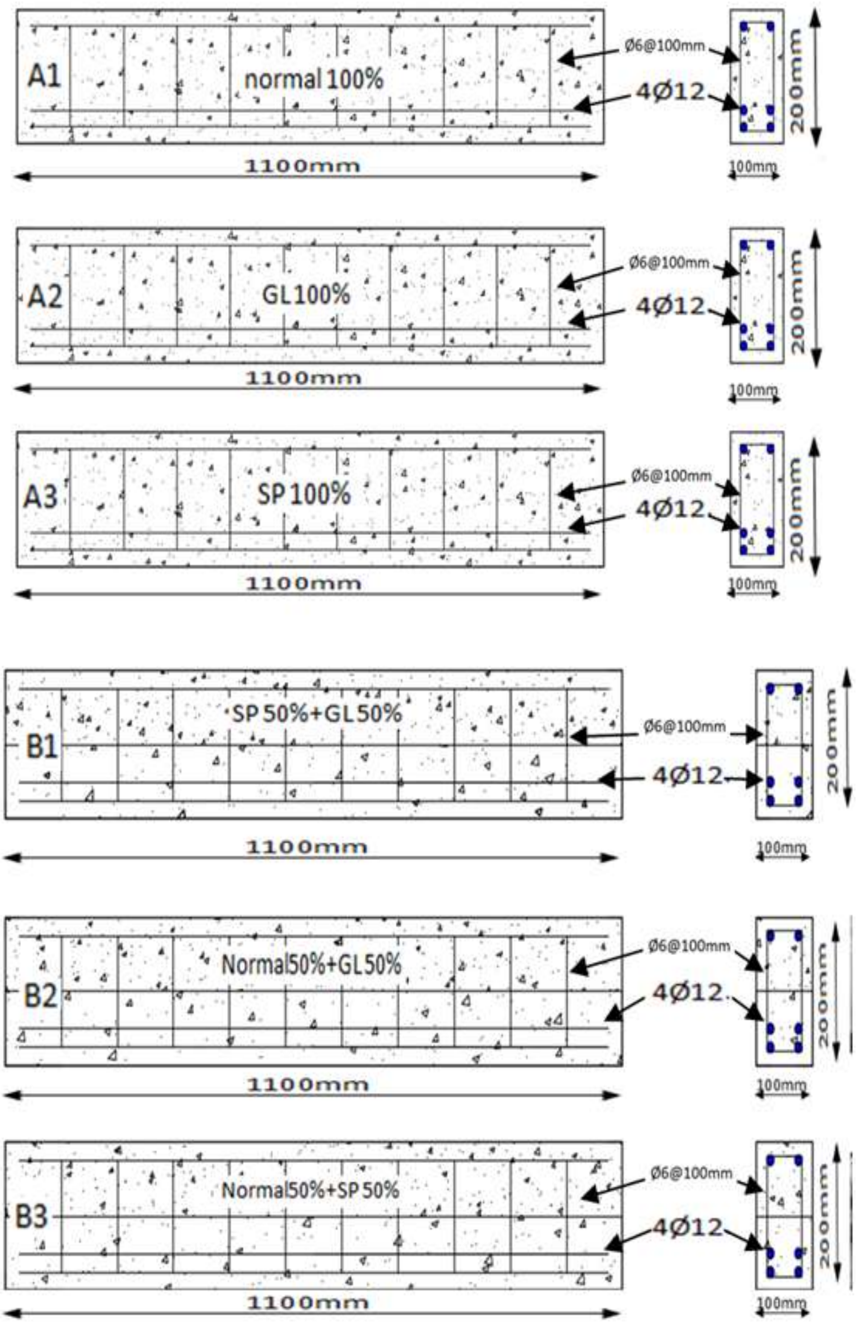
2. Experimental Work

2.1 Experimental Program

Four test slab groups were used in this study, each one of them consisted of three slab specimens identical in size but they are different in concrete type and steel bar reinforcement. All beams in groups having specific compressive strength 40 MPa .the diamention of the beams are (100 x 200 x 1100) mm. all beams are reinforced by four deformed reinforcing bar .see (table 1 ,fig 1). which made with normal concrete and high strength concrete (100%) (first and third group), another beams (second and fourth group) which made with hybrid concrete (50% normal concrete & 50% high strength concrete(additional GL51, SP 100)) . All beams width is (200mm), height is (100mm) and length is (1100mm)., see Table (1) and Figure (1). Each one of these slabs was designated in the way of refer to concrete type and steel bar reinforcement.

