Flexural and shear strength of partial RCC beams and slabs – A review

Purushothama. C. T[1], Dr. I. R. Mithanthaya[2]
[1, 2] Department of Civil Engineering
[1] SCEM, Mangaluru, India
[1] NMAMIT, Nitte, India

Abstract- Two important properties of RC beams and slabs are flexural and shear strength. This review paper shows the results obtained from analysis and experimental results by various researchers on the above mentioned strengths of partial beams and slabs. The review of these papers has shown that the ultimate strength of hollow beams and slabs is approximately equal to homogeneous or solid beams and slabs, but the initial crack load is less in hollow beams and slabs. Partial RCC beams/slabs are one of the solutions to reduce the use of cement in construction that leads to the reduction of CO_2 emission. Also it helps to usage of some waste materials those harm the environment.

Keywords- partial beams and slabs, flexural strength, shear strength, CO_2 emission, environment.

I. INTRODUCTION

According to the Royal Society of Chemistry, concrete is the single most widely used material in the world (RSC, 2008). The journal continues to explain that because of concrete's widespread use, it comes without surprise that concrete also has a large carbon footprint. Quantitatively the paper explains that the production of concrete globally, accounts for about 5% of the annual global Carbon dioxide production from human activity. That is mainly because of the vast quantities being used yearly. Partial RCC beams/slabs are one of the solutions to reduce the use of cement in construction that leads to the reduction of CO_2 emission. Also it helps to usage of some waste materials those harm the environment. Partial RCC beam/slab is defined as a beam or slab consisting of concrete with different grades or concrete with different material (waste materials) or concrete with air (vacuum), have flexural and shear strength similar to homogeneous solid RCC beam. Bending of beam divides the beam into compression and tension zone. Assumption made as concrete in the tension zone is neglected and assumption also says perfect bond between concrete and steel exists to transfer the strain to the steel. Concrete acts as a strain transferring material in the tension zone. The strain just above and just below the neutral axis is less compare to extreme top and bottom fiber. The ultimate bending moment will remains same for conventional (same grade of concrete throughout the depth) and partial beams/slabs. The partial beams/slabs will be economical, engineering and environmental friendly. Therefore developing partial beams/slabs is need of the hour.

II.STUDIES ON PARTIAL BEAMS AND SLABS

The concrete in the tension zone is called as 'sacrificial concrete'. This concrete will transfer the strain to the reinforcement. Just to transfer strain, minimum grade of concrete is enough in the tension zone and high grade concrete is used in the compression zone. Keeping and safety in mind developed a beam called 'partial beam'. A partial beam 150 x 300 x 2430 mm is a normal beam with two different grades of concrete one above and another below the neutral axis. Partial beam achieves economy as well as reduction in environmental impact. From Fig1 and Fig2 ultimate crack load in normal concrete is 106kN and in partial concrete is 98kN [1]. Less stressed concrete below neutral axis can be replaced by some light weight and low cost materials like light weight concrete, bricks etc, it will reduce the weight of the structure and reduce the cost. Behavior of reinforced concrete with brick filled concrete beams is similar to that of RCC beams. Strength will not reduce because of bricks in the tension zone. No extra cost is required to cast the beam. Reduction of weight and economy depends on percentage replacement of concrete by bricks. $X_u = (0.87\ f_y\ A_{st})/(0.36 f_{ck} b)$ as per IS 456 2000, d' = (2 x cover + diameter of bar), d' is the thickness of concrete layer available to maintain bond between steel and concrete. (X_u - d') is the area for brick fills [2].

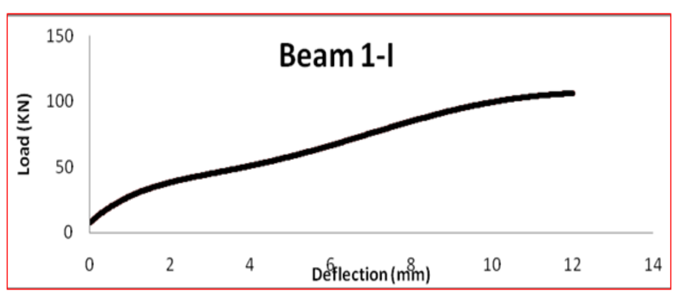


Fig.1 Load - Deflection Curve (M30 Grade Beam)

