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Review on Partial Replacement of Concrete in Tension Zone in RC Beam

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Abstract: *This paper represents review on partial replacement of concrete in tension zone with different volume proportion and different percentage of replaced material (i.e. pieces of bricks, tera cota tile, PVC pipe, polythene balls). Concrete is weak in tension therefore steel reinforcement are provided in tension zone. The concrete in tension zone acts as a stress transfer medium between the both sides of neutral axis. In RC beam strength of concrete lays below the neutral axis is not fully utilized. This unutilized concrete is also called as sacrificial concrete. So this sacrificial concrete can be replaced by some lightweight materials.*

Keywords: *Neutral Axis, RC Beam, Sacrificial Concrete, Tension Zone, Transfer Media*

I. Introduction

Concrete is the basic material for RCC structure. In RCC beam, there are mainly two zones one is compression and another one is tension. These zones are separated by neutral axis which lies at a distance of $\left(\frac{0.87 f_y A_{st}}{0.36 f_{ck} b}\right)$. In flexural member since concrete is weak in tension and strong in compression. Concrete has no tension more than strain transfer, therefore provision of reinforcement are made in structural member. Strength of concrete in tension zone is ignored with respect to compression zone. There is no need for provision of concrete in tension zone but there should be some filler material for transferring the strain to the steel reinforcement in the bottom of beam. There are several methods for increasing properties of concrete in tension zone such as pre-stressing and converting the beam into other shapes such as Tee beams. Due to this method there is change in geometry of structure and increases the cost of construction. An alternate method of replacing the sacrificial concrete in tension zone with inert weightless substances like hollow PVC pipes, Styrofoam grain, polythene balls *etc.*, will not affect much in the stress and strength characteristics of beam as well as it will not affect the geometry and shape of beam.

II. Literature Review

Basil Tom Jose and Divya Sasi (2018) [1] In this study, the authors conducted the experimental investigation on partial replacement of concrete below the neutral axis by using seeding trays and the results were compared with normal M25 grade concrete beams and replaced beams by using polythene balls. As the experiments were conducted the ultimate load value decreased with increase in percentage of replacement but replacement of seeding trays up to 3% shown more ultimate load value than polythene ball replaced beam while it was vice versa for ductility index. Authors presented an idea that partial replacement of the concrete below the neutral axis can create reduction in weight and savings in materials too.

Dhinesh N.P. and Satheesh V.S. (2017) [2] This paper presents details of the studies carried out on flexural behavior of hollow core reinforced concrete beams with different core depths. They conducted the experimental program, consists of casting and testing of reinforced concrete beams of size 150mm x 150mm x 1000mm with hollow core in different zone and they studied the flexural behavior of all beams, tested by three points loading. The load carrying capacity of the hollow core beam at various depth was more than the normal control beam.

Balamurugan R., Ashok Kumar M. and Karthik Ragunath S. (2017) [3] Authors aim was to reduce the self-weight of the structure and reduction in cost without losing its strength and serviceability in the structural design. In this paper, an experimental investigation of the light weight aggregate concrete placed below the neutral axis has been done to create reduction in weight and savings in materials. Hence the author of this research paper were compared reinforced LECA (Light weight Expanded Clay Aggregate) concrete sandwich beam with a reinforced concrete solid beam in terms of flexural strength. The ultimate load carrying capacity of sandwich beam was reduced 7.6% when compared to conventional beam. They also investigated the beam in terms of crack load and deflection curves.

Er.Ima Mathew, Er.Sneha and M.Varghese (2016) [4] In this paper, it was investigated that, in simply supported reinforced concrete beam the region below neutral axis is in tension and the region above neutral axis is in compression. The tension and compression in the neutral axis is zero. In reinforced concrete beams strength of concrete lying in and near the neutral axis is not fully utilized. The concrete below the neutral axis acts as a stress transfer medium between the compression and tension zone. In this thesis work, experiment was conducted to partially replace the concrete both in and near the neutral axis and that below the neutral axis by creating air voids using waste plastic bottles. They concluded not only it helped in reduction in concrete used but also thereby reducing self-weight, cost, etc. Since waste plastic bottles were utilized to create air voids, it adds on to sustainability.

