Comparative Study of Conventional and Partial RCC Beams and Slabs for Flexural and Shear strength – A review

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Abstract: IS456-2000, Clause 38.1 Assumptions, one of the assumptions is; the tensile strength of concrete is ignored. As per this assumption, Instead of using high grade concrete in tension zone, use of nominal grade concrete or creating vacuum near neutral axis, to develop "Partial RC beam or slab". Both beam and slab are bending structural elements, hence understanding of flexural and shear strength is very important. Review of research papers gives an insight on difference between conventional and partial bending elements. Ultimate flexural strength will be nearly same in both partial elements and conventional bending elements. Initial crack load is less in partial bending elements compare to conventional elements. But partial elements are the best solution to reduce usage of cement in RC structural elements. Understanding shear strength of partial bending elements is very essential in the shear reinforcement design, but less research work is done on shear strength of partial flexural elements. Use of less cement in partial elements reduces CO2 emission, makes structure economical and it is also the solution for global warming

Keywords: Conventional bending elements, Partial bending elements, Flexural strength, shear strength, less cement, CO2 emission, global warming..

1. Introduction

Cement is used to bind other materials together in construction. Cement is mixed with fine aggregates, coarse aggregates and water to produce concrete, the most widely used construction material in the world. Over 10^5 billion kN of concrete is used each year. Cement is the basic ingredient of concrete, around 8% of global CO_2 emissions come from cement production. Reducing usage of cement without compromising strength in construction is need of the hour. Shape optimization is the best technique to reduce the size and materials in concrete structures. But, casting different shapes of RCC cast in situ structures is difficult due to complicated form work and arrangement of reinforcement. Hence development of partial beam/slab is the best solution. In partial structural element either grade of concrete can be varied in compression and tension zone or vacuum can be created in less stressed part, ie near neutral axis. Minimum grade of concrete M_{20} will be provided in tension zone as mentioned in IS456, higher grade can be provided in compression zone. There will be great reduction in usage of cement in deep beams and also in thick (flat) slabs. Precast lightweight partial structural elements also contribute reduction in cement usage and become economical.

2. Comarative Study Of Conventional Beams/Slabs And Partial Beams/Slabs For Flexural And Shear Strength

Xu = (0.87* fy*Ast)/ (0.368*fck*b) as per IS 456 2000, d' = ((2 x cover) + diameter of bar), d' is the thickness of concrete available to develop bond between steel and concrete. (D – (Xu + d')) is the area for brick fills, where D is overall depth. Analysis of composite section is done by Method of Initial Functions (MIF). There is no much difference between strength of brick in filled beams and conventional beams. Cost of casting in filled beam is almost same as conventional beam, no extra cost is needed. Economy and reduction of weight depends on percentage of replacement [1].

Beam size 150 mm x 300 mm x 2430 mm. Conventional beam M_{30} grade throughout, Partial beam M30 + M20 NA at 91mm and M30 + M20 NA at 79 mm. Average crack load for conventional beam is 68.33 kN for conventional beam. 62.33 kN for M30 + M20 NA at 91mm and 55.33 kN for M30 + M20 NA at 79 mm beam. Average Ultimate load for conventional beam is 106.33 kN for conventional beam. 95.33 kN for M30 + M20 NA at 91mm and 95 kN for M30 + M20 NA at 79 mm beam. This shows ultimate load is nearly same for conventional and partial beams but crack load is less in partial beam compare to conventional beam, hence it is difficult to achieve limit state of serviceability [2].

Near neutral axis, stress is less; the amount of concrete required is less compare to top and bottom, where stress is high. Near neutral axis vacuum is created by providing waste PVC pipe. ANSYS 12.1 software is used to analyze the strength of beam. For concrete Solid65, steel reinforcement link8, PVC pipe shell 181, and steel plate at supports solid45 were used. Control beams, Beams with 40 mm dia PVC pipe and Beams with 50 mm diameter PVC pipe were analyzed. In both crack load and ultimate load, there is a difference of 5 kN [3].

Reinforced hollow concrete beams of size 200 mm x 200 mm with hollow core 120 mm x 100 mm, shear span length of 450 mm, 550 mm and 650 mm. Flexural span length of 600 mm. longitudinal reinforcement of 0.996%. Loading pattern is cyclic. Except S650 (span 650) all beams will fail by shear and flexure S650 will fail only by flexure. Hollow beams are inefficient in resisting cyclic loading. Hollow beams have brittle failure because of reduction in shear resistance of concrete. Energy dissipation of hollow beams is smaller than solid beams [4].

The problem of flat slab is self weight and excessive deflection. Flat slabs with large spans can be made effective by a technology called biaxial hollow slab. Different types of hollow slab systems are Airdeck, Cobiax, U-Boot and Bubble deck. Shear resistance of biaxial hollow slab is less due to reduced concrete volume; hence slab is made solid near columns. At mid span slab is more effective for flexure since reduction of self weight. This technology can be recommended for large span flat slab. It saves concrete up to 35% [5].

