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Effect of Repeated Loads on Steel -Concrete Composite Beams with High Strength Reinforced Concrete

Suhaib Yahya Al-Darzi *
Civil Engineering Department, College of Engineering, University of Mosul.

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ABSTRACT
The present study utilized an experimental tests to investigate the effects of using High Strength Concrete (HSC) on ultimate resistance, deflection and slip of steel-concrete composite beam under monotonic and repeated loads. Sixteen beams divided into four groups having concrete with compressive strength of 25, 42.6, 43.3 and 43.9MPa investigated experimentally. Results indicated that the use of HSC increases the carrying loading capacity of the beams by about 18.82 % and 52.91 % under monotonic and repeated loads, respectively. The beam resistance decreased under repeated load in comparison with monotonic load by about 5 % to 28.53 %. Use the fiber increases the ultimate strength by about 10 % to 28.65 %, and decrease the deflection and slipping by 15 % and 26.5 %, respectively. The ultimate strength estimated experimentally are less than the AISC-LRFD specifications' formulas.

تأثير الأحمال التكرارية على الاعتاب المركبة حديد – خرسانة مسلحة عالية المقاومة

الخلاصة
في الدراسة الحالية تم تحري تأثير زيادة مقاومة خرسانة البلاطات في الأعتاب المركبة من الحديد والخرسانة واستخدام الألياف الحديدية بنسبة باعية مقدارها 16 و32 على مقاومة العتب، الهطول في منتصف العتب والإنزلاق في نهايتي العتب. لهذا الغرض تم إجراء الفحص على ستة عشر نموذجا قسمت إلى أربعة مجاميع وبواقع أربعة أعتاب لكل مجموعة تم إجراء الفحص عليها باستخدام أحمال تزايدية وأحمال تكرارية، وذلك باستخدام خرسانة ذات مقاومة انضغاط لاسطوانة قياسية 25 و42.6 و43.3 و43.9 ميكاباسكال. بينت النتائج أن زيادة مقاومة الخرسانة من 25 ميكاباسكال الى 43.9 ميكاباسكال سوف يحسن مقاومة الأعتاب بنسبة 18.82 % و52.91 % للأعتاب التي تم فحصها باستخدام الأحمال التزايدية والتكرارية على التوالي. كما تبين أيضا أن الأحمال التكرارية تقلل من مقاومة الأعتاب مقارنة بالأحمال التزايدية وبنسبة تتراوح بين 5 % الى 28.32 %، فضلا عن الزيادة الحاصلة بالهطول والإنزلاق عند النهايات. هذا وقد تبين أن إضافة الألياف الحديدية للخرسانة يؤدي الى تحسين السلوك العام للأعتاب المركبة من خلال زيادة المقاومة للعتب بحدود 10 % الى 28.65 % وتقليل الهطول بحدود 15 % وتقليل الإنزلاق عند النهايات بحدود 26.5 %. النتائج العملية التي تم الحصول عليها أعطت مقاومة أقل من تلك التي يمكن حسابها باستخدام المعادلات الخاصة بمواصفات المعهد الأمريكي AISC بحدود 15 % الى 32 % باستثناء تلك المستحصلة للمجموعة HSF16 تحت الأحمال التكرارية.

الكلمات المفتاحية
فحص الاعتاب للانحناء، خرسانة عالية الأداء، خرسانة ليفية، الأعتاب المركبة، الاحمال التكرارية.

*Corresponding author.
E-mail addresses:suhaib darzi@yahoo.com

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Introduction:

Recently, the usage of High Concrete Strength (HCS) have increased tremendously. It is a relatively new product usually produced by using conventional mixing proportions or additives. The high strength concrete's characteristics differ from that of normal concrete. The concrete properties are mainly related to concrete characteristics especially compressive strength. Therefore, high compressive strength will enhance the mechanical properties of the concrete such as; tensile strength and modulus of elasticity. The HCS offers an opportunity for gaining better structure with lesser maintenance by providing more durable concrete in comparison with normal concrete [1].

Nowadays, research laboratories are still exploring ways to develop this type of concrete. The use of High Concrete strength in composite beams are rarely investigated under monotonic and cyclic loads. Daniel and Loukili, [2], investigated the behavior of High-Strength Fiber-Reinforced Concrete (HSFRC) beams under cyclic loads. It had been illustrated that HSFRC with tensile reinforcement ratio of 0.55 % exhibited behavior similar to that of a HSC beam with a tensile reinforcement ratio of 0.97 % and the fibers have no influence on strength during loading cycles at a given displacement [2].

Al-Sulayfani, et.al. [3], testing a simply supported beams made with concrete contains steel fibers, under repeated loads. The beams dimension was (150 mm X 160 mm X 1000 mm), with a percentages of steel fibers (0.0 %, 0.5 %, 0.75 % and 1.0 %). It was concluded that adding steel fiber improve the behavior the concrete beam under repeated loads [3].

Jallo, E.K., [4], tested standard concrete cylinders with dimension of (300mm *x*150mm) containing different percentages of silica fume to evaluate the effect of silica fume on compressive strength of concrete under monotonic and repeated loads. The repeated loads applied for many cycles up to failure with rate of loading (0.3) $N/mm^2/sec$. It was found that using silica fume will increase the stresses carried by concrete under monotonic load comparing with repeated load [4].

