Experimental Study of Reinforced Light Weight Concrete Beams

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Abstract:

This study provides a new technique for a lightweight concrete on one side and contribute to the application of sustainability principle by another side. The lightweight concrete was produced by replacing the coarse aggregate in the concrete mix by crushed bricks after conducting the sieve analysis process. To apply this technique to reinforced concrete beams, seven specimens having dimensions (1200 mm length × 200mm height × 100 mm width) for each were poured. The first of these beams had made from ordinary concrete, and the rest lightweight different mix design as well as the casting of three cubes and a three-cylinder with each beam. After curing the specimens with water to the age 28 days, they were examined in the laboratory. Using different design mixes of concrete and with the help of super stabilizer material , good compressive strength of concrete was obtained so it become more effective lightweight in structure. By comparing between the results of the light and normal weight concrete beams, it is found reducing in the weight of concrete by about 23% due to using this technique ,the ultimate strength increased to about 32.1% and the deflection decreased about 46.7% .
Keywords: lightweight concrete , concrete beams , crushed bricks.

الخلاصة:

تقدم هذه الدراسة أسلوب حديث للحصول على خرسانة خفيفة الوزن من جانب والمساهمة في تطبيق مفهوم الاستدامة من جانب أخر. حيث تم الحصول على خرسانة خفيفة الوزن بواسطة أستبدال الركام الخشن الداخل في تركيب الخرسانة بالطابوق المكسر بعد اجراء عملية التحليل المنخلي عليه. لتطبيق هذا الاسلوب على العتبات المسلحة تم صب سبعة عتبات بأبعاد (1200ملم طول*200ملم أرتفاع*100 ملم عرض) لكل واحد.أول هذه العتبات من الخرسانة الاعتيادية والباقي خفيفة الوزن بخلطات تصميمية مختلفة وكذلك تم صب ثلاث مكعبات وثلاث أسطوانات مع كل عتبة وبعد معالجة النماذج بالماء وبعمر 28 يوم تم فحص النماذج في المختبر. أستخدام الخلطات التصميمية للخرسانة وبمساعدة المواد الملدنة تم الحصول على مقاومة خرسانة جيدة وبهذا تصبح العتبات الخرسانية خفيفة الوزن أكثر فعالية في المنشأ. من خلال مقارنة النتائج بين الخرسانة الخفيفة والأعتيادية، نجد أن أنخفاض حوالي 23٪ في وزن الخرسانة باستخدام هذه التقنية ، قابلية التحمل تزداد بحوالي 32.1٪والهطول يقل بحوالي 46.7% في الحمل النهائي وتناقص في الهطول بمقدار 46.7.
الكلمات المفتاحية: الخرسانة خفيفة الوزن، العتبات الكونكريتية، الطابوق المكسر.

Introduction:

The purpose of using lightweight concrete is to reduce the dead loads hanging over structure and for economic purposes (Hossion,2004). There are multiple types of lightweight concrete used in world . Few researches have been studied reinforced lightweight concrete beams by crushed brick aggregate (Jafer *et. al*., 2006). For sustainability purposes, to achieve concrete environmentally friendly and solve many problems related to excess materials from the construction work and how to get rid of them in a manner consistent with conditions of environmental health. After several attempts, lightweight concrete were obtained by replacing coarse aggregates inside the concrete by crushed bricks combination after making the sieve analysis process (Dawood,2014) .

After many attempts we managed to produce lightweight concrete which achieve the above objectives and has properties distinct from other lightweight concrete in terms of compressive strength. To overcome the problem of low compressive strength of lightweight concrete, new mixes and plasticizer ratios were used. As well as the features of this type of concrete was more fire-resistant than ordinary concrete.

Material specification

Cement

Ordinary Portland cement corresponding to the Iraqi standards which produced by the general company for the manufacture of cement in Najaf have been used in this work.

Fine Aggregate

In this work natural fine aggregates (sand) from the Najaf area washed after conducting the sieve analysis and comparing the results with the Iraqi standard specifications were used. Table 1 shows the sieve analysis of fine aggregate.

