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Structural Behavior Of Simple Supported Two Layers Reinforced Concrete (Normal strength concrete & Mortar with 3-Dimension glass fiber), Beams

A B S T R A C T

This paper represents an experimental investigation of the layered concrete beam. It contains studying the possibility of using the mortar intervention with layers of glass fibre at the tension zone in a loaded supported concrete beam. To produce a beam with less weight than the beam with all Normal concrete and detecting the effect of this replacement on beam properties. A rectangular beams section (150*200*1000)mm cast with NSC (normal strength concrete) at compression zone and mortar with layers of 3D glass fibre used as a part of the tension zone. The produced beams are layered beams with a lighter weight than the homogenous RC beam. Three deferent levels of the replaced layers (1/3,1/2, and 2/3 of the beam thickness) were studied, all beams were tested under Two point load till failure.

The maximum load capacity result shows an apparent lowering in the load capacity of the beam, but as the lightweight layer increases, this lowering in the load capacity becomes less. for (1/3,1/2 and 2/3) of the beam thickness replace with mortar and 3D textile fibre, the lowering percentage of failure load compare with the homogenous reinforced concrete beam are (33.04%, 27.18%, and 19.73%), and the lowering in weight is (5.45%%, 9.07%, and 12..92%)

for the same sequence, respectively.

Stiffness, ductility and toughness of all beams are tested. An apparent lowering in the stiffness value of the layered beams is recorded with the reference ones. At the same time, it shows an increase in the toughness and toughness value.

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التصرف الميكانيكي للعتبات الخرسانية المسلحة بسيطة الاسناد ثنائية الطبقة (خرسانة اعتيادية و مونة مع طبقات الياف زجاجية ثلاثية الابعاد)

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يعرض هذا البحث الفحوصات العملية للعتبات الخرسانية الطبقية المسلحة لدراسة امكانية استخدام مونة السمنت والرمل تتخللها طبقات الياف زجاجية في الجزء الاسفل للعتبة (المعرض لأجهادات شد) الخرسانية المسلحة بسيطة الاسناد لأنتاج عتبات خرسانية ذات وزن اقل من العتبات الخرسانية الاعتيادية, ودراسة تأثير هذا الاستبدال على تصرف العتبة الناتجة. تم صب 9 عتبات بمقطع مستطيل ذو ابعاد (150,200,1000) ملم بمونة تتخللها طبقات الالياف في منطقة الشد وخرسانية اعتيادية في الجزء المتبقي للعتبة بثلاث مستويات استبدال (3/1, 2/1, 3/2) من سمك العتبة, ثلاث نماذج لكل مستوى. وصب ثلاث عتبات اخرى من خرسانة اعتيادية فقط. جميع العتبات تم فحصها بالتحميل بنقطتين حتى الفشل.
النتائج الخاصة بالتحمل الاقصى للعتبات الطبقية بين ان هناك انخفاض واضح بالتحمل مقارنة مع العتبات الخرسانية الاعتيادية, لكن هذا الانخفاض قل كلما زاد السمك المستبدل, حيث لمستويات الاستبدال المذكورة سابقا, نسبة الانخفاض بالتحمل (33,04%, 27,18%, و 19,73%) بالتسلسل. اما نسبة الانخفاض بالوزن للعتبات الناتجة فقد وجد انه (5,45%, 9.07% و 12.92%) لنفس التسلسل.
الكلمات الدالة: العتبات الطبقية ، العتبات خفيفة الوزن, الهياكل الخفيفة الوزن, الياف زجاجية, عتبات مونة السمنت .

1. INTRODUCTION

When simply supported beam subjected to a load, two types of stresses (compressive stress and tension stress) developed on the top and bottom face of it, respectively. These stresses became less as gain from the interior layers of the beam where these values became the same and average equal to zero at a level known as the N.A.
From studying the behaviour of the concrete, it is known that the concrete resistance to tension stresses is very week; therefore, Steel bars were used to resist these stresses. As the load conduct on the beam, compression and tension stress developed. The concrete firstly resists the tension stresses until losing all its resistance; the steel bars began to hold these stresses. At this stage, the concrete began to crack, and it could say that concrete in the tension zone does not affect the beam[1]. Therefore some research tends to benefit from this property by strengthening the part of the tension zone or decreasing the concrete dimension in different ways to produce a good resist concrete beam with less cost.
Ra'ad[2] cast a group of composite beams(HYSC) of standard strength concrete in the compression zone and high strength concrete in the tension one to raise the strength of the beam for tension stresses and save in the cost. The author study the behaviour of the flexural crack of this type compering with homogenous NSC beams and HSC beams .he found that there is a significant rise in strength by nearly 30% more than NSC beams with maintaining in cost compared with a beam of high strength concrete only.
Giandomenico .T. [3]proved that the composite slap made from the fibre of iron in the tension zone and a lightweight concrete in the compression zone could diminish the weight to 25% of the whole structure. Furthermore, Vanissorn. V et al. [4] studies the R.C. beams of (200*300*3000)mm dimension, with the lightweight block(180*300*75)mm of Autoclaved aerated concrete (AAC) as infill under flexural and shear test, where these block but in the tension zone (below calculated N.A.) in beams. Five beams have been cast, the first three beams designed to fail in the flexural test, one beam cast as a reference beam without any block, the second cast with completely infill by these blocks while the third one fills with half amount of the second beam. The last two beams were cast to fail in shear (one as solid and one with blocks). The result shows that under flexural test, the beam of max. The number of blocks resists load higher than the beam with the half amount and the last one higher than the solid beam, and the reason was that of the reduction in the self-weight of these beams. While Under shear, the solid beam resists loading lower than with block. It proved that there is a saving in cost and time due to the weight reduction, which led to less supporting structure and foundation.
Fathoni .u. & Norhasniyati [5] studied a composite beam (H.C.)of lightweight concrete enveloping a high-performance concrete with arch shape, tested by four-point load test and compared with a beam of normal strength concrete to enhance the behaviour of lightweight concrete beams. It shows that the two types of tested beams have the same load resistance, but the H.C. beam at this load is subjected to a high displacement of 24.96% than the R.C. beam. Barbara et al. [6] evolved layered concrete beam by strengthening the compressive zone by HPS-HSC, where three series of beams were prepared .first group were rectangular(RHN) section with HPC-HSC layers, the second with T cross-section(THN) also