Yeoh, D., et.al. [5], investigated experimentally the effect of concrete type on the behavior of laminated concrete T-beams among several parameters. It was found that the beams with high concrete strength exhibited higher collapse load than normal concrete strength beams having same stiffness [5].

Sawab, et.al., [6], investigated the behavior of composite steel plate concrete beam with ultra-high performance concrete having compressive strength higher than 150 MPa by using finite element simulation with emphasis on shear and bond behavior. A numerical model is proposed considering the cyclic softened membrane model with a new constitutive model accounts for the bond-slip behavior of steel plates.

Levon C.H., et.al. [7], investigated experimentally the effect of fiber-reinforced concrete and cementations composites in controlling cracking for bridge deck. The evaluation included the plastic and hardened mixture properties of high-performance fiber-reinforced concrete. The deflection hardening, flexural toughness, and bond strength were investigated with the addition of a small amount of fibers to concrete matrix. It was found that adding fiber will minimizes cracking and enhance the performance of concrete mix. The main objective of the present study is to investigate the effects of using high concrete strength in the deck of composite beam and the effect of using steel fiber having different aspect ratios on flexural resistance, mid-span's deflection and slip at ends of steel-concrete composite beam under both monotonic and repeated loads. The experimental results of the flexural test obtained from the present work for composite beam will give a better understanding to the actual behavior of composite beam with high strength concrete. This results might represent a valuable additive to the engineering knowledge.

Materials and Methods

Materials Preparation

Different mixing proportions are usually used to produce the high strength concrete (HSC). However, the HSC needs more ingredients, stricter construction technology and higher quality of administrative personnel and construction operating staff. In HSC the workability of fresh concrete, and the mechanical properties is greatly improved. In the present work, Ordinary Portland Cement (OPC), and local aggregates obtained from location called Khazer, lies at about 60 km to the east of Mosul city with maximum size of 20mm is used with a Turkish cement manufactured by Jemco factory. The cement, aggregate and water used in concrete are tested and prepared before construction of composite beam samples. Physical and chemical tests results of cement listed in Table (1) show that the cement is complies with the requirements of Iraqi standards [8].

The sieve analysis of the local river sand used in concrete admixture listed in Table (2) show that the sand lies within the range of fine sand according to the classification of the British Standards-882 (B.S.882). Meanwhile, sieve analysis results of the gravel listed in Table (2) show that the gravel having a maximum aggregate size of 20mm according to the classification of the B.S.882 [9]. The values of 1720 kg/m^3, 2.72 and 3.1 % are obtained for density, specific weight and absorption, respectively for the gravel used in concrete mixture. Also, values of 1698 kg/m3, 2.73

and 1.02 % are obtained for density, specific weight and absorption, respectively for the sand used in concrete mixture. A normal drinking water is used for mixing of concrete.

Several mixes are prepared to get the required compressive strength of concrete. Final mixes proportions of (cement: sand: gravel /water) are used with slump of (95 mm) for each type of the concrete. The mixes ratios of (1:2.5:3.3/0.40), (1:1.45:2.2/0.38) and (1:1.75:2.2/0.32) are used for Normal strength Concrete (NC), High Strength concrete (HS) and High Strength Fiber concrete, respectively. Since, Beshr, H., et.al. [10], classified the high strength concrete (HS) as that concrete produced with compressive strength exceeding 40MPa [1, 10,11], the (NC) group is classified as normal strength concrete. The letter (F) is used to indicate the presence of fibers in the group. The use of normal concrete (NC) give a neutral axis calculated to be at 85mm measured from the top of concrete deck, meanwhile, using high strength concrete (HS) give a neutral axis calculated to be at 95 mm measured from the top of concrete deck.

In the present work, two types of fibers are used with aspect ratio 16 and aspect ratio 32. Therefore, the numbers 16 and 32 added to the third and the fourth groups to be named as HSF16 and HSF32 in order to nominate the type of fiber used in each group. A 2.0 % of fiber is used in concrete mix as an optimum fiber percentage [12]. The letter (*R*) is added at the end of sample tested with repeated load. The concrete compressive strength is calculated for each group by testing three standard concrete cubes having size 150 mm X 150 mm X 150 mm. The cubes are tested according to the standard method specified by ASTM specification [13]. The compressive strength test results are listed in Table (3) with their standard deviation. The results then converted to the equivalent standard cylinder compressive strength f'c, by considering the standard cylinder compressive strength equal to 80 % of the standard cube compressive strength. Each composite beam specimen has a total length of 1450 mm.

The composite beam is composed of standard hot rolled steel shape W6X12 [14] connected to 120 mm thickness concrete slab with 500 mm width as shown in Fig. (1). The steel yield strength and ultimate strength are obtained from uniaxial tensile test of six strips taken from the flange and the web of steel section are listed in Table (3). The uniaxial tensile test is also used for a part of the 10 mm diameter reinforcement bars, which give a yield strength and ultimate strength listed in Table (3). The tests results of steel section, reinforcement and concrete strength are listed in Table (3). Using, uniaxial tensile test results the modulus of elasticity are estimated to be Es=197450 MPa and Er=199550 MPa for steel section and steel reinforcement, respectively.