Table 1: Tested Slabs Properties and Description

Group	Slab Designation	Concrete type	Reinforce-ment	
Group-A	A1	Normal concrete 100%	4ϕ 12	ϕ 6@ 100 mm c/c
	A1	High strength concrete (GL51) 100%		
	A3	High strength concrete (SP100) 100%		
Group-B	B1	HSC (GL51) 50% & (SP100) 50%	4ϕ 12	ϕ 6@ 100 mm c/c
	B2	HSC (GL51) 50% & NC 50%		
	B3	HSC (SP100) 50% & NC 50%		
Group-C	C1	Normal concrete 100%	6ϕ 12	ϕ 6@ 100 mm c/c
	C2	High strength concrete (GL51) 100%		
	C3	High strength concrete (SP100) 100%		
Group-D	D1	HSC (GL51) 50% &(SP100) 50%	6ϕ 12	ϕ 6@ 100 mm c/c
	D2	HSC (GL51) 50% & NC 50%		
	D3	% & NC 50% HSC (SP100) 50		


A1
normal 100%
Ø6@100mm
4Ø12
200mm
1100mm
100mm
A2
GL100%
Ø6@100mm
4Ø12
200mm
1100mm
100mm
A3
SP 100%
Ø6@100mm
4Ø12
200mm
1100mm
100mm
B1
SP 50%+GL50%
Ø6@100mm
4Ø12
200mm
1100mm
100mm
B2
Normal50%+GL50%
Ø6@100mm
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B3
Normal50%+SP 50%
Ø6@100mm
4Ø12
200mm
1100mm
100mm

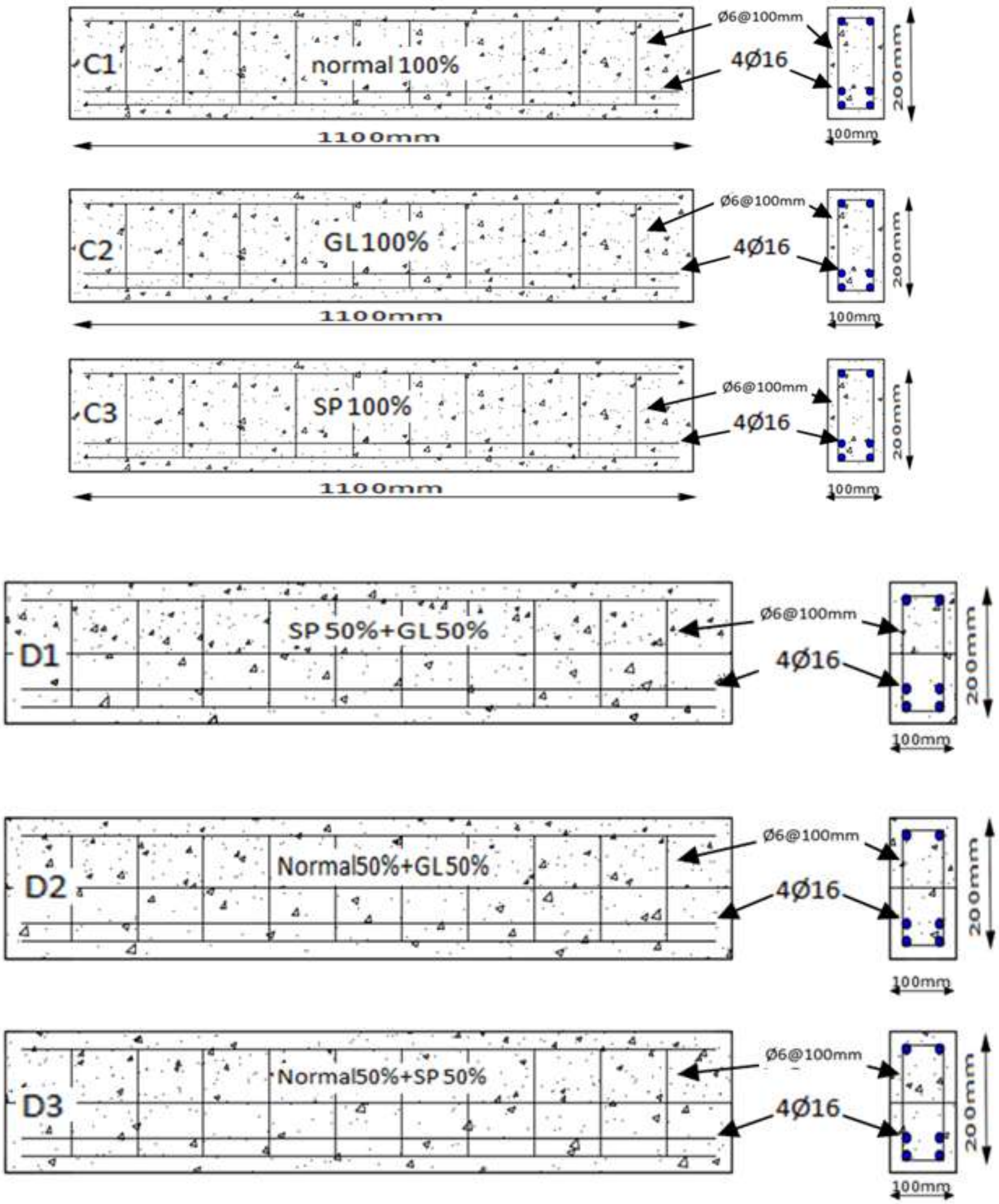


Figure 1: Each beam was designated in a way to refer to concrete type and steel bar reinforcement

2.2 Materials

The following materials are used In manufacturing test specimens as: (type I) ordinary Portland cement produced at Northern cement factory (Tasluja-Bazian) in this investigation the research use , properties of this material comply with the Iraqi standard specification No.5/1984 requirements; and also the research used AL.ukhaider natural sand of 4.75 mm maxim size as fine aggregates. The grading of fine aggregate complies with the Iraqi Standard specification No.45/1984, Crushed gravel with maximum size of(10 mm) from AL.nibaee area. The grading of the coarse aggregate complies with the Iraqi standard specification No.45/1984 and also the research used high water reducer super plasticizer (GL51) (SP100) and that clean tap water was used for curing and mixing. The concrete mix proportions are presented in Table (2).