Table 1: The sieve analysis of fine aggregate

No.	Size	Passing (%)	Passing (%) According Iraqi specification 45/1984 for zone No.(2)
1	10 mm	100	100
2	4.75 mm	92.55	90-100
3	2.36 mm	87.35	75-100
4	1.18 mm	70.25	55-90
5	600 µm	53.75	35-59
6	300 µm	22.55	8-30
7	150 µm	5.15	0-10

Coarse Aggregate

Crushed bricks were used in this work with maximum size of 19 mm. The sieve analysis of the crushed bricks is shown in Table 3. The results of the sieve analysis indicated that the coarse aggregate sieving was acceptable according to Iraqi specifications (Iraqi specifications No.45, 1984) and ASTM C192 specification (1990).Figure 1 shows the sieving process of crushed brick. Table 2 shows the properties of the aggregate used in the study.

Table 2: Physical properties of aggregate

Aggregate Type	Absorption %	Specific Gravity
Sand	1.8	2.62
Lightweight crushed brick	14.7	1.96

Table 3: The sieve analysis of light weight crushed brick

No.	Size	Passing (%)	Passing (%) According to Iraqi specification No. 45/1984 (%)	ASTM (1990) (%)
1	19 mm	100	-	100
2	12.5 mm	90	90-100	90-100
3	9.5mm	50	30-60	20-55
4	4.75mm	10	0-10	0-10
5	2.36 mm	0	0-5	0

Figure 1: light weight coarse aggregate

Mixing Water

The use of tap water for casting process tap and curing as well as for the process of spraying gravel

Steel Reinforcement

Ukrainian steel reinforcing bars were used as longitudinal and transverse reinforcement for the tested beams. Two bars Ø12 mm in top and bottom were used for longitudinal reinforcing and closed stirrups Ø6 mm were used for transverse reinforcing at 200 mm c/c. Figure 2 shows the steel reinforcement.

Figure 2: The steel reinforcement

Forms

The dimensions of the samples were made to be (100 × 200 × 1200 mm). The mold contained: bottom, sides and sectors for ends. They were made of plywood with a thickness of (12 mm). The method of fixing was carried out by using nails to all parts of the plywood form. A wood arm was fixed in the mold to prevent any movement during casting process. The internal surfaces of the forms were well oiled to ensure that the sides of the beam would be smooth and free from imperfections. Finally the base and sides took the general shape of the sample, Figure 3

Figure 3: The forms

Specimens Description

Seven reinforced concrete beams were poured. All specimens had the dimensions (1200 mm × 200 mm × 100 mm)(length × height × width) respectively. The beams were tested by using three points load of simply supported as a line load. Two line supports were 50 mm from the beams edges were considered, so the effective span of the beam was 1100mm.

Mix Design

The mix were designed according to table 4.

Table 4: Mix design of each normal and light weight beams

Components	Designation						
	B0 **1:2:4**	B1	B2	B3	B4	B5	B6
Cement (Kg/m^3)	312.5	300	400	450	400	400	450
Sand (Kg/m^3)	625	567	467	467	467	467	467
Aggregate (Kg/m^3)	1250	816	816	816	816	816	816
Water (l/m^3)	150	150	150	150	125	100	100
Super plasticizer (l/m^3)	……	…..	…..	…..	…..	6	6
Slump (mm)	50	50	50	50	50	50	50
W/C ratio	0.48	0.5	0.38	0.33	0.31	0.25	0.22
$f'_{c\ 28d}$ (MPa)	18	21.1	22.8	23.9	22.9	25.2	27.4

Mixing, Casting and Curing of the Specimens

Seven reinforced concrete beam specimens were poured in laboratory. Also, three standard cubes (100) mm and three standard cylinders (200x100) mm were cast from the concrete for each specimen. The concrete casting and curing Procedures are described below:

- Before mixing, all the quantities were weighted.
- The coarse, fine aggregates and the cement were mixed.
- The water was added with continued mixing.
- The super plasticizer (Glenium 54) was incorporated into two specimens.
- The mix had satisfactory homogeneity.
- The molds of specimens, cubes and cylinders were treated with oil before mixing the concrete **(Neville AM,1995).**
- The reinforcement has been arming for each beam, taking into account the cover.
- The cubes and cylinders were compacted mechanically by vibration table.
- The beams were removed from their form after 24 hours of setting time casting.
- The specimens were put in the water until the date of test.

The form removing process of beams are shown in Figure 4.