In case of solid slab below the neutral axis can be provided with light weight filler materials, tiles or hollow bricks called filler slabs. Filler slabs save concrete up to 30% and finishing is not required for inside portion that saves cost. Filler slabs are preferable for roof slabs, also for slab where live load is less. The dead weight of structures reduces, there is saving in cost of foundation. National Building Code (NBC) of India 2005 mention the filler slab satisfies and confirms to the provisions of relevant parts concerned to material, design and construction and the material, method or work offered is for the intended purpose [6].

Hollow beams 200 mm x 200 mm internal dimension and 300 mm x 300 mm external dimensions; length of 3800 mm. Solid beams of 300 mm x 300 mm x 3800 mm, both hollow and solid beams are provided with longitudinal and transverse reinforcement are tested with combination of bending, shear and torsion. Solid beams carry more crack load than hollow beams. Combination of bending and shear carries more failure load in both hollow and solid, but torsion decreases failure load in both the cases. Wherever load is less and to save concrete, hollow beams are advisable. But, if the load is more and in important structures where there is a combination of loads, solid beams are advisable [7].

Four-point flexure tests to investigate the bending behavior of hollow beams. Four parameters are mentioned, they are percentage of size reduction, quantity of steel fiber, longitudinal reinforcement ratio and the presence of shear reinforcement. Four conventional beams in addition to 10 partial beams with central square holes having sides of 60, 80 and 100 mm are tested to evaluate the mentioned parameters. Beams are either reinforced with 1% steel fiber or with no fiber. In addition to the experimental results, analytical formulae are introduced to find the cracking and ultimate loads of the hollow beams. The beam with the reduction of size 16% (60 mm x 60 mm hoe) results the highest crack load and ultimate loads, which were even higher than the corresponding solid beams [8].

Synthetic fibers 19mm, 38mm, 57 mm and steel fibers of 10mm are used to enhance tensional strength of hollow beams. Beam size is 100 mm x 100 mm x 500 mm. Conventional beam without fibers carries a flexural strength of 4.12 MPa. Hollow beam H_{20} (20mm dia PVC) with 19 mm fibers carries a flexural strength of 5.84MPa, Hollow beam H_{30} (30mm dia PVC) with 38 mm fibers carries a flexural strength of 6.21MPa, Hollow beam H_{50} (50mm dia PVC) with 57 mm fibers carries a flexural strength of 6.74MPa. This shows aspect ratio affects on strength. Hollow beam is less brittle compare to solid. In tensional resistance also H_{50} carries more torque 7.38 kN-m, where as conventional beam carries 5.55 kN-m. to overcome the problem of partial beams with less crack and ultimate loads, fibers are the best solution [9].

Sandwich beams with paper honeycomb, one type without filler, other is foam filled. 6mm, 12mm and 25mm thick are used width is 50mm. Nonlinearity can be observed in bending. Load - deflection curve shows honeycomb without filler show less load carrying capacity almost 50% of the load carrying capacity of foam filled beams, deflection is huge in non filler case. Load - strain curve also shows honeycomb without filler shows more strain for less load compare to foam filled beam less strain for more load. Moment - curvature curve also shows non filler have less moment capacity compare to foam filler. The study declared this can be tried for biaxial bending thin structures [10].

Steel – Concrete hybrid composite precast beam reduces cost of construction and time, also reduces environmental effect compare to conventional RCC cast in-situ beam. Steel I-section filled with light weight filler between two flanges, nominal longitudinal reinforcement and nominal stirrups are provided outside the steel section, rectangular formwork is arranged and nominal grade concrete is filled to prepare composite precast beam. in both composite and hollow beam damage is minimal before failure, but damage is severe in hollow beam in case of hollow beam at failure compare to composite. Ultimate flexural strength of composite beam is 8.41% more than hollow beam. Considering the strength, cost, and time hybrid steel – concrete composite beam is most suitable [11].

Beam size 200mm x 300 mm x 2300 mm, grade of concrete M_{30}, conventional and circular hollow below neutral axis. Reinforcement 3 bars of 16 mm diameter and nominal stirrups.40 mm and 50 mm diameter PVC pipes at 160 mm depth. Crack load of hollow beams is more than conventional beam, but ultimate load is same for both. Deflection of hollow beam is more than conventional beam, may be because of less stiffness [12].

3. Discussions

From the literature review, it can be observed that much research has been carried out on hollow or partial beams/slabs and conventional beams/slabs. Many researchers are concluded that ultimate load in both cases is nearly same. In many of the literature failure is only by flexure. More study is required on failure by both flexure and shear. It is observed that initial crack load is less in partial structural element compare to conventional structural element. Initial crack load plays a major role in limit state of serviceability. Once reinforcement is yielded strain transferring will be reversed, steel to concrete, since there is no sufficient concrete or high grade concrete in tension zone in partial structural element, cracks appear early and also propagation of cracks. To increase initial crack load, fibers can be used in concrete. Fibers restricts the propagation of cracks

Literature study shows there is a less information on shear failure, but it is very severe in medium and deep beams and also in hollow flat slabs. Hence more insight is required to understand the effect of shear and to reduce its effects to make partial beams and hollow flat slabs become efficient in construction and to save cement. Finally we can save environment.

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