The steel reinforcement have (4ф 12 & 4ф 16) and (ф 6) in diameter at (100 mm) c/c spacing in each way for all groups. A clear cover of (5mm) was but below the mesh. For all slabs, the steel reinforcement were designed to ensure the tested specimens to fail either by punching shear or flexural.

Table 2: Concrete Mixes

Mix proportions	Water (l/m3)	Cement (kg/m3)	Sand (kg/m3)	Gravel (kg/m3)	Superplasticizers (l/m3)
Normal conc.	180	450	610	1220	0
HSC	181.16	500	640	1280	5 (Gl)
HSC	181.16	500	640	1280	5(Sp 100)

2.3 Instrumentation and Measurements Test

The research used hydraulic universal testing machine (MFL system) to test the slabs specimens as well as control specimens. Central deflection has been measured by means of (0.01mm) accuracy dial gauge (ELE type) and (30mm) capacity. The dial gauges were placed underneath at the center of the bottom face. All tests were made in the structures laboratory of in Al-Mustansiriya University, college of Engineering, Baghdad, Iraq.

2.4 Results of Specimens Test

Test results of mechanical properties of hardened concrete specimens are showing in Table (3). Compressive strength was carried out on (100x100x100mm) cubes and (150 x 300) mm cylinders.

Table 3: Mechanical Properties of Concrete

Mix Designation	Property (MPa)	
	Cube Compressive strength (f_{cu})*	Cylinder Compressive strength (f_{cu})*
A1	40	30
A2	38	32
A3	41	33
B1	38	31
B2	40	33
B3	42	31
C1	39	34
C2	38	30
C3	40	34
D1	42	31
D2	41	34
D3	39	32

* Three samples average of (per mix) by using (150x150x150mm) cubes.
** Three samples average of (per mix) by using (150x300mm) cylinder.

2.5 Procedure Test

Figure (2) show the setup of tested specimens. All beams specimens were tested by using the universal testing machine (MFL system) with monotonic loading to ultimate states. The tested beams were simply supported and loaded with a load of single-point. The beams have been tested at (28) days age. The centerline, supports, point load and dial gauge were in their best locations. Because that the beam specimens were placed on the testing machine and adjusted.

Loading was applied slowly in successive increments;. observations and measurements were recorded for the mid-span deflection and crack development and propagation on the beam surface , At the end of each load increment. smaller increments were applied until failure When the beam reached advanced stage of loading, where the deflections increased very fast and the load indicator stopped recording anymore without any increase in applied load.
crack pattern were marked by a pencil at each load increment.

Figure 2: Setup of Tested Specimens

3. Results and Discussion

3.1 General Behavior

The test results of all (12) beams included first crack and ultimate load and failure mode are listed in Table (4) and photographs (1-12).

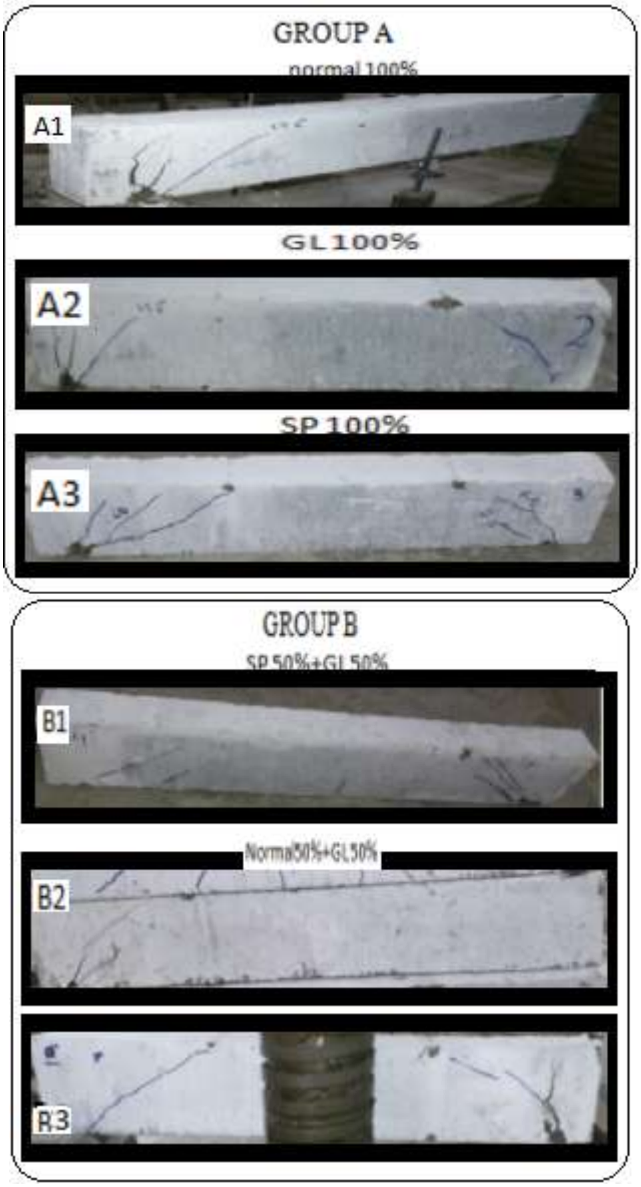
Table 4: Tested beams Cracked load, Ultimate and type of Failure