Soji Soman and Anima P. (2016) [5] Partial replacement of the concrete below the neutral axis was an idea that can create reduction in weight and savings in materials. In this paper, an experimental and analytical investigation on partial replacement of concrete in the tension zone that was below the neutral axis by creating air voids was discussed. Air voids were created by using polyethylene balls and PVC pipes. Beams were cast by using different percentage (4%, 8% and 16%) of polyethylene balls and PVC pipes. The best results were found at 8% replacement of polythene balls and 8% replacement of PVC pipes. In this paper, the results obtained for control specimens, beams with polyethylene balls and for beams with PVC pipes is compared. They also concluded that the initial cracks are developed at supporting points and widen when load increases. Analytical study of the same is done using ANSYS.

Anju Varghese and Basil.M.Joseph (2016) [6] Beams are structural members which resists load by bending. Flexural action depends on compressive stress of concrete on compression side and tensile stress of steel on tension zone. In reinforced concrete beams concrete on tension zone had no effect on the flexural action. So this unutilized concrete can be removed by replacing with any lightweight material. For this study material incorporated in the concrete beam which was expanded polystyrene, which occupy the concrete volume below the neutral axis. Specimens of solid reinforced concrete beams and hollow core reinforced concrete sandwich beams with various core thickness were casted and tested for three point flexure. Then the results were compared and effects studied. Authors also conducted parametric study to know the effect of varying depth of replacement using ANSYS. If weights of this developed hollow core reinforced concrete sandwich beams were reduced hence proving the beam to be economical. They concluded that the hollow core sandwich beams shows similar behavior in flexure as that of control beam.

V.P. Roshan Ahamed and Priyanka Dilip P. (2016) [7] In this paper, an experimental and analytical investigation on partial replacement of concrete below the neutral axis by light weight concrete was discussed by V.P. Roshan Ahamed and Priyanka Dilip P. Experimental models of light weight composite beams were cast and tested in UTM of 600KN and compared the analytical and experimental result of composite beam using brick pieces. Experimentally and analytically load vs deflection characteristics was found to be similar for composite beam. Then modeling light weight concrete of tensile layer in reinforced concrete prisms using a continuum-based finite element model test was conducted in ANSYS 16.1 and the experimental and analytical results were analyzed and discussed.

Ayush Srivastava (2015) [8] In this work, Ayush Srivastava studied the demonstrated the use of filler-slab in building construction to reduce cost of construction as well as the dead load of the structure. This technology also aimed at increasing the strength of the slab as compared to reinforced concrete slab. The used materials were compiled in such a way that the structural strength and its durability increases as compared to the conventional RCC slabs used in building construction technologies.

Yasser, Herman Parung, Muhammad W. Tjaronge, and Rudy D. Jamaluddin (2015) [9] It is well known that the concrete in tension zone is neglected in the design. Therefore, it is reasonable if the concrete on the tension zone used low compressive strength concrete by mixing them with the Styrofoam grains. The concrete that filled with the concrete grains was named with Styrofoam filled concrete. Styrofoam as waste can be used as a filler to reduce the volume of concrete, especially for areas where the concrete section was neglected in design. Styrofoam concrete was used in this study with 30% Styrofoam volume fractions.

Results which were determined by Yasser, Herman Parung, Muhammad W. Tjaronge, and Rudy D. Jamaluddin indicated that the BN (natural beam) had maximum flexural load of 38.8 KN, while vertical external reinforcement beams (BTL) had decreased load of 24.2 KN and truss system external reinforcement beam (BTR) of 36.0 KN, close to the normal beam specimen. Loading test of the beam with SFC-30 using vertical reinforcement (BSC) and beam with SFC-30 using truss system reinforcement (BSCTR) had maximum load of 38.2 KN and 48.3 KN, respectively. It can be concluded that the use of Styrofoam concrete in tension zone of

the concrete beams showed a good agreement in performance compared to the normal reinforced concrete beams. The use of truss system reinforcement can increase the strength of the loading capacity of the beam was significantly compared to the vertical reinforcement.