Table (1) The physiochemical tests results of ordinary Portland cement

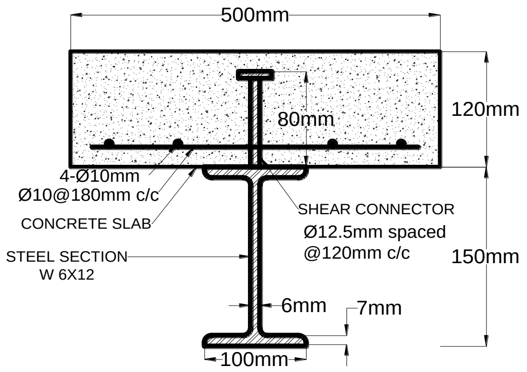
Chemical test		
Elements	Results%	IQS: No.5/1984
Al_2O_3	4.9	3.0-8.0
SiO_2	20.2	17.0-25.0
Fe_2O_3	4.8	0.5-6.0
CaO	61.5	60.0-67.0
SO_3	2.3	≤ 2.8 %
MgO	2.6	≤ 5%
C_3S	37.4	31.03-41.05
C_2S	33.20	28.61-37.90
C_3A	12.15	11.96-12.30
C_4AF	7.89	7.72-8.02
Physical test		
Properties	Results	IQS: No.5/1984
Fineness remain on sieve170	5.5%	≤ 10%
Initial Hardening minute	90	≥ 45 minute
Final Hardening minute	690	≥ 600 minute
Compressive strength - 3 days	18.2 MPa	≥ 16 MPa
Compressive strength-7 days	27.3 MPa	≥ 24 MPa
Tension strength -3 days	1.78 MPa	≥ 1.6 MPa
Tensile strength - 7 days	2.9 MPa	≥ 2.4 MPa

Table (2) Gradation of aggregate

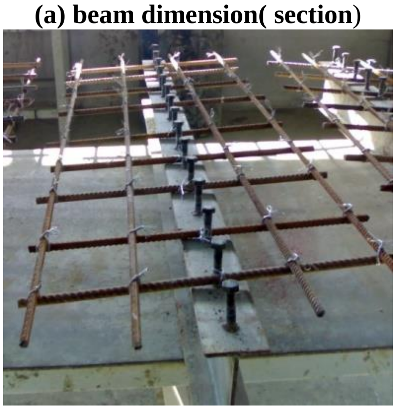
Sand		
Sieve size mm	B.S.882 %	% Passing
5 mm No.4	89-100	100
2.36mm No.8	60-100	82
1.18mm No.16	30-100	68
600μm No.30	15-100	49
300μm No.50	5-70	19
150μm No.150	0-15	2
Gravel		
Sieve size mm	% Passing	B.S.882 %
20mm	100	90-100
14mm	52	40-.80
10mm	43	30-60
5mm	0.5	0-10

Table (3) Concrete cube compressive strength and steel and reinforcement yield strength

Group	fcu (MPa)	Av. fcu (MPa)	Av. f'c (MPa)	Standard Deviation
NC	26.7	25.00	20.00	$15.1x10^{-1}$
	24.3			
	23.9			
HS	52.55	53.25	42.60	$7.0x10^{-1}$
	53.24			
	53.95			
HSF16	53.45	54.08	43.26	$6.1x10^{-1}$
	54.66			
	54.12			
HSF32	55.2	54.84	43.87	$3.4x10^{-1}$
	54.78			
	54.53			
Reinf. Bar No.	fy MPa	Strip No.		fy MPa
1	478	1		353
2	466	2		354
3	482	3		358
4	480	4		338
5	476	5		344
6	490	6		348
Average Yield Strength	491	Average Yield Strength		349
Ultimate strength	648	Ultimate strength		478
Standard Deviation	9.9	Standard Deviation		10.63



(a) beam dimension(section)



(b) Section, studs and reinforcement

Figure 1: Geometry and installation of composite beam sample

A steel-headed stud mechanical shear connectors having 12.5 mm diameter and 80mm height are used to connect the steel section to concrete deck. The connectors designed to comply with the (AISC) specification in order to give a fully interaction between concrete and steel section. [14] The uniaxial tensile test is used to obtain the yield strength of fy= 480 MPa and ultimate strength of fu= 654 MPa of the stud connectors used in composite beam sample with a modulus of elasticity E_{st}= 207520 MPa.

Testing Method:

The present work considered the effects of using different concrete compressive strength with or without fibers on the slip and the deflection of composite beam. Therefore, a total of sixteen composite beam specimens divided into four groups are constructed and tested in the civil engineering laboratory of Mosul University. The headed stud shear connectors are welded to the steel beam flange using a standard procedure. The connectors spaced at 100 mm C/C as shown in Fig. (1). Reinforcement mesh consists of a minimum number of bars having 10mm diameter are placed at the bottom of concrete flange in longitudinal and transverse directions. Then, the concrete flanges are casted by using wood forms. After casting of the concrete, the concrete surfaces of the beams are kept moist with wet burlap for 3 days. The wood forms are then removed and the specimens are cured in air-dry conditions until testing. The composite beam specimens are supported at its ends with a span between supports of 1350 mm.

A 500 kN hydraulic jack is used to apply the two points load test for both monotonic and repeated loads. The load is applied at the top of concrete flange through a distribution beam and two cross shafts generating the loading condition shown in Fig. (2). The test setup generates a two shear zones near the ends and a pure bending zone at the middle of the simply supported beam. The load is gradually applied monitored and recorded using a load cell. The first cycle begin with about 0.1Pult and increased by about 0.1Pult for each cycle until the failure of specimen. The slip at ends of the beam and deflections at mid-span are recorded using three digital transducers with an accuracy of (0.0001 mm). The mean value of the samples and the standard deviation statistical methods are adopted and used in analyzing the data obtained from experiments [15].

