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Shear Behavior of Reinforced Lightweight Concrete T-Beams

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ملخص البحث

يحتوى هذا البحث على دراسة معملية لسلوك الخرسانة الخفيفة ذات الكرات الرغوية فى القص. و قد تم التوصل الى الخرسانة الخفيفة عن طريق الاستبدال الجزئى للركام بفوم البوليسترين، و ذلك بهدف خفض الوزن الجاف لوحدة الحجوم من 23 كن/م^3 الى 18 كن/م^3. و قد تم اجراء دراسة معملية على عدد 4 كمرات وقد شمل البحث المتغيرات الاتية : عرض الجزء المضغوط من الكمره . وقد شمل البحث ايضا خصائص المواد المستخدمة، و ادوات القياس المستخدمة.

ABSTRACT

In order to study the shear behavior of reinforced lightweight Concrete (LWC) simply supported beams. An experimental program has been conducted. The test program included four reinforced concrete simply supported beams. The main parameter examined was the effective width of the compression flange.

The details of specimens, material properties, instrumentation, tests apparatuses and the testing procedure are presented in this paper. The effect of the studied variable is presented and discussed.

KEYWORDS: LWC behavior, Concrete type, Beam, Foamed concrete, Lightweight, Shear behavior.

Introduction

Most of the current concrete researches focus on high-performance concrete, by which is meant a cost-effective material that satisfies demanding performance requirements, including durability. Light-weight concrete (LWC) is very important to the construction industry due to it's cost-effective and high numerous advantages. The primary advantage of using LWC is to reduce the dead load of the concrete structure, which allows the structural designer to reduce the size of carrying columns, footings, and other load-bearing elements.

Furthermore, the reduced mass will reduce the lateral load that will be imposed on the structure during earthquakes, hence simplifying and reducing the lateral load carrying system. Structural light-weight concrete mixes can be designed to achieve similar strengths as normal weight concrete. The same is true for other mechanical and durability performance requirements. Structural lightweight concrete provides a more efficient strength-to-weight ratio in structural elements. In most cases, the marginally higher cost of lightweight concrete is offset by size reduction of structural elements, less reinforcing steel and reduced volume of concrete which result in lower overall cost.

Light-weight foamed concrete is a new kind of Lightweight concrete, which combines the advantages of normal density concrete, cellular concrete and self-compacting concrete through partially replacing the normal weight aggregates with polystyrene foam, hence, leading to concrete unit weight reduction while maintaining adequate strength. The latter material can, therefore, be produced using standard methods familiar to the construction industry with a dry unit weight of 18.0 kN/m3, which in turn leads to dead load reduction of 15 – 20 % and the associated decrease in the structure's overall cost, hence, providing a feasible challenge to normal density concrete (NDC).

Shear behavior of R.C. beams has been frequently investigated over the last decades due to the several parameters affecting the concrete shear resistance. Shear transfer actions and mechanisms in R.C. beams are complex and difficult to identify clearly. Complex stress redistributions occur after cracking, and those redistributions have been shown to be influenced by many factors. The major components contributing to the shear resistance are the shear strength of the uncracked concrete, the vertical component of the aggregate interlock shear, the dowel force in the longitudinal reinforcement and the shear carried by the shear reinforcement, respectively.

One of the parameters affecting the shear strength of R.C. is the shape of its cross-section (rectangular versus T-section); nevertheless, the study of shear resistance in the case of T-beams is limited. In international design codes such as ACI Building Code and the Euro code, the shear force in a T-beam is assumed to be carried only by its web. This simplified assumption, which has prevailed in the shear design practice, requires more investigation, especially in the case of using Light-weight concrete, (LWC) mixes.

Zararis et al. developed an equation to predict the shear strength of slender T-beams. They reported that the increase in the shear strength of T-beams compared to that of rectangular beams is due to the large compression zone; however, increasing area of steel stirrups does not give any advantage to T-beams over the rectangular beams. They also reported that the ACI-code prediction for the shear strength of T-beams is conservative. However, the effect of concrete flange width and the shear span-to-depth ratio on the behavior of T-beams with varying compressive concrete strengths including LWC.

Experimental Program

The performed experimental work consisted of four large-scale lightweight concrete T-beams. All specimens with an overall length of beam 24000mm were simply supported and tested under the effect of two concentrated loads.

The group consists of four beams with stirrups 5 Ø 8/m ordinary stirrups one of the specimens (R-sec) and three of specimens (T-sec) with cross sec (120x300mm), slab thickness 50mm with different flange width (320, 520, 720mm).