Group	Slab Designation	First crack load (Vcr) (KN)	Ultimate Load(Vc) (KN)	Vcr/Vc	Failure mode
Group-A	A1	25	150	0.166	Shear
	A2	66	175	0.377	Shear
	A3	66	260	0.253	Shear
Group-B	B1	50	200	0.250	Shear
	B2	89	225	0.395	Shear
	B3	60	395	0.151	Shear
Group-C	C1	79	215	0.367	Shear
	C2	45	240	0.187	Shear
	C3	165	420	0.392	Shear
Group-D	D1	65	250	0.392	Shear
	D2	100	290	0.344	Shear
	D3	185	450	0.411	Shear

3.2 Failure Mode and Crack Pattern

Layout of the diagonal crack patterns which leads to shear failure can be shown in Figure (3). There are numbers nearby the cracks which representing the load when the cracks have reached to the indicating position. Moreover, Figure(4) illustrating the crack patterns photographs of all project tested beams after the final failure. Generally, similar linear behaviour will be exhibited by all the tested beams from the initial loading up to the load causing failure. Also, in all the beams, no observation of the vertical flexural cracks will be noticed in the region of pure bending between the two points loads for each load stage. In general, the progression for cracking of each specimen can be summarized as follows:

Through the early stages of loading, the beams are cracks free. With further increase in load, there will a formation of an inclined tensile crack in one of the shear spans between point load and support which distribute above the longitudinal reinforcement, while a curved one will be formed toward the loading point. Later, the diagonal crack will be developed from the higher point of this crack in the shear span and will extend towards the point load with the increasing load. Ultimately, a faster extension of the diagonal crack will be taken place in the compressive zone towards the point load and horizontally towards the position of the tension steel leading to failure. Progressing behaviour of all beams is managed by micro-cracking, which particularly associated with the interfacial transition zone. Thus, using chemical and mineral admixtures,. Subsequently, good results of tensile strength can be expected. The last failure behaviour can be considered as a mode of diagonal tension failure. The shear cracks development is sudden and immediately followed by a severe and totally destructive shear failure.



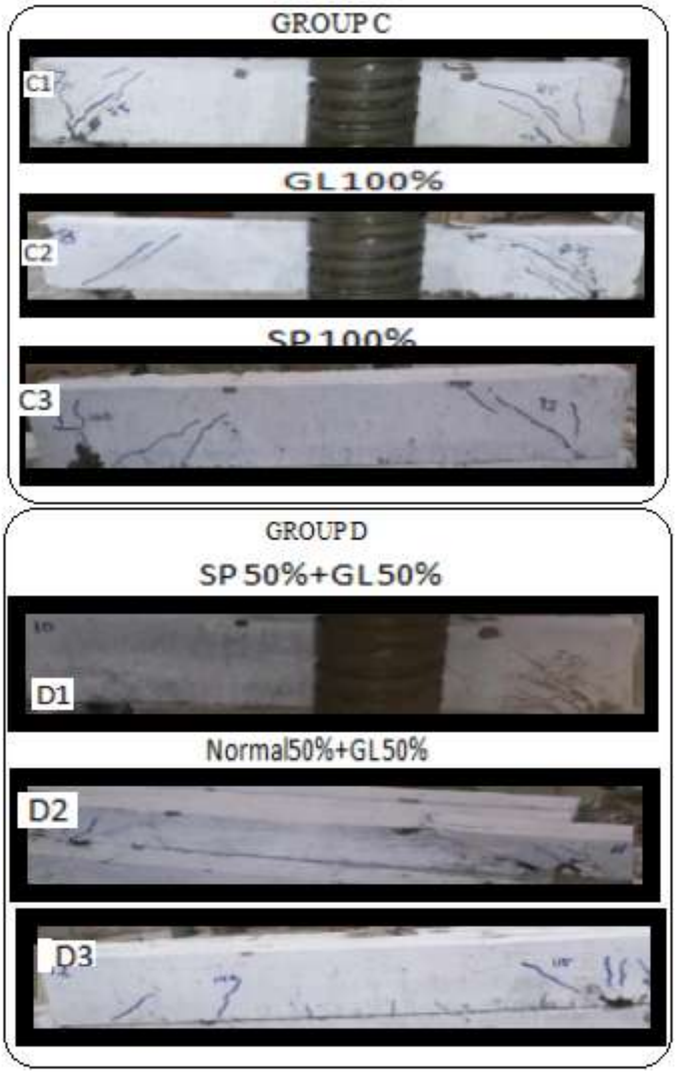


Figure 3: Crack pattern specimens at failure shear and flexural (A,B,C,D)

3.3 Ultimate Loads

This section of the research is important to find the difference in ultimate load capacity when using three types of concrete, beams which made with normal concrete and high strength concrete (100%) (first and third group), another beams (second and fourth group) which made with hybrid concrete (50% normal concrete & 50% high strength concrete(additional GL51, SP 100)).