with HPC-HSC layers the last group of rectangular section with normal concrete RNN. Each typecast with dimension layers with a deferent reinforced ratio of 1%, 2%, and 3%. The special adhesive agent used a steel device bond to the top surface to strengthen the bond between the two-layered. All beams tested under flexural till failure. The author confirmed that an increase in the flexural strength by 30 % for the THN series and 16% for the RHN series compared with beams of normal strength concrete only improved the composite flexural structure's effectiveness.

Inmaculada M. et al.,[7] determine the demeanour of layers of steel fibre reinforced concrete beams(SFRC) .beams consist of steel fibre reinforced concrete in the two outer layers. In contrast, the internal layer of standard strength concrete .two beams cast all with R.C. as a reference, the second two beams cast all with SFRC. The last four beams consist of two types of layered beams with deferent thickness, two beams with the same layers thick (one-third of beam thick each), while the last two beams have the external layer with one five the beam thickness each. All beams were tested by four-point loading. The outcomes proved that all beams have nearly the same flexural load capacity, while the measured deflection shows that the layered beams have less deflection than the homogenous ones.

Fang. et al. [8]study the behaviour of horizontal shear for a composite T-beam of average weight and lightweight concrete, where the author confirms the possibility of using a proposed formula in obtaining the horizontal shear strength of concrete composite T-beams by testing 12 beams using three different lightweight concrete strength and different shear interface condition (rough or smooth). The test result shows that horizontal shear failure occurs for most of the composite beams and is affected by the strength of concrete, clamping stress, and interface preparation method. While at Zena J., et al.,[9] examine the demeanour of layered beams result by replacing the tension zone with LWC (result by replacing the average coarse aggregate with crushed limestone). Three replacement levels (1/3, 1/2, and 2/3 from the bottom of the beam thickness) were studies. The result shows an apparent decrease in load capacity, but this lowering rate decrease as increasing the replaced thickness. The result of lowering in the maximum load capacity was (18.96%, 8.39%, and 7.70%) for the three levels, respectively, compared with the reference beam (regular concrete only).

2. EXPERIMENTAL PROGRAM

2.1. Material and method:

2.1.1 fine and Coarse aggregate

Normal weight natural sand from the river was used as fine aggregate. Furthermore, a Well graded natural aggregate was used with M.A.S =12.5 mm for the typical concrete mix. The physical properties are shown in table 1.

Table 1
Physical properties of fine and coarse aggregate.

Sr. No.	Properties	Fine aggregate	Normal coarse Aggregate
1	Fineness modulus	2.8	-
2	Specific gravity	2.6	2.68
3	Water absorption	1.21%	0.8%
4	Oven dry density	1590	1600

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Fig. (1) shows the sieve analysis of the used fine aggregate, and Fig. (2) the sieve analysis of coarse aggregate.