Table (1) Details of specimens.

	Beam	b	t	t_s	Flange width (B)	B/b	Span to depth ration (a/d)
	Specimen	mm	mm	mm	mm	-	-
1	B1	120	300	50	120	1	3
2	B2	120	300	50	320	2.67	3
3	B3	120	300	50	520	4.3	3
4	B4	120	300	50	720	6	3

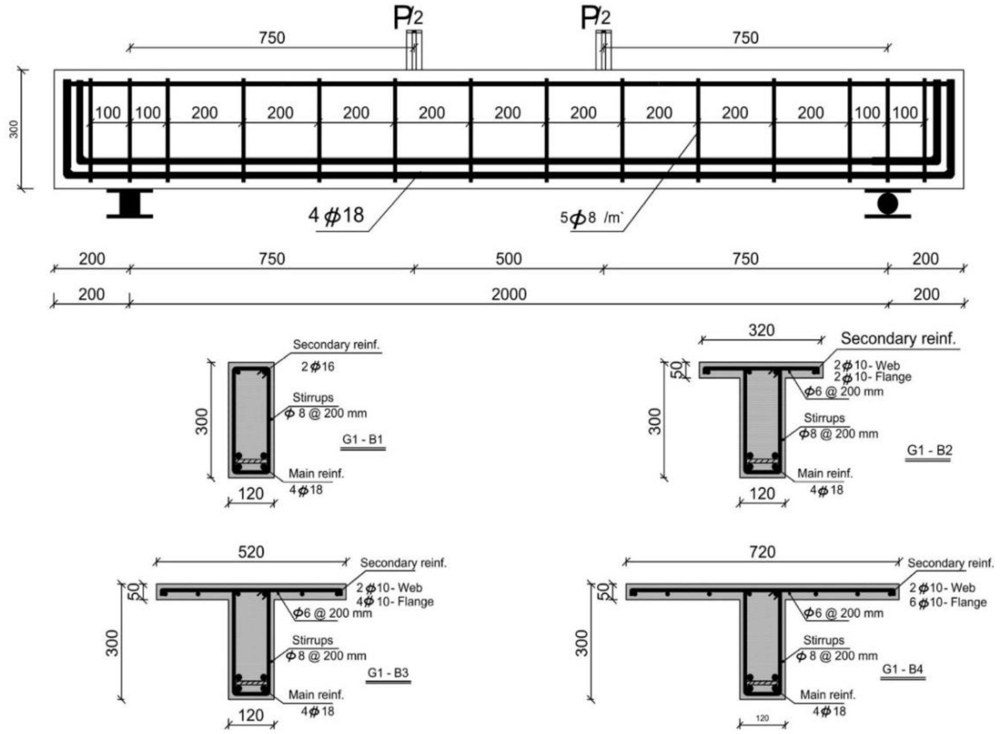

Fig.1 Details of specimens.

Concrete Mixtures Evaluated

The quantities required by weight for one cubic meter of fresh concrete for the L.W.C specimens are as given in table (2)

Table 2 Material Quantities in Kg/m^3 for The LWC Specimens.

	Cement (kg/m^3)	Silica Fume (kg/m^3)	Coarse Aggregate (kg/m^3)	Sand (kg/m^3)	Polystyrene Foam (liter/m^3)	Super Plasticizer (liter/m^3)	w/c ratio
LWC	450	40	630	630	330	13.5	0.308

Preparation of Specimens

Wooden forms were designed and prepared to allow for simple and correct placing of concrete. The steel bars were tied with the stirrups forming reinforcement cages corresponding to that required for connections. Electrical strain gauges of 6 mms length and 120.3± 0.5-ohm resistance were fixed on the steel bars to follow the reinforcement strains during loading. The strain gauges were covered with silicone sealant to protect them during casting and consolidation of concrete. The forms were coated with a thin layer of oil (Sika®form oil) to facilitate their removal after hardening of concrete. The reinforcement cages were then placed in the forms and lifted by small blocks to permit appropriate concrete cover.

The steel was inserted into the formworks; concrete spacers were also inserted from all sides using small concrete pieces of thickness 1.5cm to ensure the designed concrete cover. Figure (2) show the steel cage insertion in the formwork with maintaining the concrete cover.