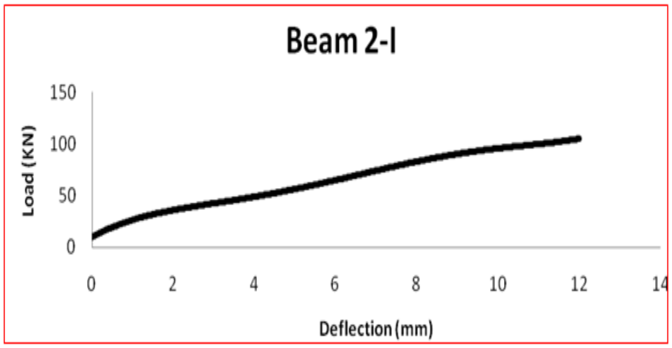


Fig.2 Load - Deflection Curve (M30 + M20 NA at 91mm)

As concrete is weak in tension, steel is introduced in the tension zone to take the tension, but as strength of concrete is ignored in tension zone with respect to compression zone. So logically no concrete is required in tension side. But this concrete needs to be provided on tension side to act as strain transferring media to steel and may be called as 'sacrificial concrete'. If this concrete has no tension more than strains transferring, then why to go for same grade of concrete which is used in upper zone? This is basic question which led to the idea of concrete grade reduction in tension zone for RCC beams to reduce construction cost. All Partial beams structural behavior in flexure is typical. The overall flexural behavior of Partial beam used closely resembles that of equivalent beam made with Normal beam Fig3, [3].

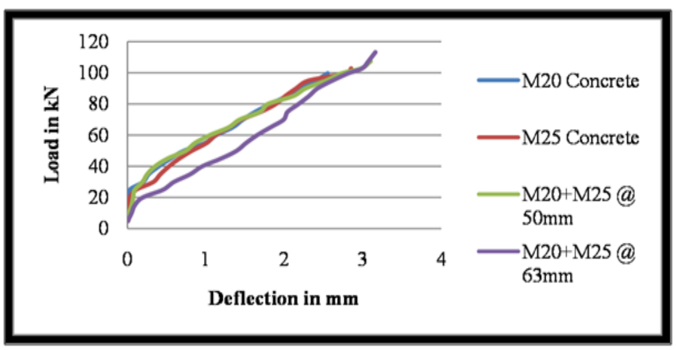


Fig.3- Load-Deflection Curve

The strength of concrete lying in and around the neutral axis is not fully utilized. This un utilized concrete is removed by replacing with any light weight material. The marital used is PVC pipe, which occupy the concrete volume in the neutral axis. Beam becomes hollow at the neutral axis. The properties of PVC pipe is not considered since it is used as a filler material in concrete. The self weight of this developed RC beams are expected to be reduced with the decrease in concrete volume hence the beams to be economical. Experimental validation has been done analytically with ANSYS 12.1 software. The hollow beams cracked at lower loads than the solid ones. The difference in loads is small which is about 5kN only Fig4 [4].

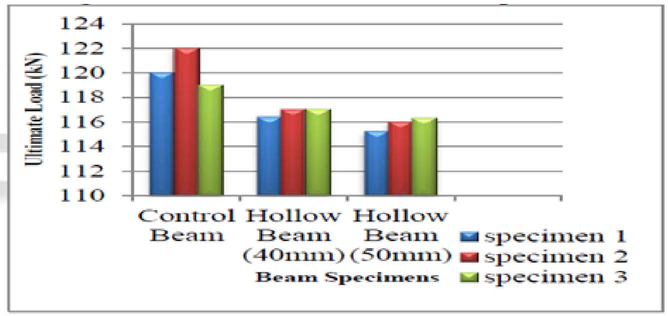
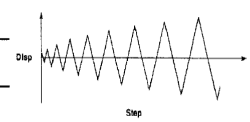


Fig.4- Ultimate Crack Load of beam

Ultimate deformation and energy dissipation capacity of hollow beams are somewhat smaller than those of the corresponding solid beams without hollow part, and the ultimate failure mode of the former is more brittle than that of latter due to reduction in shear resistance of concrete. In the hollow beams diagonal cracks are generated at early stage of loading. This leads to considerable increase in the strain of stirrups, and the ratio of shear deformation to the total deformation becomes higher near the ultimate state Table1 [5]