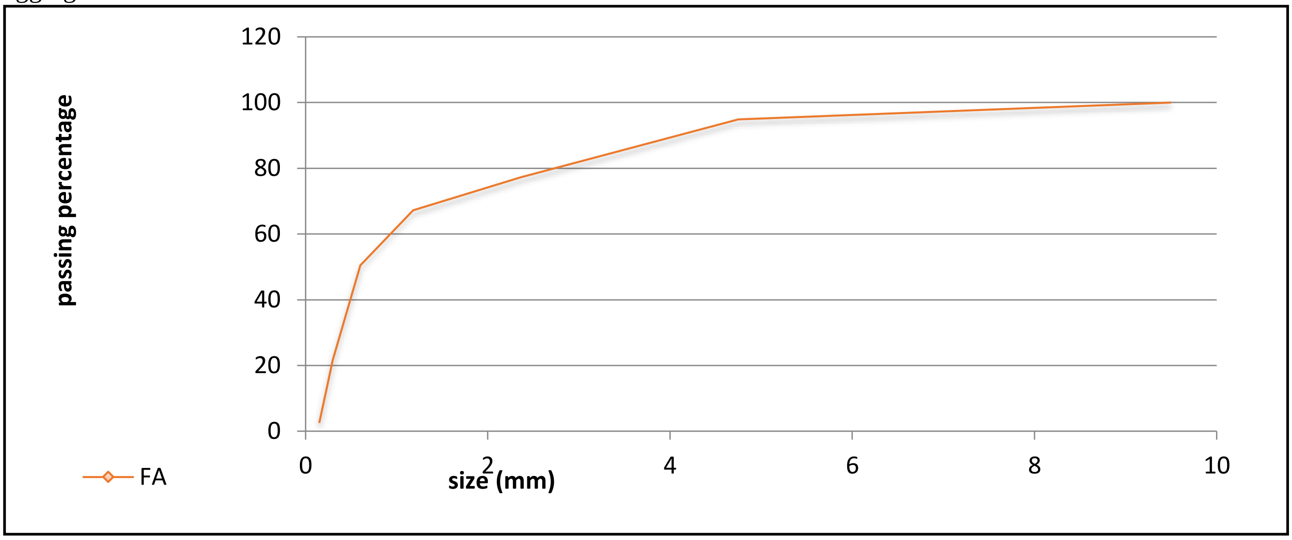

Fig. 1. Sieve analysis result of used fine aggregate.

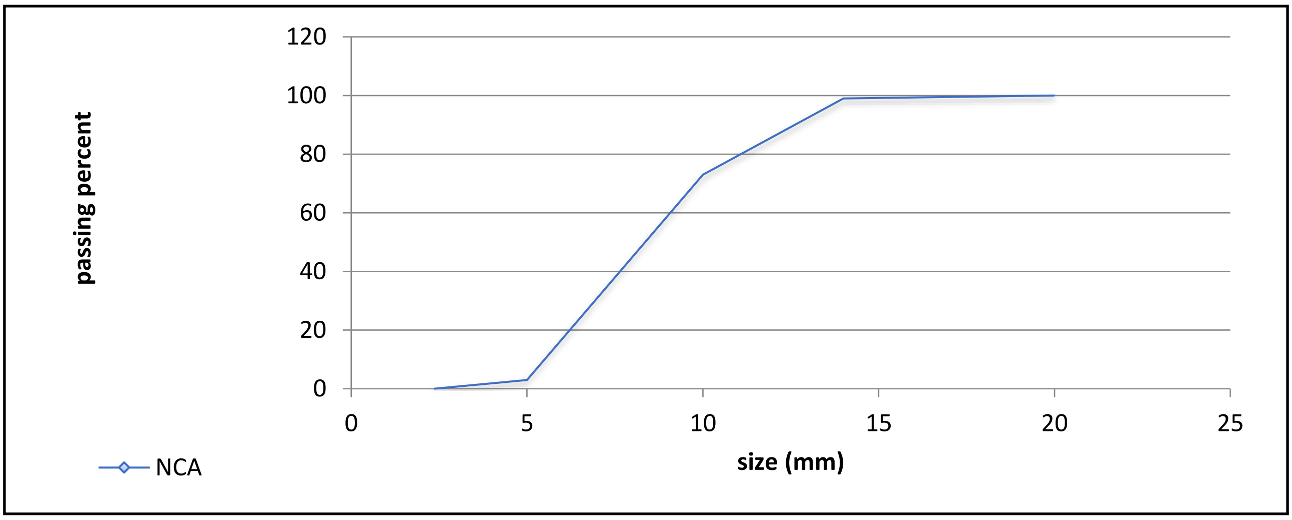

Fig 2. Sieve analysis result of used Normal coarse aggregate (NCA)

2.1.2. Cement

Ordinary Portland Cement type I[10], Iraqi manufacture produce by Al- a mass company with physical and chemical properties as shown in the table (2) and table (3) use Throughout this investigation.

Table 2 A
physical result of Portland cement.

Properties	Test result	Requirement[12]
Fineness modulus(m2/kg)	237	**≥230**
Relative density	3.1	**-**

Table 2 B chemical composition and the main component of cement

Cement composition	Content %	Limit of Iraqi specification No.5/1984(35)
CaO	59.83	-
SiO2	19.8	-
Fe2O3	4.63	-
Al2O3	4.06	-
MgO	3.3	5% max
SO3	2.02	2.8% max
Free CaO	0	0
L.O.I	3.1	4% max
Lime Saturation Factor	0.92	(0.66-1.02)
Insouluble Residue	1.39	1.5% max
Main component (Bogue equation)		
C3S	53.43	
C2S	16.64	
C3A	2.93	
C4AF	14.09	

2.1.3. Silica fume

In this work, for the typical concrete mix, silica fume MegaAdd MS(D)[11] was used. Table (3) shows the physical properties that met the ASTM C1240[12] Requirement to increase the mix properties.