Figure 4:Form removing of specimens

Testing Equipment and Procedure

Testing Setup

Each specimen was positioned in the universal testing machine on two supports and under midpoint line loading as shown in Figure 5. The beam specimen of the 1.2 m long to be simply supported by 2.5 cm diameter steel roller located at 10 cm from each edge of the beam.

After the beam was centered and leveled,Cardboard was placed between the surface of the beam and the loading plate to reduce the effect of irregularities. Throughout the setup procedure, care was taken to assure that the sample was vertically aligned with all loading points and reactions in order to minimize the possibility of a stability failure.

Figure 5: The applied load

Instrumentation

Figure 6 shows a micro crack which was used to measure the width of the cracks and be thoroughly 0.02 mm . Figure 7shows a dial gauge was located under midspan of the beam which was utilized to scale the deflection of the beam as it is loaded.

Figure 6: Micro-crack meter

Figure 7: Deflection gauge

Testing Procedure

Tests were carried out by using universal testing machine with capacity of 1000kN.The universal testing machine is a closed loop servo hydraulic testing system controlled manually.The experiments were executed in load control with manually data monitoring and recording both the load and mid span deflection. Whole of the specimens had statically examined to fail in one cycle of loading. load was slowly applied, the rate of loading equal to 0.5 kN/s, in successive increments up to failure. The load steps were initially 250 kg then they were increased to 500 kg until specimen failure. At each increment, the load was held constant so that deflection gauge reading could be recorded. See Figure 8.

Figure 8: Testing the samples

General Behavior

All specimens were designed with a flexural 2Ø12 reinforcement in the tension zone with a clear cover to the reinforcement of 30 mm, which is higher than the minimum reinforcement ratio that required for ACI building code ***(ACI 318-2014)*** to avoid the shrinkage and temperature effects, All details were chosen according to ACI building code requirements.

Ultimate Load, Cracking Behavior and Mode of Failure

Figure 9 shows the cracks at the ultimate load for each beam. All light weight beams after applying loads first cracks appeared in the flexural area ,the cracks developed up to become inclined in flexural- shear zone and then moved to shear zone at maximum load . All lightweight beams failed by shear

Figure 9: Crack patterns of the beams

Table 5 shows density ,compressive strength, first crack load ,ultimate load, increase in ultimate load with respect to control beam, ultimate deflection and type of failure for each beam.

Table 5: Ultimate load and mode of failure for all specimens.

Failure Type	Δ_u (mm)	$((P_u-P0)/P0)$ %	P_u (kN)	*First Crack Load (kg)*	*f"c*	*Density (kg/m³)*	*Specimen*
Flexure	**8.2**	**-**	**53**	**30**	**18**	**2358**	**B0**
Shear-Compression	**9.3**	**1.84**	**54**	**20**	**21.1**	**1869**	**B1**
Shear-Compression	**7.37**	**9.43**	**59**	**25**	**22.8**	**1888**	**B2**
Shear-Compression	**9.97**	**13.21**	**60**	**20**	**23.9**	**1890**	**B3**
Shear-Compression	**9.09**	**22.64**	**65**	**27**	**22.9**	**1917**	**B4**
Shear-Compression	**5.15**	**32.1**	**70**	**30**	**25.2**	**1916**	**B5**
Shear-Compression	**4.37**	**32.1**	**70**	**32**	**27.4**	**1916**	**B6**

Load-Deflection Curves

Seven reinforced concrete beams were cast, and tested. The load-deflection curves of experimental test are show in Figures (10 to 16)

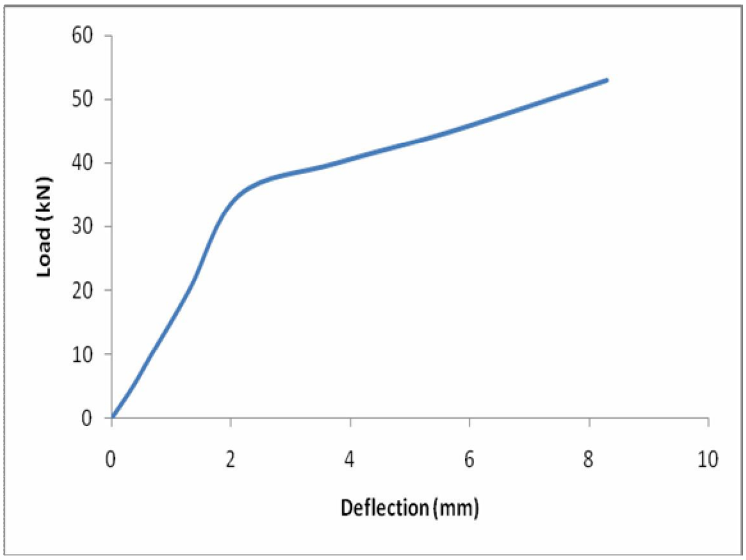

Figure 10: Vertical load against def., beam B0.