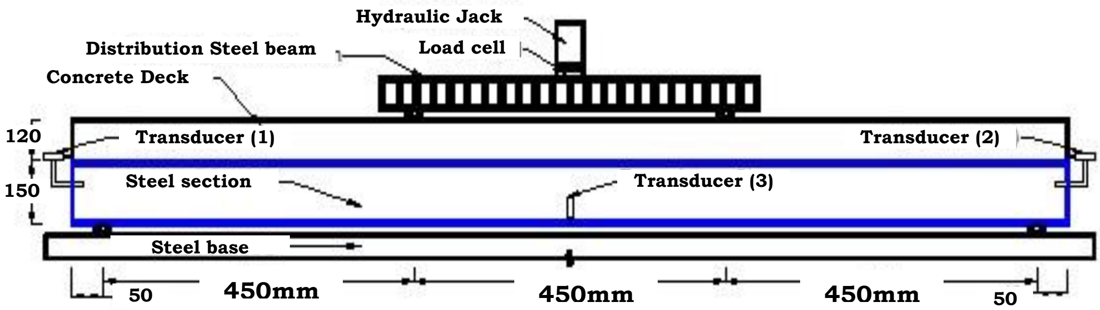


Figure 2: Beam test setup (Dimensions in mm)

Results and Discussions:

The results of the present work may express the behavior of the locally constructed and tested beams only. However, the behavior of these beams are compared with the previous literature to show their agreement and disagreement in order to conclude the overall behavior of the composite beam's properties considered in the present investigation. During the test of each beam specimen, the applied load, the deflection at the mid-span and the slip at ends of the beam are observedو and recorded at each load step. It is observed that at early stages, cracks are initiated at the bottom of concrete flange in all specimens, and then the cracks are extended further by increasing the applied load up to failure. All beams have a flexural failure mode observed clearly in the concrete flange after generating major cracks, as shown in Fig. (3). The test results are plotted in terms of load-slip curves and load-deflection curves for both monotonic load and repeated load, as seen in Fig. (4, 5, 6 and 7) for groups NC, HS, HSF16 and HSF32, respectively.

It is remarked that the cracks in group NC are started at the early stages, but the cracks in group NCR are initiated at the second load cycle. However, cracks in groups HS and HSR are mostly started at about 40 % of the ultimate load. Meanwhile, cracks in groups HSF16 and HSF32 initiated at about 60 % of the ultimate load. After cracks initiation, the composite beams constructed with steel fiber (groups HSF16 and HSF32) show a cracks separations and increasing rates lesser than those noticed in beams constructed without steel fiber. The test results in terms of ultimate load, deflection and slip are listed in Table (4) and drawn in Fig. (8). The flexural failure modes in concrete flange after generating a major cracks are comply with the conclusions stated by Liang, Q.Q., et.al., [16]. The differences may be due to the inelastic behavior of the concrete as specified by Elghazouli, A.Y. and Treadway, J., [17].

Effect of Repeated Loads

The results obtained from monotonic load teats and from repeated load teat are plotted in Fig. (4, 5, 6 and 7) and listed in Table (4). The results show that the repeated load test will decrease the beams resistance comparing with monotonic load test of about 28.53 %, 8.021 %, 5.02 % and 17.16 % for group NC, group HS, group HSF16 and group HSF32, respectively. The deflection and slip obtained from beams tested using repeated load are more than those obtained from beams tested using monotonic load, as shown in Fig. (8). It can be seen that the slip in group NC and group HS obtained from repeated load test are much more than those obtained from monotonic load test with a differences of about 228 % and 113 % for group NC and group HS, respectively. However, a lesser increasing ratios of about 12.8 % and 1.23 % are observed for group HSF16 and group HSF32, respectively. The deflection and slip obtained from the beams tested using repeated load are more than those obtained from the beams tested using monotonic load which are comply with the conclusions stated by Parthasarathi, N., et.al., [18].

Table (4) Testing matrix and experimental results

Group	Pult. kN	Ave. Pult. kN	Defl. mm	Ave. Defl. mm	slip mm	Ave. Slip mm
NC1	285.61		35.23		2.202	
NC2	281.21	283.41	40.39	37.81	2.698	2.45
HS1	339.74		44.12		3.252	
HS2	333.74	336.74	37.25	40.68	2.707	2.98
HSF16-1	368.49		30.75		4.313	
HSF16-2	372.20	370.35	38.60	34.68	5.733	5.02
HSF32-1	435.05		40.85		3.698	
HSF32-2	431.35	433.20	31.00	35.92	2.806	3.25
NCR1	200.65		38.44		7.146	
NCR2	204.43	202.54	45.87	42.16	8.936	8.04
HSR1	306.34		44.12		7.226	
HSR2	313.12	309.73	33.49	38.80	5.485	6.36
HSF16R-1	354.94		42.22		6.082	
HSF16R-2	348.54	351.74	35.46	38.84	5.250	5.66
HSF32R-1	351.52		20.74		2.827	
HSF32R-2	366.21	358.87	28.02	24.38	3.757	3.29

Effect of Compressive Strength

It can be noticed from the results shown in Fig. (8) and listed in Table (4) that the compressive strength has a significant effect on the ultimate strength of the composite beams tested by using both monotonic load and repeated load. The ultimate strength of the beams in group HS are increased comparing with the ultimate strength of the beams in group NC by about 18.82 % and 52.91 % for beams tested by using monotonic load and repeated load, respectively. The results plotted in Fig. (8-b and d) show that the deflection of the beams in group HS are decreased comparing with the deflection of the beams in group NC at ultimate stage by about 73.6 % and 76.3 % for beams tested using monotonic load and repeated load, respectively. Fig. (8) shows that the slip resistance are improved by using high strength concrete. At ultimate load stage, the slip of beams in group HS are less than those obtained from beams in group NC by about 91.8 % and 81.4 % for beams tested using monotonic load and repeated load, respectively. The above results are agreed with the conclusions stated by Luo, Y., et.al. [19].