For group (A&B) there is an increasing in ultimate load capacity about (A2 (14.28%) & A3(42.30%) with regard to A1) ((B2 (11.11%) & B3(49.36%)) with regard to B1 .

This experimental revealed that the ultimate load capacity increase with the addition of super plasticizers to the mix of concrete.

For group (C&D) there is an increasing in ultimate load capacity about (C2 (10.41%) decreasing & C3(48.80%) increasing with regard to C1), (D2 (13.79%) decreasing & D3(44.44%) increasing with regard to D1).

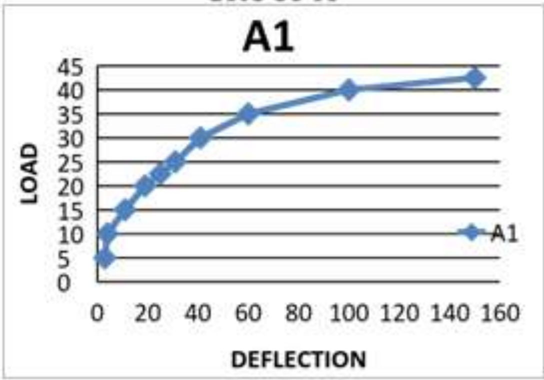
3.4 Cracking Loads

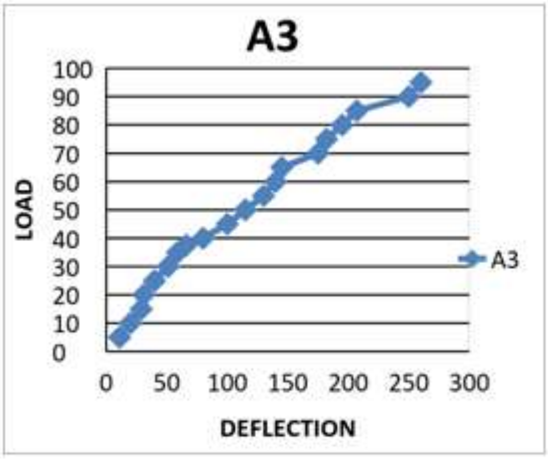
The cracking loading has been decreased with the addition of super plasticizers to the mix of concrete for the same strength of concrete (40 MPa). For beam specimen (A1, A2, A3, B1, B2, & B3) the crack has been occurred at shear force of sacrificial (25%, 45%, 66%, 66%, 50% & 89%). For beam specimen (C1, C2, C3, D1, D2, & D3) the crack has been occurred at (60% , 50%, 100%, 40%, 55% & 85%). These results of group (A&B) are dissimilar to results of group (C&D) because of difference in reinforcement.

3.5 Behavior of Load – Deflection

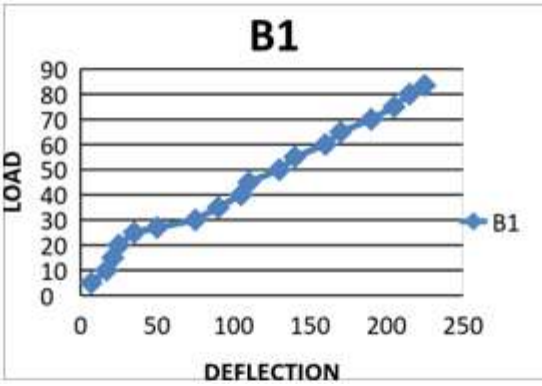
For all tested beams all load-deflection curves are under the center of loaded area and the are all set and showed in Figure (4).