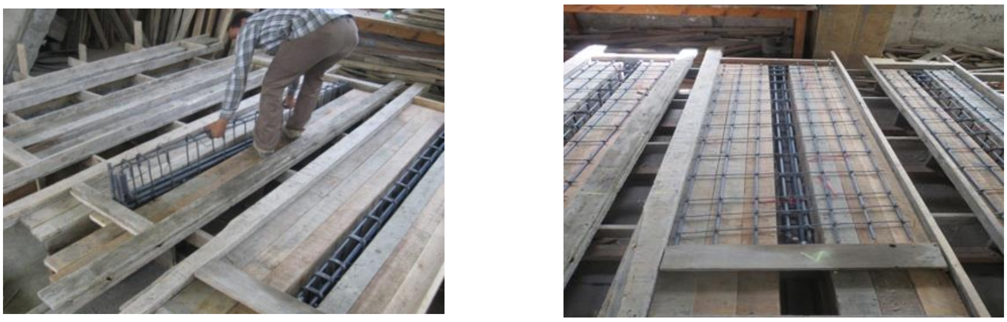

Fig.2 Details of specimens.

Mixing and Curing

Dry materials and water were mechanically mixed in a drum mixer for two minutes and cast in the forms just after mixing. The cast concrete was then vibrated with an electrical needle vibrator, and hence the final concrete surface was smoothed. The forms were removed after 24 hours from casting, and specimens were moisture continuously with water for 7 days and kept in laboratory atmosphere for about 4 to 6 weeks until they were tested. Cone test was performed to measure the workability fresh concrete, and the result obtained value 4" which acceptable.

Quality control specimens were prepared during casting specimens to obtain the mechanical properties of the used concrete. Two sets of six cube specimens (15.8 cm. side) and nine cylindrical specimens (15 cm. diameter and 30 cm. height) ware cast alongside the beams, weighted and tested at the age of 7, 14 and 28 days (the same day of beam testing). After 24 hours, the specimens were kept under water until the day of testing.

Loading of Specimens

The specimens were loaded in increments up to failure. The tested specimens were instrumented to measure the deformational behavior after each load increment. The recorded data include measurements in concrete, main steel, transverse reinforcement (stirrups) and longitudinal bars strain; deflection and crack propagation. After each load increment, the cracks were traced and marked on the painted sides of the specimen according to their sequence of occurrence.

Test procedure

The specimens were tested by using a hydraulic jack. At the beginning of each test, the specimen was installed on the two supports as a simple beam. The reading of the hydraulic jacks and the steel strain gauges were taken by special instruments as shown in figure (3).

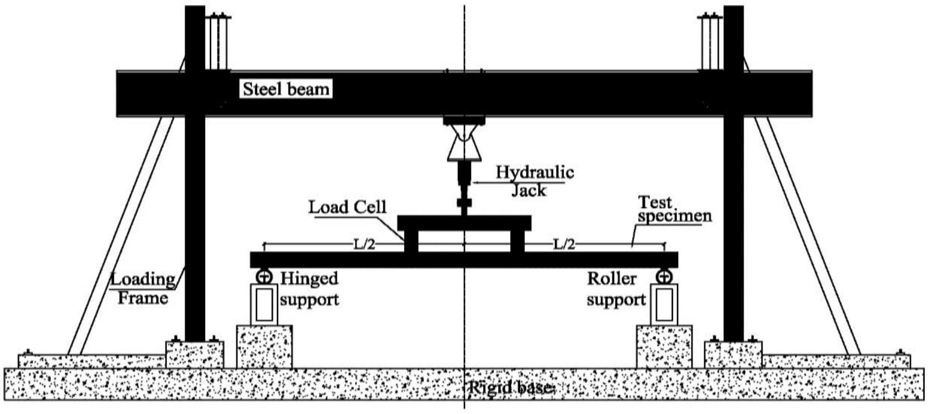

Fig.3 Test Setup.

EXPERIMENTAL RESULTS AND DISCUSSION

Cracking and Failure load

A total of four beam specimens were tested to failure. All of them failed in shear before flexural capacity is reached. No slip of the flexural capacity is reached. No slip of flexural reinforcement was observed during any of the beam tests. A summary of the test results for each tested beam specimens is presented in Table 3, includes the flange width, span to depth ratio, moment cracking load, shear cracking load, and the failure load.

Table 3 Summary of test results for beam specimens.