Effect of Steel Fibers

The results obtained from testing beams in groups HS, HSF16 and HSF32 are shown in Fig. (5) to Fig. (7) and listed in Table (4). The ultimate resistance of beams in group HS tested using monotonic load are increase of about 10 % and 28.65 % comparing with group HSF16 and group HSF32, respectively, as well as the ultimate resistance of beams in group HS tested using repeated load are increase by about 13.6 % and 15.9 % comparing with group HSF16 and group HSF32, respectively. It is clearly that the presence of fiber in high strength concrete composite beam samples will increase the ultimate resistance. The deflection obtained from beams in group HS tested using monotonic loads are decreased of about 14.8 % and 11.7 %, comparing with group HSF16 and group HSF32, respectively. As well as the deflection of the beams in group HS tested using repeated load are decreased of about 37.2 %, comparing with group HSF32, which remark clearly that the presence of fibers will decrease the deflection. Fig. (8-a and c) show that the presence of fiber will enhance the slip resistance for the composite beam, which may be related to the contribution of the fiber on the nonlinear behavior of concrete [20]. Using the formula stated by (AISC-LRFD) specification [14], the ultimate strength of each composite beam are estimated, and compared with the experimental ultimate resisting load obtained by test for each group and the results are listed in Table (5). The results listed in Table (5) show that the (AISC) formulas overestimated the ultimate strength for all beams in groups tested using monotonic load. The results also show that the formula underestimated the ultimate strength for beams in group NC tested using repeated load and overestimated the ultimate strength for the beams in other groups tested using repeated load.

Table (5) Experimental and (AISC) composite beam resistance results

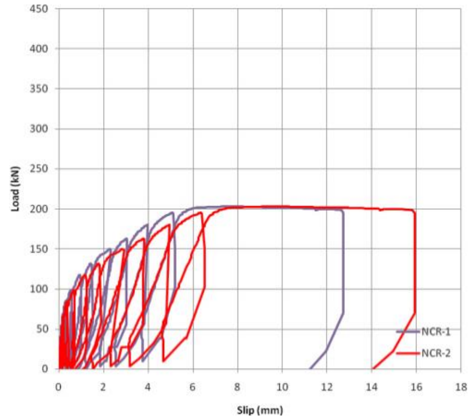
Group	Exp. Ave. Pult. kN	Pult. kN (AISC)	%Diff .
NC	283.41	239.53	-15.48
HS	336.74	291.64	-13.39
HSF16	370.35	292.34	-21.06
HSF32	433.20	292.97	-32.37
NCR	202.54	239.53	18.26
HSR	309.73	291.64	-5.84
HSF16R	351.74	292.34	-16.89
HSF32R	358.87	292.97	-18.36

Conclusions:

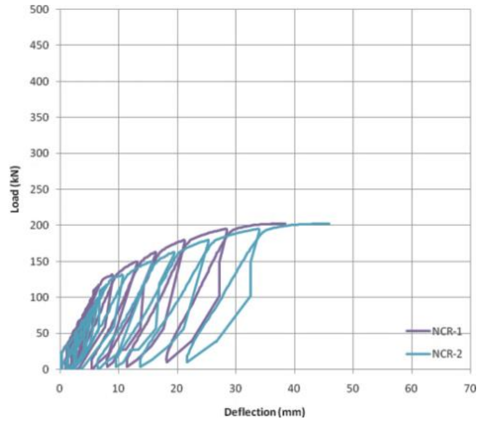
Using the results obtained from the experimental tests of composite steel-concrete beamd, the following conclusions can be drawn;

1. Using repeated load initiates the cracks in the concrete deck at earlier stages compare to that one under monotonic loading.
2. Using HSC increases the ultimate resistance of composite beam up to 18.8 %.
3. The deflection of composite beam is decreased with using high strength concrete by 48 % and 25 % using monotonic load test and repeated load test, respectively.
4. The midspan deflection decreases by using fibered concrete of about 15 % under monotonic load test.
5. Slip at the beam ends decreases by using high strength concrete up to 26.5 % and decreases with adding more steel fiber to the concrete mix.
6. The ultimate strength estimated by AISC’s formula is more than those obtained experimentally of about 15 % to 32 % for beams tested under monotonic load test and repeated load test, respectively.