Table 3
physical properties of silica fume.

Properties	Result [13]
Bulk density kg/l	0.65
Form	Powder
Appearance	Grey

2.1.4. Reinforcement steel bars :

Ukrainian manufacturing Steel reinforcement bars used in this research .10mm diameter (deformed bar) for the primary reinforcement and 6mm diameter (deformed bar) for shear reinforcement. The below table (4) shows the test results for three specimen laboratory tests

.

Table 4.
test result of steel reinforcement**.**

Φ mm	Φ mm measured	Area mm2	Modulus of elasticity (GPa)	Fy MPa	Fu MPa
6	5.97	27.32	210	386.32	432.4
10	9.87	79.47	208	468.9	505

2.1.5. 3D- fiber fiberglass weaved fabric :

Product Characteristics:

The 3-D spacer fabric consists of two bi-direction woven fabric surface, which is mechanically connected with vertical woven piles. Two S-shaped piles combine to form a pillar, 8- shaped in the warp direction and I-shaped in the weft direction.

The 3-D spacer fabric composites can provide high skin-core debonding resistance and impact resistance, lightweight, high stiffness, excellent thermal insulation, acoustic damping. Table (5)show the fibre specification.

Table 5

3D Fiberglass woven fabric Specifications.

Area weight (g/m2)	**Core thickness (mm)**	**Density of warp (ends/cm)**	**Density of weft (ends/cm)**	**Tensile strength warp(n/50mm)**	**Tensile strength weft(n/50mm)**
900	6	15	10	5500	9400

Fig 3: 3D-glass fiber

2.2. Mix design

The standard strength concrete NSC mix designs according to ACI-211.1 code[13]. The proportion ratio was 1:1.74:1.93 by weight and W/C = 0.43 for a compression strength (30 MPa) at 28 days of curing. 10 % of cement for this mix was replaced by silica fume to get higher strength. The oven-dry density of this mix is(2363.5 kg/m3).
To check the mix strength for standard strength concrete, cubes, cylindrical and prisms specimens were cast. All mould part has been cleaned and coated with mineral oil to prevent the adhesion of the mix with mould surface and connected in such way it could remove the specimen without any damage, as described by BS: 1881: part 3:1970.and for mortar mix, a cub specimens with (50*50*50)mm, cylinders of (100*200)mm and prisms (40*40*160)mm are used. Mould filled with three layers (for cylinder and cube). Two layers for prisms, each layer 50mm thickness compacted mechanically by electrical vibrator then the surface levelled by a spade and covered by nylon overlay for 24 hours, where at period end, the specimen took out of the mould for curing in clean water till testing day (after 28 days). Table (6) shows the dimension, test type, and specimen number for each mix.

Table 6.
specimen dimension and number for each test type.

Mold shape	Test type	No. of specimen
Cube(150* 150* 150)mm	Compression	3
(50*50*50) mm		3
Cylinder (300*150) mm	Splitting	3
(100*200)mm	tensile	3
Prisms(100*100*500)mm		3
(40*40*160)mm	Flexural	3

2.3. Beams specimens

Eight beam specimens with (150 *200 *1000)mm dimension were cast, reinforced by 3Φ10 mm in the longitudinal direction at tension zone and 2Φ6 mm at compression zone(to hold tension bars) and shear reinforcement stirrups Φ6mm @50mm were set. The details of each beam specimen as shown in table (7) and figure (4).

Table 7.
Beams details.

Beam type	The thickness of LWC mix mm	The thickness of NSC mix mm	No. of specimen
HRC	-	200	**2**
LRC1	67.7	133.3	**2**
LRC2	100	100	**2**
LRC3	**133.3**	**67.7**	**2**

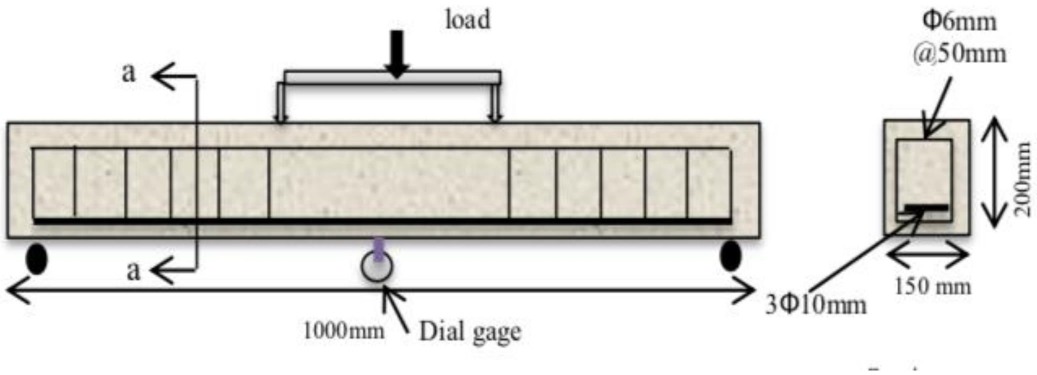

Fig. 4. A: loaded simple supported beam.