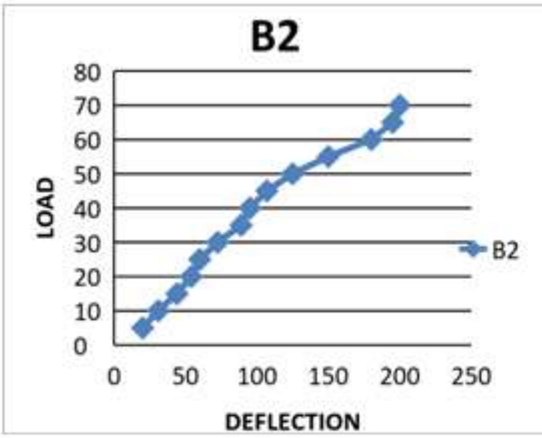
GROUP A



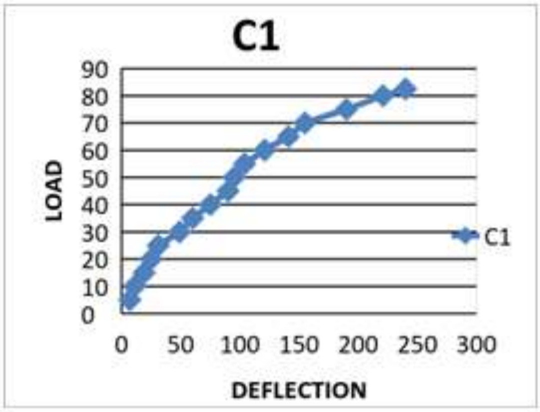


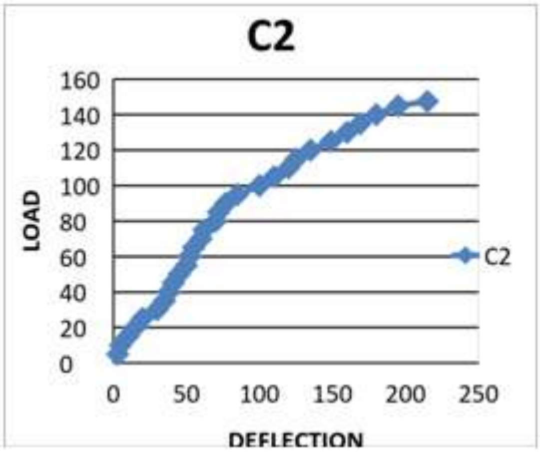
Group B

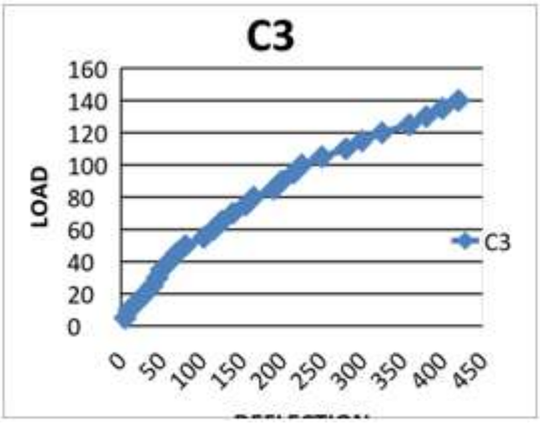




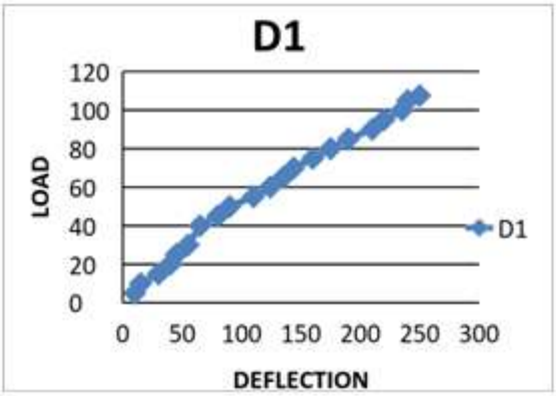
Group C







Group D



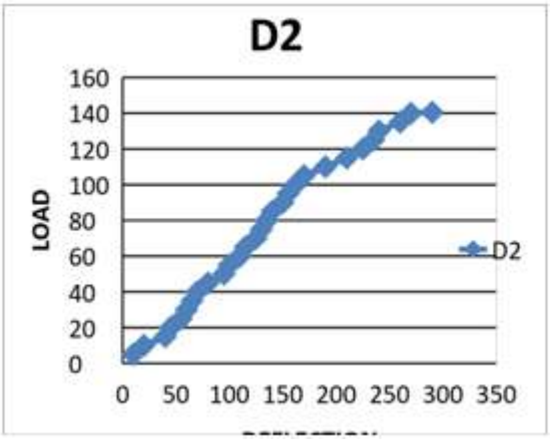


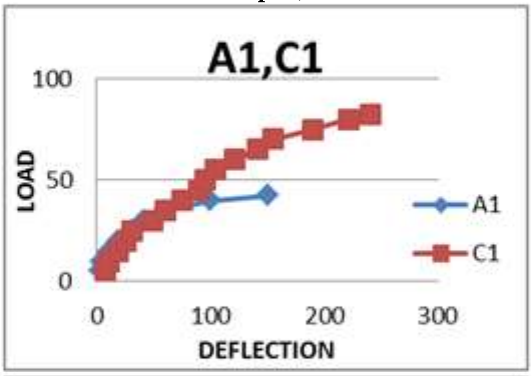
Figure 4: Load-Deflection Curves Group (A, D, C, D)

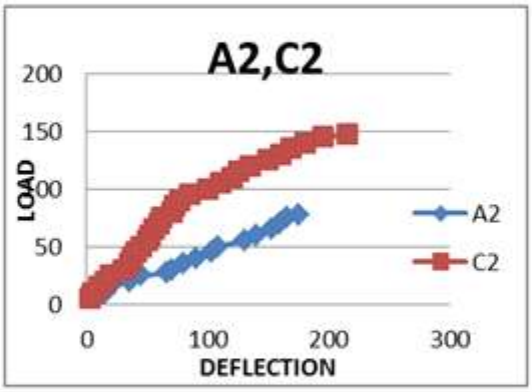
3.6 Effect of bar daimeter in Ultimate Capacity

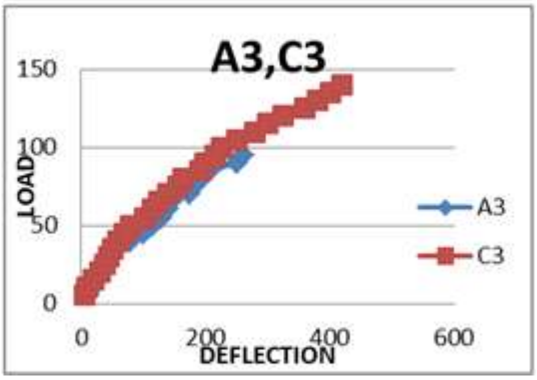
According to the experimental results, the ultimate load capacity of tested specimens reinforced by 16 mm C1 increased by (30.23%) in comparison with beam A1 reinforced by 12 mm , for the beam specimen C2 increased by about (27,08%) in comparison with beam A2, C3 increased by about (30.09%) in comparison with beam A3.