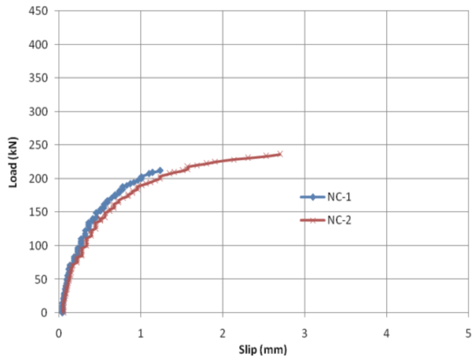
Figure 3: Cracks in concrete deck



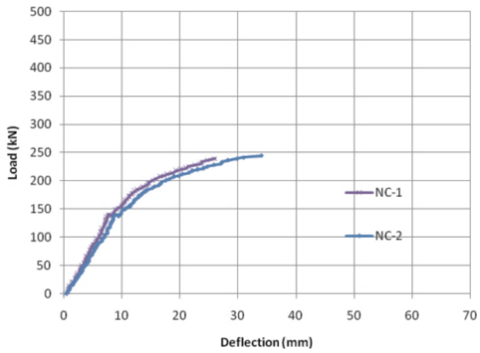
(a) slip of under repeated load



(b) deflection under repeated load

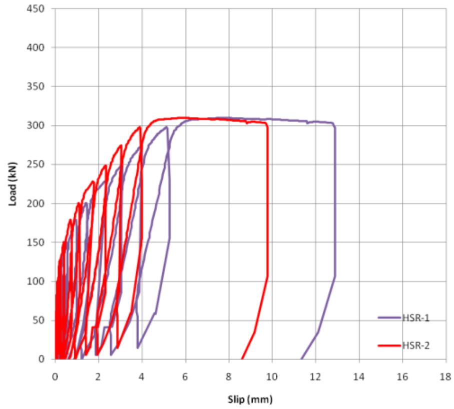


(c) slip under monotonic load

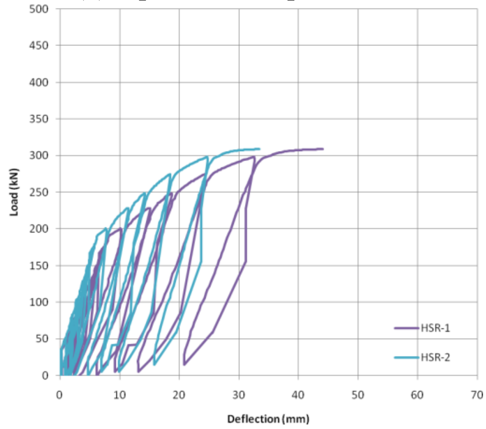


(d) deflection under monotonic load

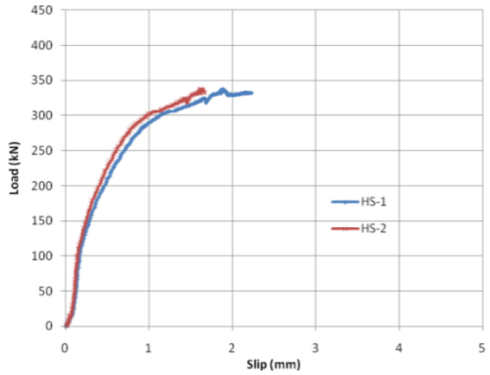
Figure 4: Load-deflection and load-slip curves for group NC under repeated and monotonic loads.



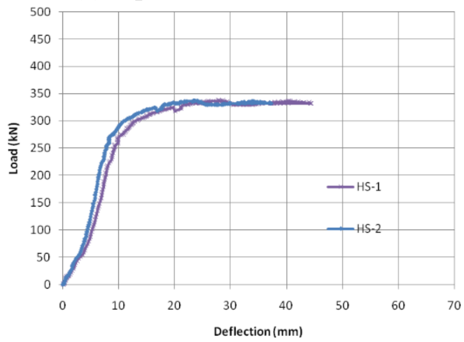
(a) slip of under repeated load



(b) deflection under repeated load

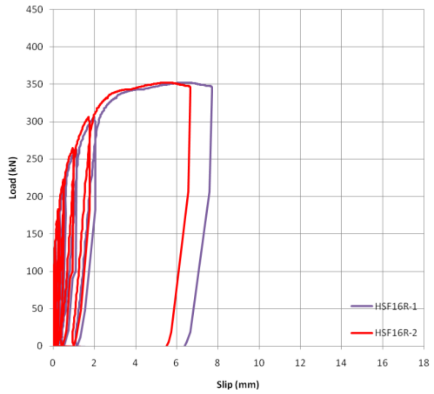


(c) slip under monotonic load

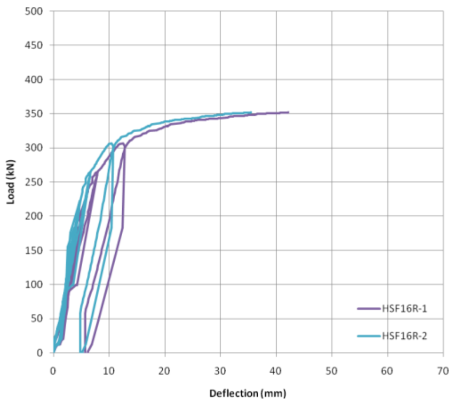


(d) deflection under monotonic load

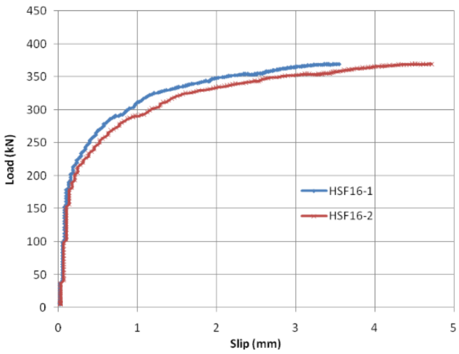
Figure 5: Load-deflection and load-slip curves for group HS under repeated and monotonic loads.