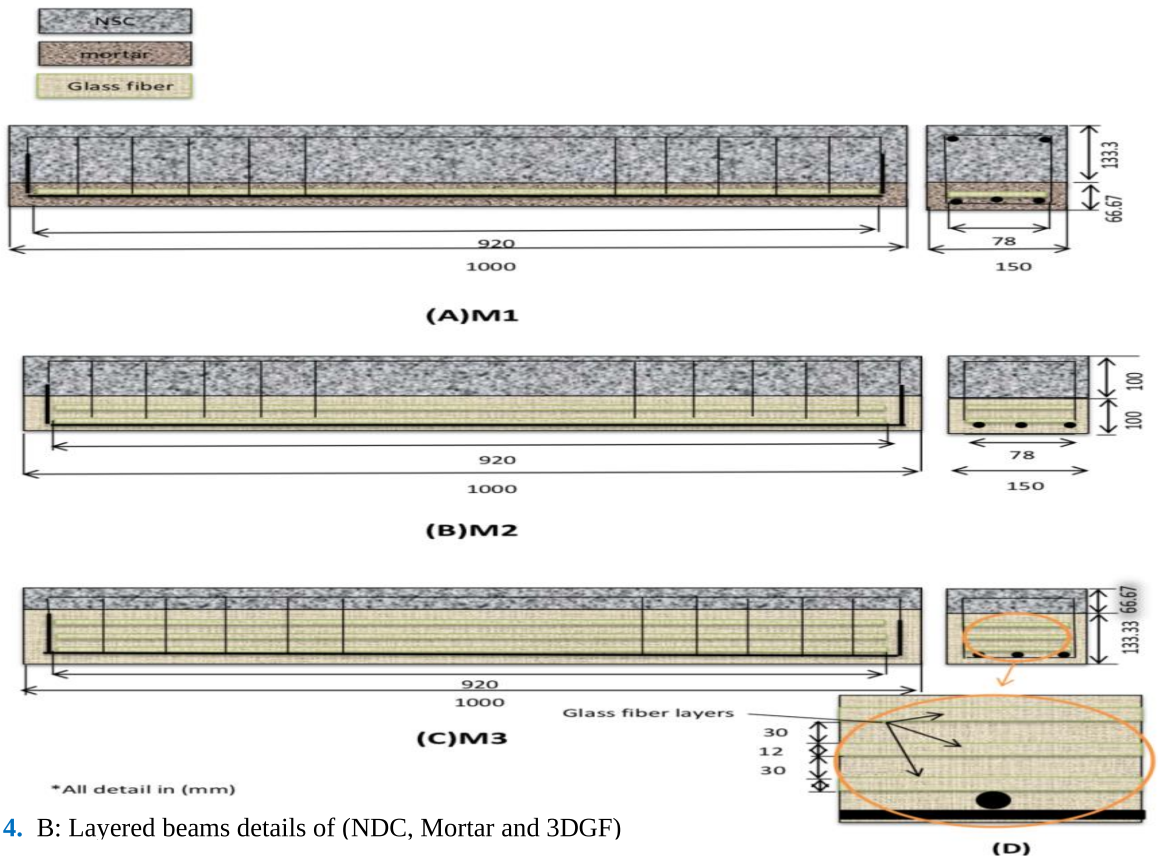

Fig. 4. B: Layered beams details of (NDC, Mortar and 3DGF)

The Beams of HNC specimens were cast according to ASTM C192[14] using steel mould as shown in Fig.(5) with a smooth inside surface and free of indentations, with the right angle at sides, bottom, and ends. All insides part coating with a mineral oil .mixing done by mixing machine and the mechanical vibrator has been used, powered by an electrical motor.

Fig.5. beam specimen mold during casting.

While LBC beams were cast at Two levels, the first one with the mortar mix intervenes with layers of 3D-fabric glass (12mm thickness) with bores to allow the mortar to interfere in these bores. For the second level cast with NSC mix, the detail of each level thickness were described in Fig.(4-B). The time period between the first and second stage was at the end of the Primary hardening time to overtake the danger of the pervasion of the two-layer because of the difference between the densities (upper layer higher density than the bottom layer) but not exceed this time to overstep the shear failure between the two-layer that caused by the low cohesion between them. The mould was covered by nylons after all surfaces equalized with the mould edge to get a planar surface. The mould was open after 30 hours and put in the water basin to get curing for 28 days.

The beams specimen take out from curing water after the end of the intended period and allowed to dry. To discern the apparition of the cracks during the test, the beams paint in white paint. Each beam simply supported and loaded (Two-point loading) with a loading speed of 2.5kN/sec. Dial gage is used to detect the load increment and the counted deflection. Load value versus a deflection recorded at each specific time.