Jain Joy and Rajesh Rajeev (2014) [10] The objective of Jain Joy and Rajesh Rajeev was to investigate the reinforced concrete beam with hollow neutral axis which may replace the position of reinforced concrete beam in near future. However, in reinforced concrete beams strength of concrete lying in and near the neutral axis is not fully utilized. So this un-utilized concrete can remove by replacing with any light-weight material. The material incorporated in the concrete beam was PVC pipe, which occupied the concrete volume in the neutral axis, where the compression and tension is zero thereby making the beam hollow. The properties of PVC was not been used since it is used only as a filler material in concrete. Specimens of solid reinforced concrete beams and hollow reinforced concrete beams were cast and tested for four point flexure.

The results which were obtained, Jain Joy and Rajesh Rajeev compared the results and the effects were studied. The self-weight of this developed reinforced concrete beams were expected to be reduced with the decrease in concrete volume hence proving the beams to be economical. Experimental validation is carried out analytically with ANSYS 12.1 software.

B.S. Karthik, Dr. H. Eramma and Madhukaran (2014) [11] Based on the investigations, the following conclusions were drawn .All Partial beams showed typical structural behavior in flexure. The overall flexural behavior of Partial beam used in this study closely resembles that of equivalent beam made with Normal beam. The experimental ultimate moment gives a conservative estimate for Partial beams for 28% to 40% of a theoretical ultimate moment. Deflection of Partial beam calculated using Equation under service loads can be used to give reasonable predictions. The deflection under the service loads for beams were within the allowable limit provided by IS 456-2000.Partial beams show good ductility behavior. All the beams exhibited considerable amount of deflection, which gives enough warning before failure. The crack width at service loads varies from 0.10 mm to 0.3 mm and this was within the maximum allowable limits.

Authors observed that as the depth of higher grade concrete increased in compression zone, resistance to the first crack development also increased. All type of beams shown flexural failure and no shear cracks were seen. It may be small span of the test specimen crack patterns and their developing system, failure mode and the sustainability leads to select the Partial Beams as safer and serviceable than the Normal Beams. It suggested that the M20+M25@ 63mm Neutral axis can be considered as optimum content of Partial beam. From the overall study, it can be concluded that Partial beam is more efficient and economical than normal RCC beam, this was considered as best strengthening RCC beam among all the process. It was concluded that, Partial beam is a beautiful result of the application of engineering in building construction works to achieve economy as well as reduction in the environmental impact due to construction works.

Rakesh Patel, S.K. Dubey and K.K. Pathak (2014) [12] This paper presented the study carried out on reinforced concrete infilled beams. In reinforced concrete beams, less stressed concrete near neutral axis can be replaced by some light weight material like bricks pieces to reduce the weight of the structure and also achieve the economy. Infilled zone was obtained with the help of stress block diagram, used for limit state design of reinforced concrete beams as per IS 456-2000. Rakesh Patel, S.K. Dubey and K.K. Pathak used finite element method (FEM) method of initial functions is used for the analysis of infilled reinforced concrete composite beams. The results obtained by method of initial function were compared with those predicted by finite element method based software ANSYS, and it is observed that they are comparable.

W.Godwin Jesudhason and Dr. G. Hemalatha (2014) [13] This paper presented the experimental investigation criteria to replace the portion below the neutral axis of the beam with expanded polystyrene sheet. Expanded polystyrene sheet is a waste material obtained from the packing industries. It has good flexibility property. Normally in beams failure occurs by bending, but by embedding expanded polystyrene sheet in concrete, shear cracks only occur while loading. While considering weight criteria expanded polystyrene sheet embedded beam weighs lesser compared to conventional beam.