But the ultimate load capacity of tested specimens reinforced by 16 mm D1 increased by (20%) in comparison with beam B1, for the beam specimen D2 increased by about (22.14%) in comparison with beam B2, D3 increased by about (12.22%) in comparison with beam B3 As shown in Fig. (5).

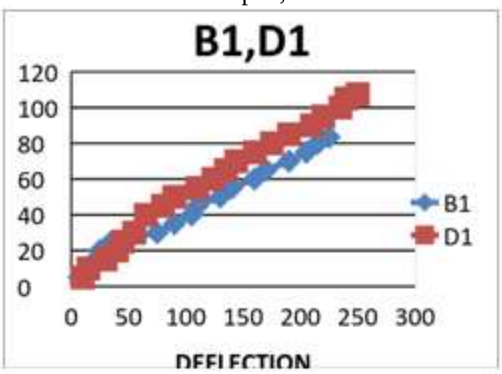
Group A, C

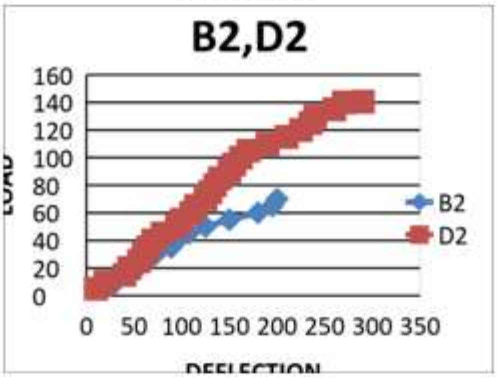






Group B, D





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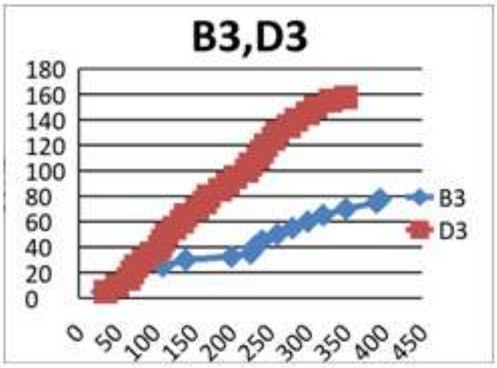
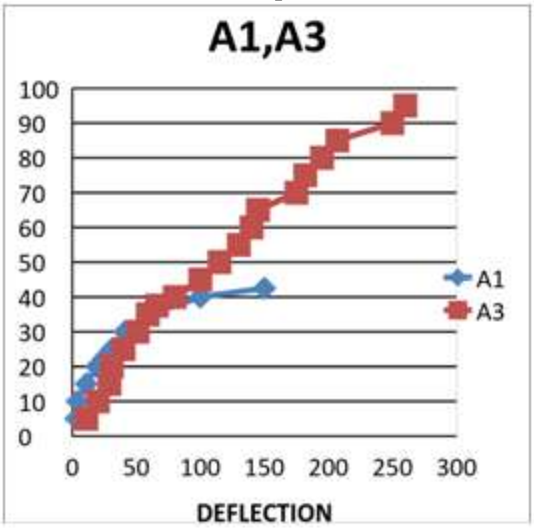


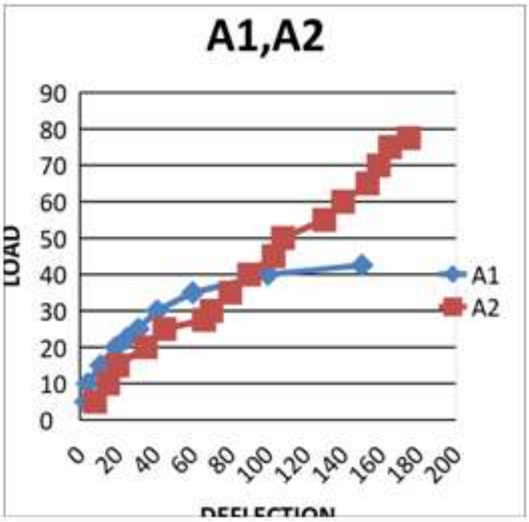
Figure 5: Effect of bar diameter in Ultimate Capacity GROUP (A.B.C.D)