2.4. Result and discussion

2.4.1. Mechanical properties result in each mix

The mechanical results of each concrete mixes are clarified below in table 8.

Table 8.
test result of mechanical properties.

Mix type	Compression strength		Flexural strength MPa At 28 curing day	Splitting strength MPa At 28 curing day
	7 curing days	**28 curing days**		
NSC (10%) SF	31.71	44.24	7.335	**2.813**
Mortar mix	**25.36**	**38.5**	**4.69**	**2.932**

4.2. Beams result

The average of two specimens for each study case was recorded .result of the first crack load and the maximum load and failure type for all beams, which clarified in Table 9

Table 9.
test result of beams.

Beam type	Crack load kN	Failure load kN
HNCB	76.5	174
LB1	49.6	116.5
LB2	55.7	136.5
LB3	61.4	148

4.2.1. Load-deflection relation

For Fig. (6), which represents the load-deflection relation of the layered beam with mortar and layer of glass fibre (for all replacement thickness) and the HRC beam result from the test, high effects of the layer type on the curvature of the result line and so on the load capacity of the beams, stiffness, ductility and toughness.

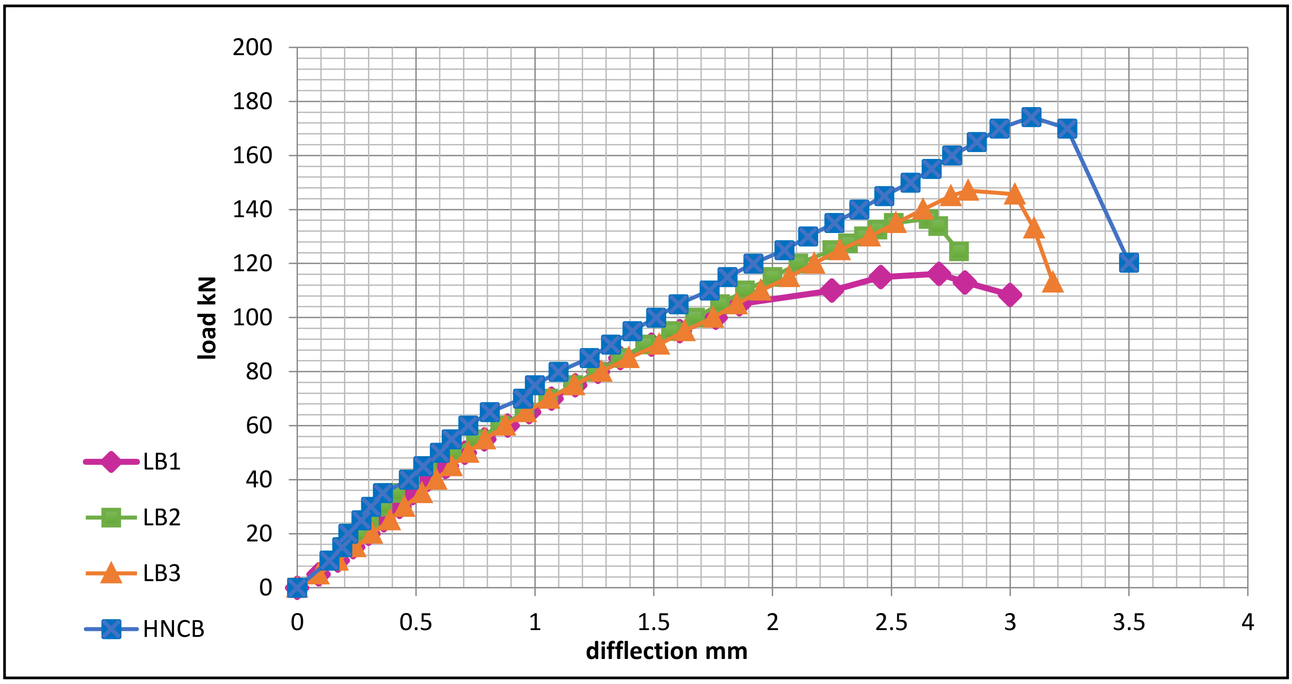

Fig. 6. load deflection relation for HRC beam and layered beams of LWC with limestone.

4.2.2. crack and failure load

Comparing the result of the layered beams with the normal beam clarify that there are a high recede in the crack load of the layered beams; where this decrease are (35%, 27% & 19%) for (1/3, 1/2 & 2/3) of the beam thickness replaced in sequence. For the failure load, the lowering in load capacity is (33%, 21%, 14.9%) for the same sequence. These results show that replacing part of the tension zone has a high negative effect on its resistance. As well, the thickness of the replaced part has an important influence on its behaviour.