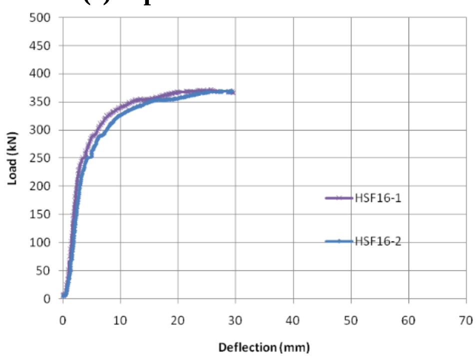
(a) slip of under repeated load



(b) deflection under repeated load

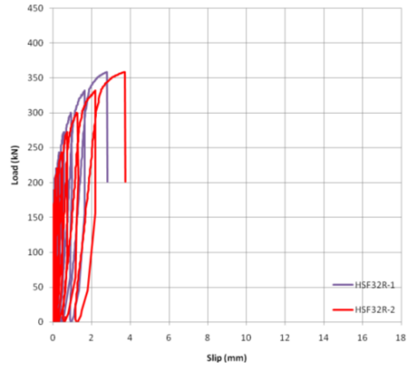


(c) slip under monotonic load

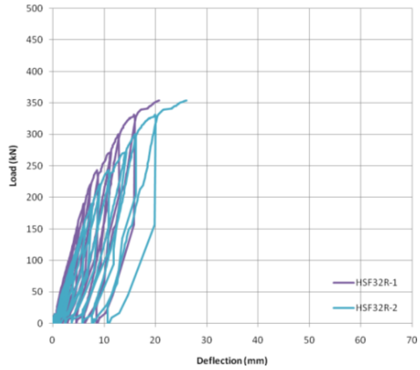


(d) deflection under monotonic load

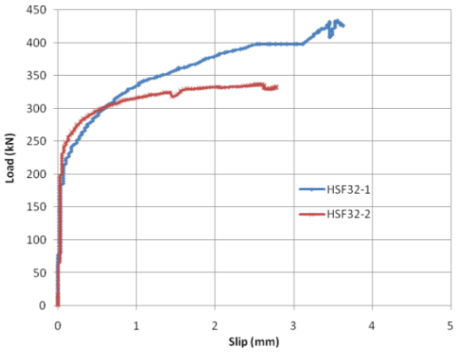
Figure 6: Load-deflection and load-slip curves for group HSF16 under repeated and monotonic loads.



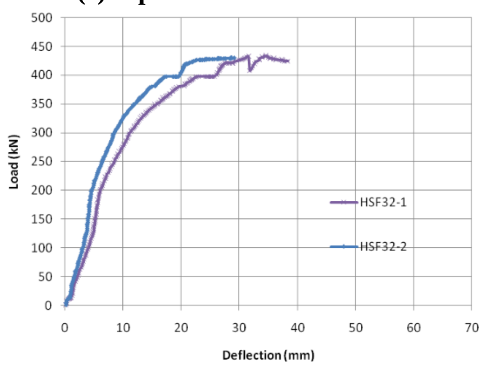
(a) slip of under repeated load



(b) deflection under repeated load

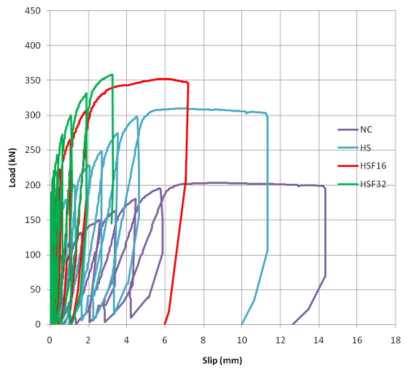


(c) slip under monotonic load

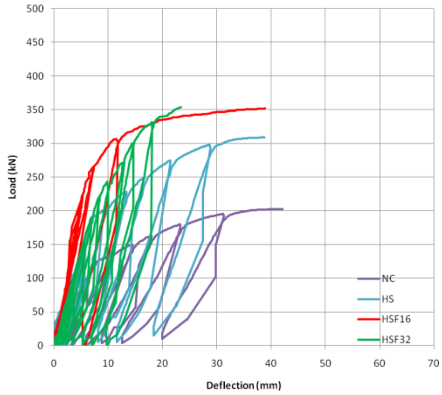


(d) deflection under monotonic load

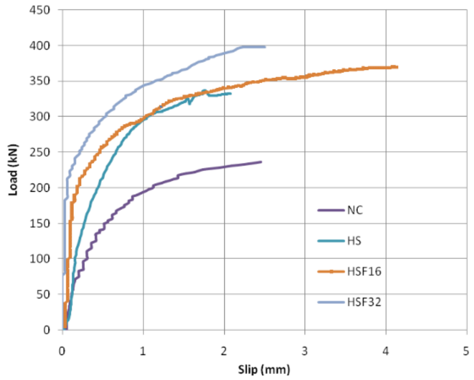
Figure 7: Load-deflection and load-slip curves for group HSF32 under repeated and monotonic loads.