3.7 Effect of concerte type in Ultimate Capacity

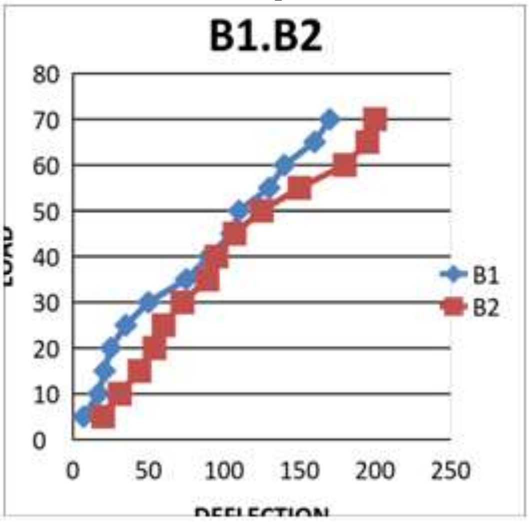
The experimental results of ultimate load capacity of tested specimens are showed in Fig. (6). For the steel bar reinforcement (Ø 12 mm) with different concrete type (CC & HSC) (HSC with GL51 & HSC with Ssp100). The results showed that the ultimate load capacity of tested specimens A2 , A3 was increased with this retio (14.28% & 42.30%) in comparison with beam A1. B2 , B3 increased by (11.11% & 49.36%) in comparison with beam B1. In group C & D with steel bar diameter (Ø 16 mm), the results showed increased in ultimate load capacity of tested specimens for the beam specimen C2 increased by about (10.41%) in comparison with beam C1, D2 increased by about (13.79%) in comparison with beam D1 , but increasing in ultimate load capacity of tested specimens for the beam specimen C3 increased by about (48.80%) in comparison with slab C1, D3 increased by about (44.44%) in comparison with beam D1

Group A

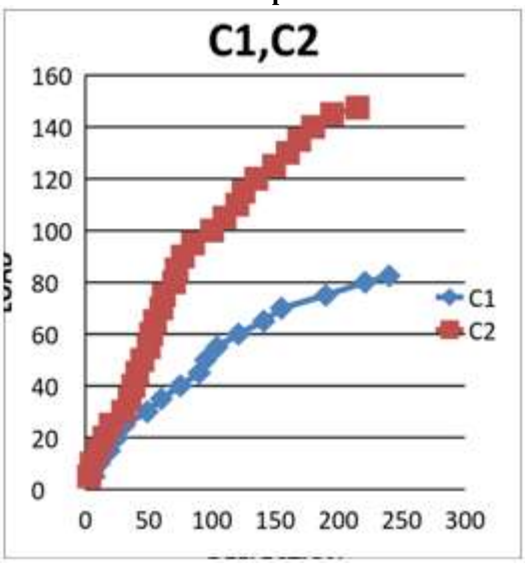


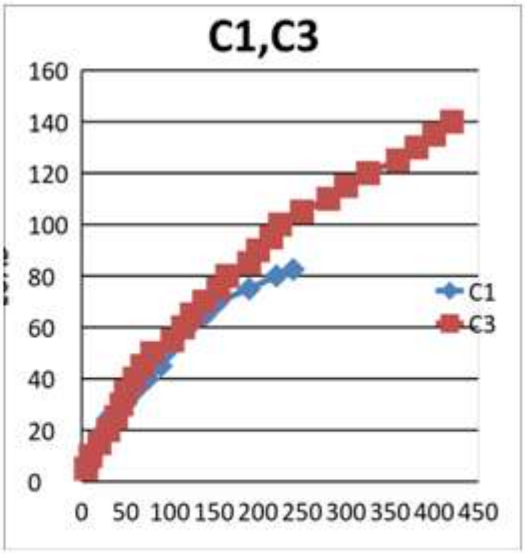


Group B



Group C





Group D

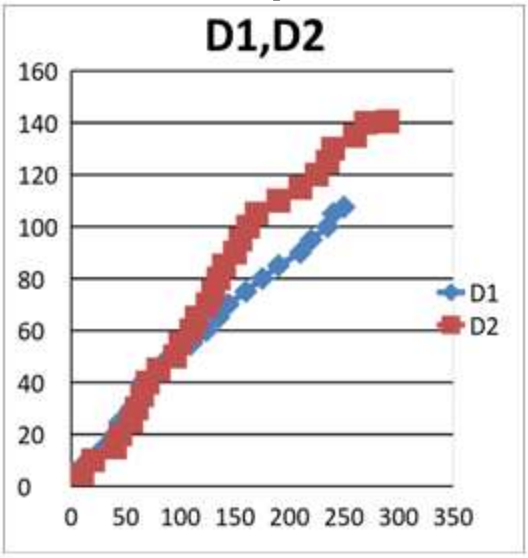


Figure 6: Effect of concrete type in ultimate capacity Group (A, B, C, D)

4. Conclusions

1) For specimens which that made with hybrid high strength concrete the ultimate capacity of tested specimens increased with (10.41% - 48.80%) in comparison with normal concrete.
2) The ultimate capacity of tested specimens increased for beams which made with HSC by about (14.28% - 42.30%) in comparison with normal concrete.
3) For specimens reinforced with steel bar Ø 12mm , the results of ultimate load capacity showed increasing for specimens made with hybrid and high strength concrete in comparison with normal concrete. But for specimens reinforced with steel bar Ø 16 mm, the results of ultimate load capacity showed increasing for specimens made with hybrid concrete (normal & SP100) but increasing for specimens made with hybrid concrete (normal & GL51).
4) The failure perimeter increased significantly with specimens which made with high strength concrete and hybrid concrete in comparison with normal concrete.
5) The amount of steel reinforced beams does not have a significant effect on the value of the first cracking load but it has effectiveness on the value of the ultimate load.

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