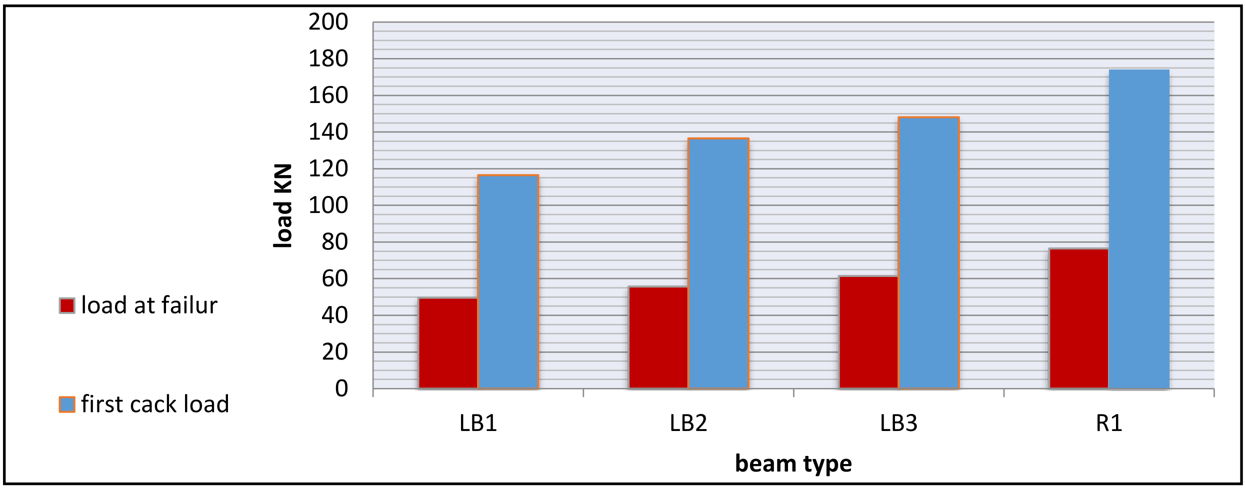

Fig.7. Crack and failure load result for each beam.

4.2.3. Beams stiffness

The result illustrates that for the load that causes a unit deflection (stiffness) shown in Fig. (8), there is a high reduction in this value. This reduction became less as the replaced thickness became higher. The proportion of the reduction for the tested beams is (13.22%,8.24%, and 7.8%) for the replacing thickness (1/3, 1/2 and 2/3) Comparing with the normal beams.

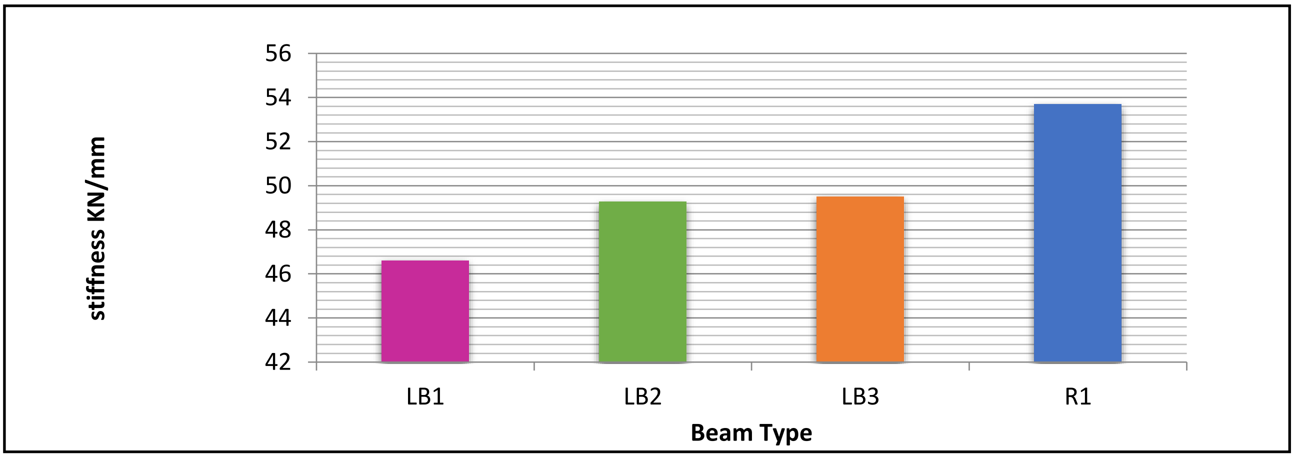

Fig. 8. stiffness result for each beam.

4.2.4. Ductility of beams:

The ability of the material to deform easily under tensile load know as Ductility[15]. As shown in Fig. 9; it is clear for the beam when the replaced thickness is 1/3 of the beam high, there is a small reduction in ductility (3.11%), but for the other two-layered beams with (1/2, 2/3) replaced thickness, this value became higher than that for the normal beam (2.59% and 6.23%) respectively compared with the normal beam.