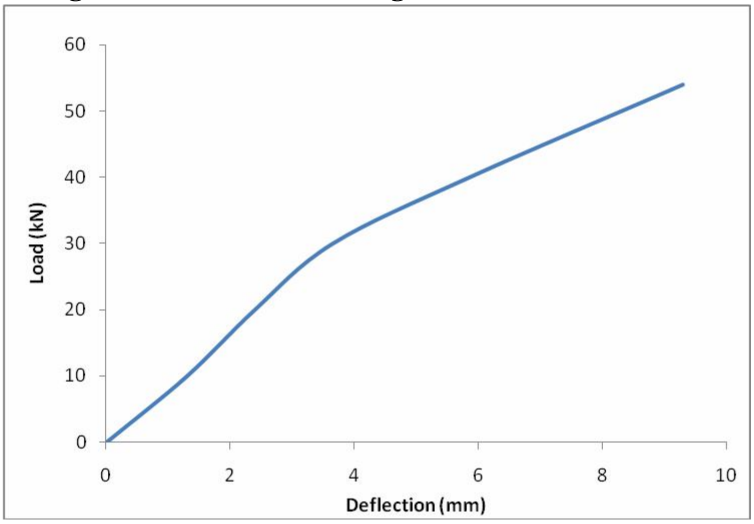

Figure 11: Vertical load against def., beam B1.

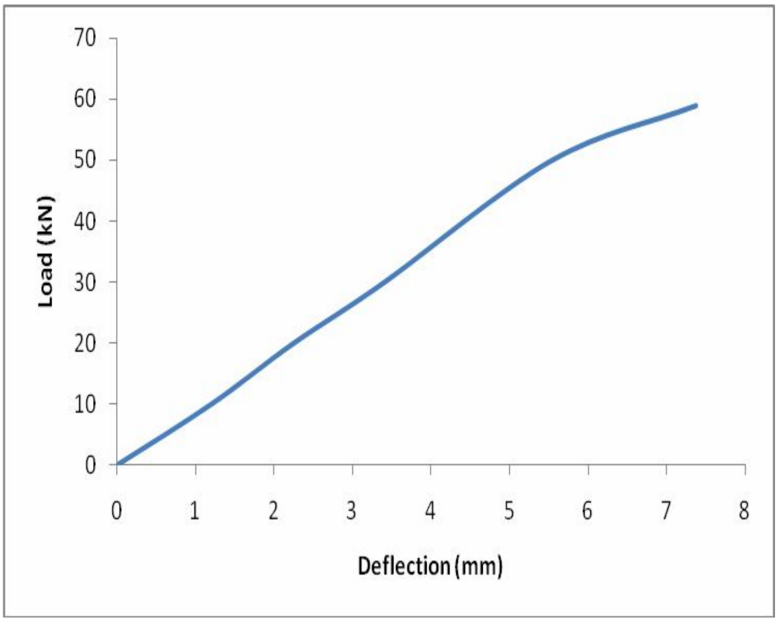

Figure 12 : Vertical load against def., beam B2.