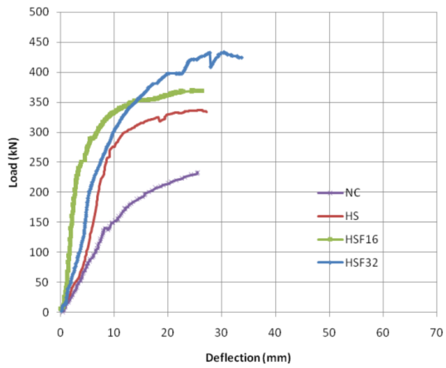
(a) slip of under repeated load



(b) deflection under repeated load



(c) slip under monotonic load



(d) deflection under monotonic load

Figure 8: Load-deflection and load-slip curves for groups NC, HS, HSF16 and HSF32 under repeated and monotonic loads.

References:

1. Zaina, M.F.M., Mahmud, H.B. Ilhama, A. and Faizala, M. 2002, "Prediction of Splitting Tensile Strength of High-Performance Concrete", Cement and Concrete Research, Vol. 32,pp. 1251–1258.

2. Daniel, L. and Loukili A. 2002, "Behavior of High-Strength Fiber-Reinforced Concrete Beams under Cyclic Loading", Structural Journal, American Concrete Institute, Vol.99, No.3, pp.248-256.

3. Al-Sulayfani, B., Abdullah M., Shamas S., 2010 "Experimental Study of The Behavior of Fiber Reinforced Concrete Beams Under Repeated Loads", AL-Rafidain Engineering Journal, University of Mosul, Vol. 18, No.4, pp. 1-9.

4. Jallo, E.K., 2012, "Experimental Study on the Behaviour of High Strength Concrete with Silica Experimental Study on the Behaviour of High Strength Concrete with Silica Fume under Monotonic and Repeated Compressive Loads", Al-Rafidain Engineering Journal, University of Mosul, Vol.20,No.2, pp.55-65.

5. Yeoh, D., Fragiacomo, M., Deam, O. , 2011,, "Experimental Behaviour of LVL–Concrete Composite Floor Beams at Strength Limit State", Journal of Engineering Structures, Vol. 33,pp.2697–2707.

6. Sawab, J.C.H., Mo, L.Y.L. and Mo L., 2016, "Finite Element Simulation of Steel Plate Ultra High Performance Concrete Composite Modules Subjected to Shear", Proceedings of the World Congress on Engineering Vol. II WCE, London, U.K.

7. Levon C.H., Ozyildirim, H.C., and Michael C. B., 2017 "Evaluation Of High-Performance Fiber-Reinforced Concrete for Bridge Deck Connections, Closure Pours, and Joints", Final report FHWA/VTRC 17-R15, Virginia Transportation Research Council, Charlottesville, Virginia, U.S.A.

8. Iraqi Specifications IQS No.5.1984, "Properties of Normal Portland Cement" Iraqi Central Organization of Standardization and Quality Control, Ministry of Planning, Baghdad, Iraq.

9. BS.882-1992, "Aggregates from Natural Source for Concrete", British Standard Institution. ISBN: 0 580 21463 X.

10. Beshr, H., Almusallam, A.A. and Maslehuddin, M. , 2003, "Effect of Coarse-Aggregate Characteristics on Mechanical Properties of High Strength Concrete", Construction and Building Materials,pp. 1797–103.

11. ACI Committee 318M-11, 2011 "Building Code Requirements for Structural Concrete" (ACI 318M-11), American Concrete Institute, Farmington Hills, MI48331), 509. ISBN-10: 087031744X

12. Ali, A.A.M., 2011 “Nonlinear Analysis of High Strength Fibrous Reinforced Concrete Corbels Using Plane Stress Elements”, M.Sc. Thesis, Civil Engineering Department, College of Engineering, Mosul University146.

13. ASTMC39/C39M-12 , 2012 “Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens”, ASTM International, Farmington Hills, West Conshohocken), 5,U.S.A.

14. AISC, 2006 “Steel Construction Manual”, 13th ed., American Institute of Steel Construction, Inc., 2nd Printing, , U.S.A. ISBN 1-56424-055-X.

15. Morrison, S.J. , 2009, “Statistics for Engineers an Introduction”, A John Wiley and Sons, Ltd., Publication, Printed and bound in Great Britain by TJ International, Padstow, Cornwall. ISBN: 978-0-470-74556-4

16. Liang, Q. Q. Uy, B. Bradford, M. A. and Ronagh, H. R., , October 1, 2005 “Strength Analysis of Steel–Concrete Composite Beams in Combined Bending and Shear”, Journal of Structural Engineering, Vol. 131, No. 10),pp. 1593-1600.

17. Elghazouli, A.Y. and Treadway, J.2008, “Inelastic Behaviour of Composite Members under Combined Bending and Axial Loading”, Journal of Constructional Steel Research, (64), pp. 1008–1019.

18. Parthasarathi, N., Satyanarayanan, K.S., Tamilarasu, V., Prakash, M., July - August (2016 “Behaviour of High Performance Fibre Reinforced Concrete Beam under Cyclic Loading”, International Journal of Environment, Agriculture and Biotechnology (IJEAB), Vol-1, No.-2, ISSN: pp.2456-1878.

19. Luo, Y., Li, A. and Kang, Z. , 2012, “Parametric Study of Bonded Steel–Concrete Composite Beams By Using Finite Element Analysis”, Journal of Engineering Structures, Vol.34, pp.40–51.

20. Reena, V.E., October, 2016. “Behaviour of High Performance Concrete Using Steel Fiber”, “International Journal of Enhanced Research in Science”, Technology & Engineering, Vol.5 No. 10.