	Beam	Flange width (B)	B/b	Span to depth ration (a/d)	Group NO.	Moment cracking load	Shear cracking load	Failure load
	Specimen	mm	-	-	-	KN	KN	KN
1	B1	0	1	3	G1	60	70	173
2	B2	320	2.67	3	G1	70	80	190
3	B3	520	4.3	3	G1	70	80	200
4	B4	720	6	3	G1	70	80	205

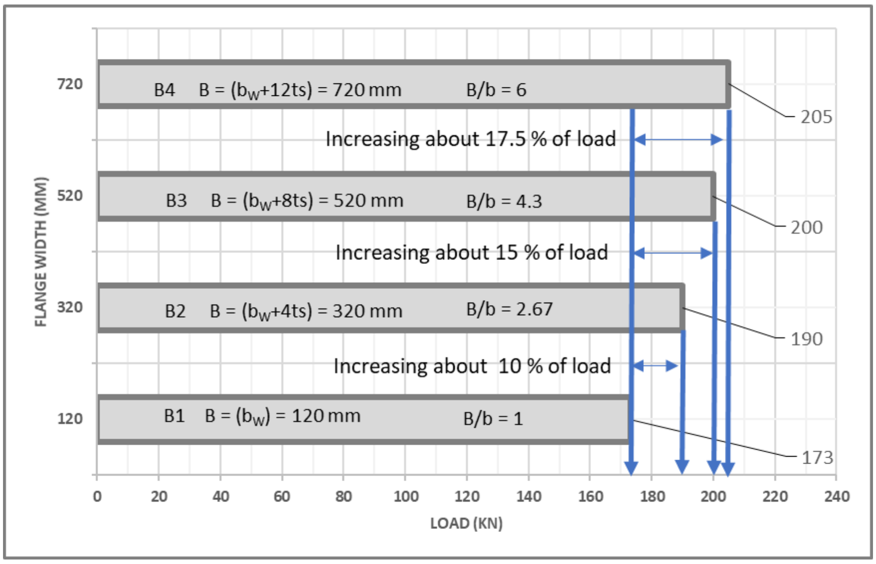

Fig.4 Failure Load of tested beams.

After the peak of each loading, the crack pattern was marked to provide the necessary information required for defining the failure mechanism of each specimen. Figure (4) show the failure mode of all the tested specimens.

From these figures, the following remark could be concluded

- . For all specimens, the flexural cracks initiated on the tension side in the middle of the beam span, the cracks propagated upward with the increase of load. For solid beam, the first diagonal crack suddenly developed at mid-depth within the shear span. Diagonal cracks were observed parallel to the compression strut and propagated towards the loading region and supports.

Fig.5 Crack pattern of beam specimens.

Load Deflection Response

During testing of each beam, the deflection at mid-span was measured at the end of each load increment. The measured load-deflection curves are shown in figure (5).

The load-deflection curves for the tested beams were nearly linear at the early stages of loading from zero up to the first cracking of the concrete. The great decrease in stiffness due to excessive cracking had resulted in relatively great increase in the deflection values, approaching the failure load, the deflection continued to increase even with the applied load being maintained constant.

Comparing the deflections of beams at the same load the deflections were inversely proportional to the slab width. For beam specimens B1, B2, B3, and B4 which having flange width from 120mm to 320mm, 520mm, and 720mm respectively, it was found the vertical deflection decreased by about 11%, 17%, 21.4% respectively from B1 which have a rectangular section with stirrups at the same load.

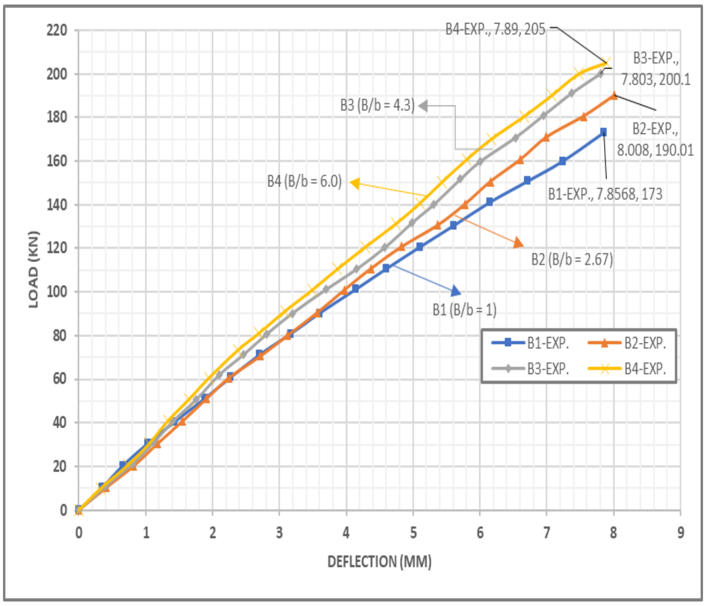

Fig.6 Applied load versus deflection for beam specimens.