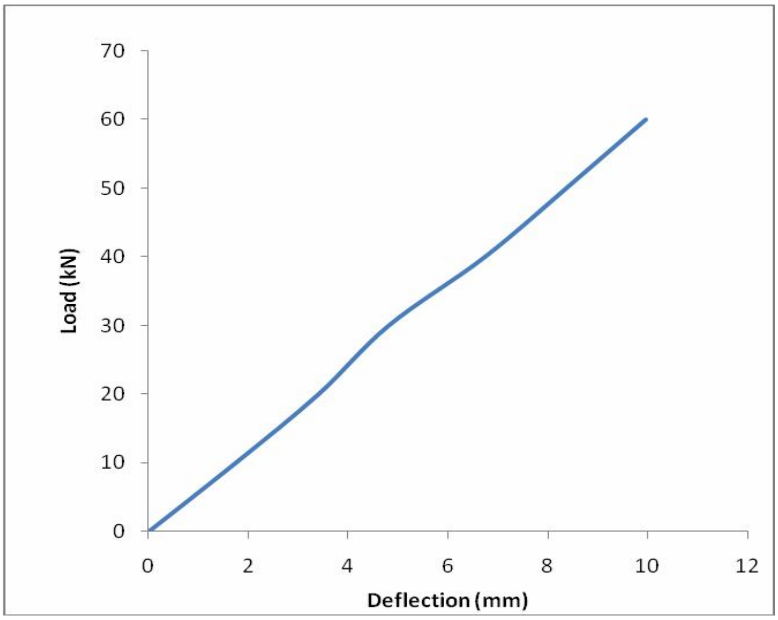

Figure 13 : Vertical load against def., beamB3.

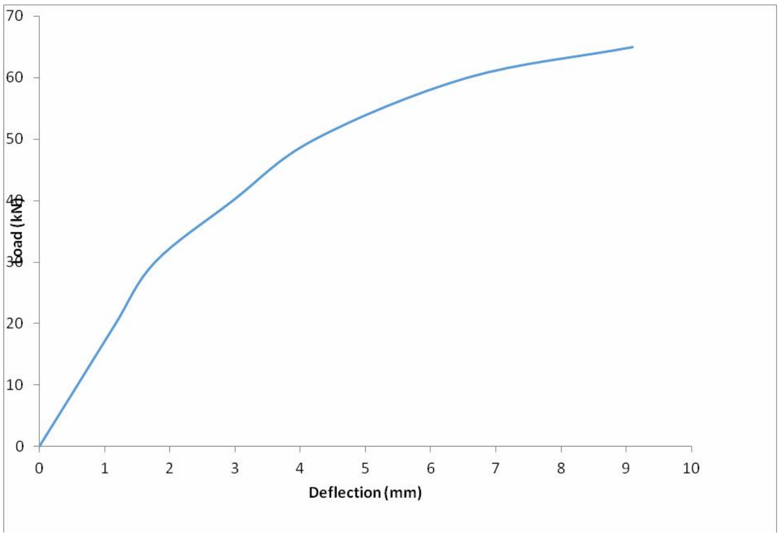

Figure 14 : Vertical load against def., beam B4.

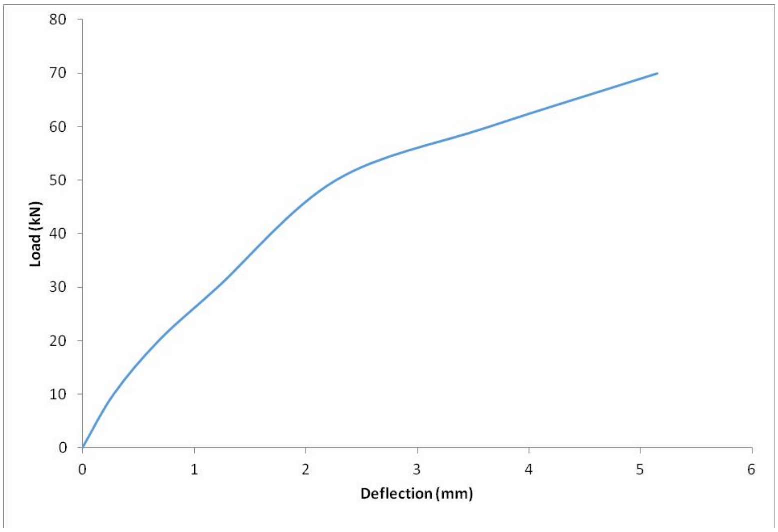

Figure 15*:* Vertical load against def., beam B5.