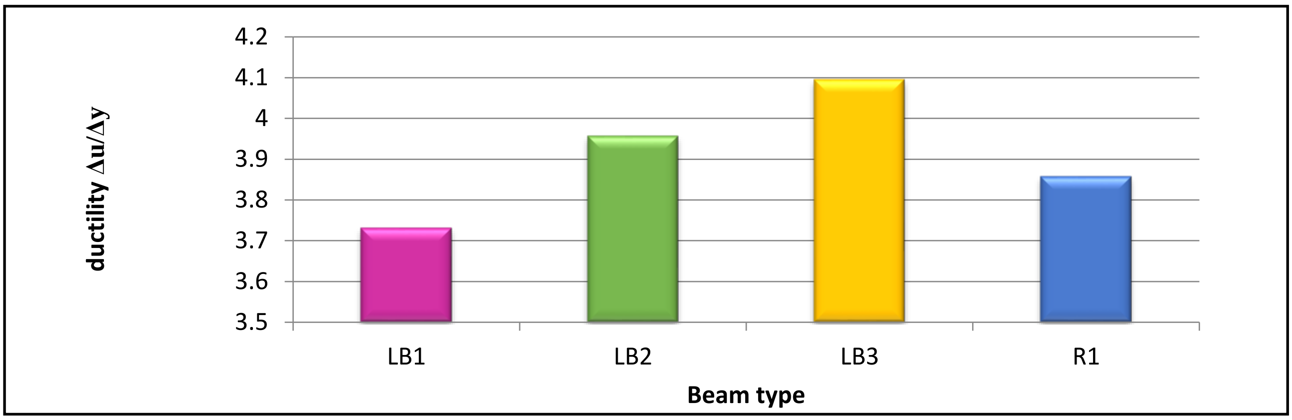

Fig.9 ductility of all tested beam.

4.2.5.Toughness index :

Toughness is defined as a material's resistance to fracture when stressed. It is the energy equivalent to the area under the load-deflection curve up to the first crack deflection. It's also defined as the ability to absorb impact without fracturing. the toughness index (I5) could be defined as the number obtained by dividing the area up to the deflection of 3 times the first crack by the area up to the first crack[16][17]

The plot state that the resulted layered beams have a fracture resistance higher than the normal beams. As the replaced thickness increase as less toughness value. For all tested beams (LB1, LB2, and LB3), the result are (10.38%, 8.45%, and 3.41%) more than the normal beam, as shown in Fig. (10)

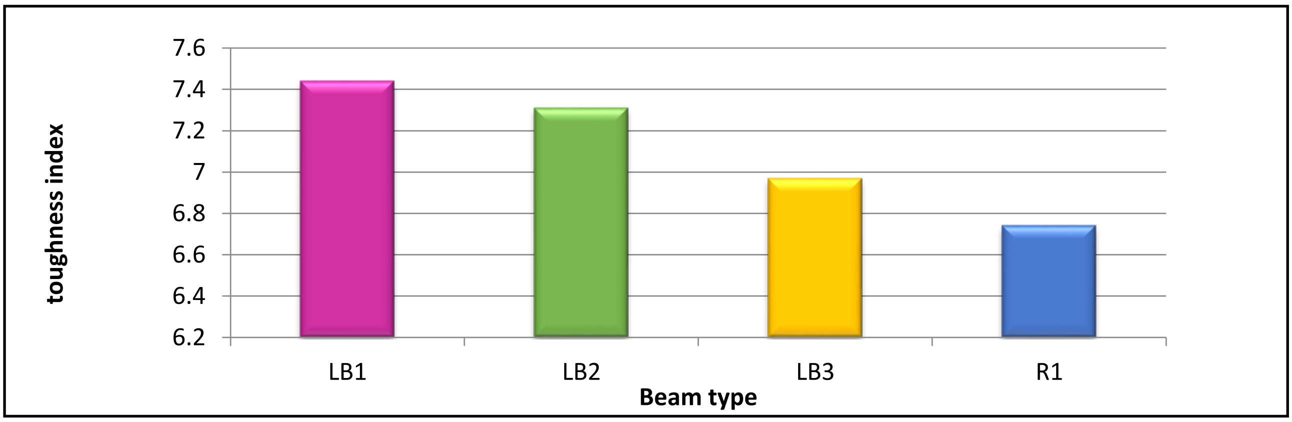

Fig. 10 toughness index for each tested beam.

5. Conclusion :

Detecting the effect of using mortar with a layer of glass fibre as a part of the tension zone in a concrete beam is the goal of this study. Three levels of replacing thickness were tested. The result shows many interesting points:

Replacing a part of the tension zone in a simply supported beam with a mortar and inter with layers of glass fibre result in a layered beam with less mechanical properties.

Minimum decreasing in load capacity in the layered beam is(14.9%) for the beam with 2/3 replaced thickness.

Max lowering in self-weight of the layered beam is (12.92%) for the beam with 2/3 replaced thickness.

· Replacing a part of the tension zone increases the stiffness of the beam and its ductility, but this replacement decreases its toughness.

· The convergence surface between the mortar layer and NSC layer is a weak point which as it could form a structural joint due to the deferent properties for each layer such as when a variation in temperature happened it could result in a deferent shrinkage ratio for the Two layers and increase the failure probability as it found near the region of high stresses. Therefore, it must give attention to think while casting this type of beam.

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