Longitudinal Steel Strain

Attached strain gauges at the bottom longitudinal bars were used to measure the steel reinforcement strain during testing process connected to data acquisition system.

For beam specimens B1, B2, B3, and B4 which having flange width from 120mm to 320mm, 520mm, and 720mm respectively, it was found the longitudinal steel strain decreased by about 4%, 11%, 15 % respectively from B1 which have a rectangular section with stirrups at the same load.

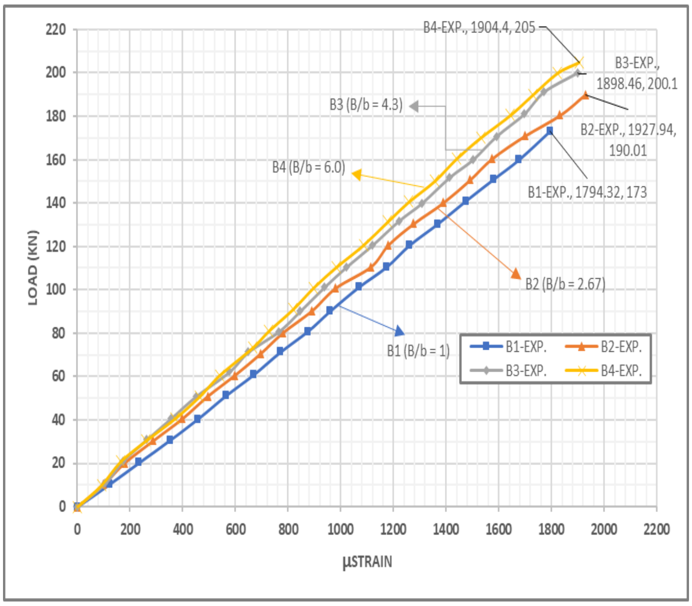

Fig.7 Applied load versus longitudinal steel strain for beam specimens.

Stirrups Steel Strain

Attached strain gauges at the Stirrup bars were used to measure the stirrups steel strain during testing process connected to data acquisition system.

For beam specimens B1, B2, B3, and B4 which having flange width from 120mm to 320mm, 520mm, and 720mm respectively, it was found the stirrups steel strain decreased by about 5%, 11%, 18 % respectively from B1 which have rectangular section with stirrups at the same load

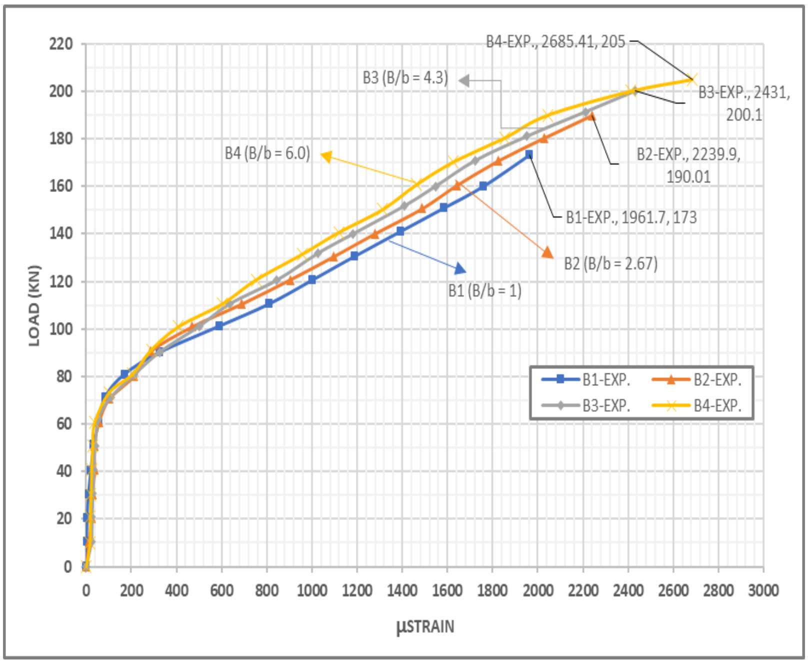

Fig.8 Applied load versus stirrups steel strain for beam specimens.

CONCLUSIONS

1) Increasing of flange width 320mm, 520, and 720 mm leads to increase the failure load by about 10%, 15%, and 17.5% respectively.
2) The shear failure modes of lightweight concrete beams are similar to normal weight concrete beams.
3) Use Polystyrenes Foam size smaller than usually given a better result than use normal size from Polystyrenes Foam.

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