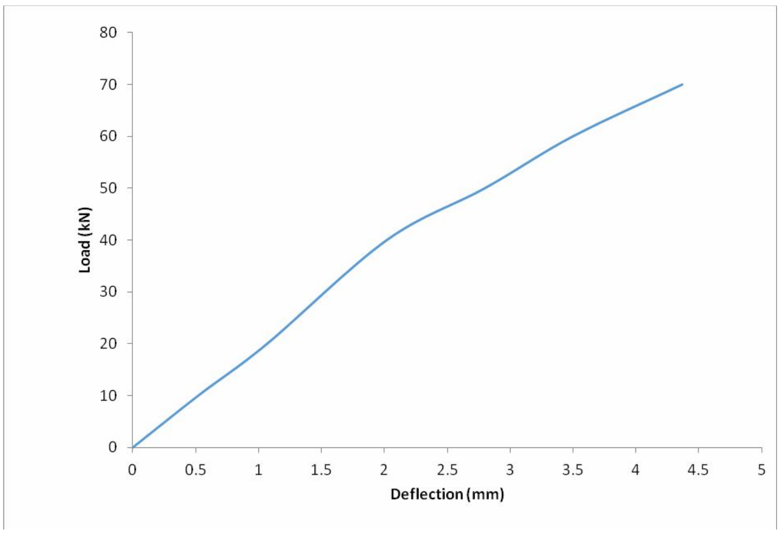

Figure 16: Vertical load against def., beam B6.

Effect of the compressive strength:

Figure 17 explains the behavior of load-deflection curves of (B0,B1,B2,B3,B4,B5and B6) specimens respectively . Each specimen which has the same tensile reinforcing bar ratio and dimensions with different compressive strengths of 18,21.1,22.8,23.9,22.9,25.2 and 27.4 MPa respectively. This figure shows the same behavior before the yield of the steel bars and shows the ultimate load increases by about 1.84%, 9.43%, 13.21%,22.64%,32.1% and 32.1% respectively compared with the normal weight beam (B0). Therefore, it can be confirmed that the compressive strength has very slight effect on the behavior of the lightweight aggregate (LWA) beam technique.

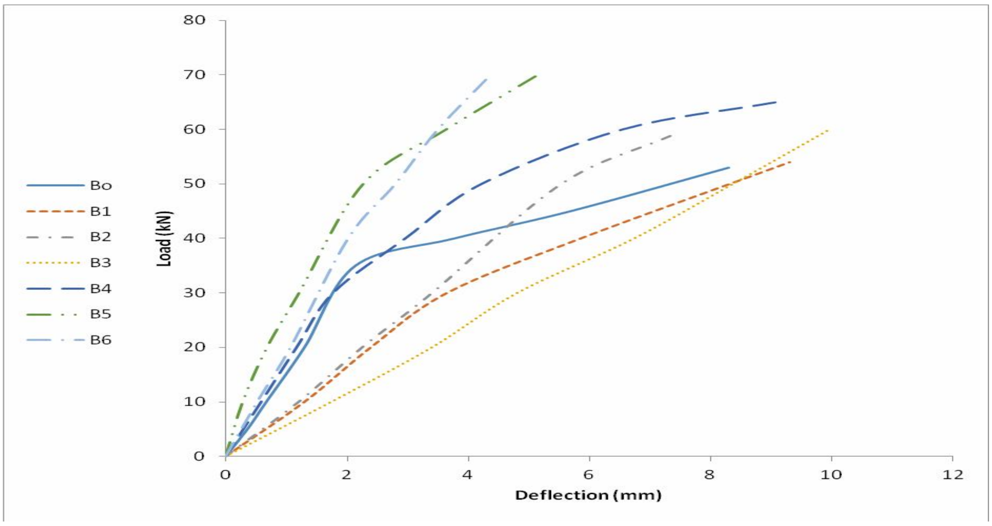

Figure 17: Vertical load against def., beams B0,B1,B2,B3,B4,B5 and B6

Conclusions

In order to study the behavior of reinforced light weight concrete beams, an effective experimental program was carried out. Main conclusions drawn from the experimental work can be summarized as :

1- The light weight concrete beams have an ultimate strength is greater than that of normal weight concrete beam.

2- LWC (Light Weight Concrete) beams have higher ultimate loads than reference beam (normal weight) so that the light weight crushed brick concrete technique is effective.

3- First cracks appeared in the flexural zone in all light weight beams . After increasing loads diagonal cracks in the shear zone will appear. All light weight beams failed with shear.

4- The light weight crushed brick concrete technique can be get the compressive strength higher than 20 MPa by this technique.

5- The reducing approximately 20% in the weight in concrete by using this technique and at the same time increasing the ultimate load from 1.84% to 32.1% compared with normal weight.

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