Table 1. Details of specimens and failure mode

specimen	cross section	shear span ratio *a/d*	longitudinal reinforcement ratio, *p*(%)	loading pattern	failure * mode
H45	hollow	2.51	0.996		SF
S45	solid	2.51	0.996		SF
H55	hollow	3.07	0.996		SF
S55	solid	3.07	0.996		SF
H65	hollow	3.63	0.996		SF
S65	solid	3.63	0.996		F

* SF: shear failure after flexural yielding F: flexural failure

A solid slab can only carry approximately one third of its own weight, and have problems with long spans due to its high weight. The investigations of Bubble Deck's biaxial deck allow solving this problem by eliminating 35% of concrete, while maintaining strength. Test have shown that for a Bubble Deck slab with the same load-carrying capacity can be used only 50% of the concrete required for a solid slab, or with the same thickness of a Bubble Deck slab the load-carrying capacity can be increased up two times by using 65% of concrete [6]. Strength of conventional slab and filler slab is nearby same. There are no any effects of making filler slab instead of conventional slab. Economic point of view, 30% of concrete is saving in filler slab technique. In filler slab technique 30% cost is saving, which is greatly effect on economy. In manufacture of cement, filler slab technique saves 30% of carbon emission which proves eco-friendly [7]. It was found that all solid beams cracked at higher loads than the hollow beams. The differences are more pronounced when the bending moment was dominant. Every solid beam resisted more load than hollow one. Most of the hollow beams failed near the design loads while the solid beams failed much more than the design loads. For both types, large values of bending moment and shear stress due shear force lead to increased failure load while the presence of torsion reduces the failure load [8].

III. DISCUSSIONS

From the literature review, it can be observed that much research has been carried out on hollow or partial beams/slabs and solid beams/slabs. Many researchers are concluded ultimate load in both cases is nearly same, in many of the literature failure is by flexure. They declared partial beams/slabs are economical and eco friendly.

The literature review does not provide sufficient information on shear failure i.e. very severe in medium and deep beams and also in hollow flat slabs. Hence much research work is needed to understand the effect of shear and to prevent its effects to make partial beams and hollow flat slabs popular in construction to save cement, finally to save environment.

REFERENCES

[1] S.B. Kandekar, P.D. Dhake, M.R. Wakchaure: International Journal of Innovative Research in Science, Engineering and Technology (ISO 3297: 2007 Certified Organization) Vol. 2, Issue 8, August 2013- Concrete grade variation in tension and compression zones of RCC beams.

[2] Patel Rakesh, Dubey S.K, Pathak K.K: International Journal of Advanced Engineering Technology E-ISSN 0976-3945 - Brick filled reinforced concrete composite beams.

[3] B.S Karthik, Dr.H Eramma and Madhukaran: International Journal of Advanced Technology in Engineering and Science www.ijates.com Volume No.02, Issue No. 07, July 2014 - Behavior of concrete grade variation in tension and compression zones of RCC beams.

[4] Jain Joy and Rajesh Rajeev: IJSRD - International Journal for Scientific Research & Development| Vol. 2, Issue 10, 2014 - Effect of reinforced concrete beam with hollow neutral axis

[5] Susumu Inoue and Noriaki Egava: Paper No 1359. Eleventh world conference on Earthquake Engineering - Flexural and shear behaviour of reinforced concrete hollow beams under reversed cyclic loads.

[6] A. Churakov saint- Petersburg Polytechnical University, 29 Polytechnicheskaya st., St Petersburg, 195251, Russia:ISSN 2304-6295. 6 (21). 2014. 70-88 - Biaxial hollow slab with innovative types of voids.

[7] Amit D Chougule, MR.Manoj H. Mota, DR. Mrs. Ushadevi S Patil: ISSN: 0975 – 6744| NOV 14 TO OCT 15 | Volume 3, Issue 2 - To study the filler slab as alternative construction technology-a review.

[8] Ali Said Al-Nuaimi Khalifa S. Al-Jabri Abdel Wahid Hago: Materials and Structures (2008) 41:269–286 - Comparison between solid and hollow reinforced concrete beam.