Addition of EPS in the beams prevented the bending failure since EPS sheets undergo large without failure. However the shear failure shown that EPS sheets does not provided the necessary cross section to resist shear .Hence replacing the core of concrete with EPS in the middle zone of the length of beam can be an effective solution of concrete and effective behavior in bending and shear.

Aswathy S. Kumar and Anup (2013) [14] The concrete below the neutral axis act as a stress transfer medium between the compression and tension zone. Partial replacement of the concrete below the neutral axis was an idea that could create reduction in weight and savings in materials.

In this paper, Aswathy S Kumar and Anup, they investigated that the effect of partial replacement of concrete below the neutral axis by creating air voids using polythene balls was discussed. They replaced concrete by 4% and 8% polythene balls in beams and tested on 100t loading frame. They found that slightly decrease in ultimate load carrying capacity at 4% and 8% replacement of concrete by polythene balls.

S. B. Kandekar, P.D. Dhake and M.R. Wakchaure (2013) [15] Concrete has no tension more than strain 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 reinforced concrete beams to reduce construction cost. They casted and tested composite beam with lower grade concrete in tension zone. Results were that the ultimate bending moment was not change and bending moment was also same when first crack varies. Increasing depth of higher grade of concrete in compression zone was lead to increase resistance against first crack development and no shear cracks were seen in all partial beam.

Delsye C.L. Teo, Md. Abdul Mannan and John V. Kurian (2006) [16] This paper presented an investigation on the flexural behavior of reinforced concrete beams produced from oil palm shell aggregates. Using oil palm shell ops in concrete production not only solved the problem of disposing this solid waste but also helped to conserve natural resources. Delsye C. L. Teo, Md. Abdul Mannan and John V. Kurian casted a total of 6 under-reinforced beams with varying reinforcement ratios (0.52% to 3.90%) were fabricated and tested. Data which was presented included the deflection characteristics, cracking behavior, ductility indices and end-rotations. The investigation revealed that the flexural behavior of reinforced oil palm shell ops concrete beams was comparable to that of other lightweight concrete and the experimental results were compared reasonably well with the current codes of practice. They observed that the beams with low reinforcement ratios satisfied all the serviceability requirements as per bs 8110.

Yue Qingl U and D.J. Lauriek Ennedy (1992) [17] In standard CAN/CSA S16.1-M89, the contribution of the concrete to the flexural capacity of concrete-filled hollow structural sections is acknowledged as an alternative approach, but no method of assessing was given. Preliminary studies had indicated that the concrete increased the ultimate moment capacity, the initial flexural stiffness, and the ductility, and delayed local buckling of the steel, thus enhanced the behavior considerably. A series of four flexural tests on rectangular and square cold-formed hollow structural steel sections and twelve on concrete filled sections were undertaken to assess the general behavior of these composite sections. They selected that the test specimens were selected to examine the effects of different ratios of depth to width and therefore of the proportions of steel and concrete in compression, and of different values of shear span to depth as related to the transfer of forces from one to the other when no direct means is provided for this transfer. The tests showed that the ultimate flexural.

III. Conclusion

After the study of all literature reviews we have observed that all the authors used materials like polythene ball, brick pieces, PVC pipes, Styrofoam, light weight concrete, lower grade concrete, hollow core space, expanded polystyrene, rice husk *etc.* as replaced materials of sacrificial concrete. After using all these materials in beam, they found that the ultimate load carrying capacity slightly decreased except partially replaced beam with PVC pipes. Load *vs* deflection curve shown the deflection occurs more than conventional beam at slightly decreased amount of load.

We concluded that the only problems in partial replacement of concrete is slightly reduction in ultimate load carrying capacity which can be overcome by using lower grade of concrete with steel slag in tension zone of composite beam which help in increasing the load carrying capacity of beam.

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