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Flexural Behaviour and Validation of Reinforced Concrete Beams with Opening using Foundry Sand

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Abstract: The provision of transverse openings in floor beams to facilitate the passage of utility pipes and service ducts results not only in a more systematic layout of pipes and ducts.it also translates into substantial economic savings, in the construction of a multi-storey building. Along with opening, the partial replacement of foundry slag sand with crushed stone is done which further reduces the cost of the beams. In order to obtain the optimum level of replacement, foundry slag sand is varied from 0-100% and tested under compressive strength for maximum strength. With help of ANSYS software, various shapes of openings, keeping equivalent area of cross section such as rectangular and provided at critical zone are modelled and analysed. To reduce stress concentration at corners of the openings, Special reinforcements are provided as per ACI specification. With that optimum shape experimental work is carried out. Where 3 beam were casted of size 2000*450*230mm and tested under loading frame with two pint loading and simply supported condition. The results obtained such as deflection, initial cracks, and ultimate failure load were compared with the beams without openings, with openings using foundry slag sand and without using foundry sand. Also comparison of analytical results with that of experimental results was carried out.

Key words: Compressive Strength, ANSYS, Openings.

I. INTRODUCTION

A. General

In the present scenario, we know that the second widely utilized material is cement next to water, hence it has a very adverse impact on the present environment.

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Engineers and scientists are trying all the possible alternatives for replacement of building material, which are eco-friendly and emphasizing on the use of reprocessed and reutilized metallurgical waste, such that accumulation of industrial waste like iron and foundry slag can be minimized and put into practice to produce concrete by making use of it efficiently to its full extent. Foundry sand is solid waste disposed in huge amount by iron and steel industry across the world.

It possess similar property as that of river sand, hence can be used as replacement for fine aggregate or coarse aggregate depending on the application of the concrete. Foundry sand can also be used with cement as active admixture to order to enhance the concrete properties. These supplementary cementitious materials greatly reduce the impact on natural resources along with decrease of CO_2 emissions. Due to fast economic growth there is an urgent need to pay attention towards alternatives and research work needs to be carried out towards it. In the current study, the usefulness of foundry sand is studied in reinforced concrete beams with different duct opening. Experimental and analytical work is carried out to understand the behaviour of the RC beams. For the conveyance of pipes and ducts for various purposes such as air conditioner, sewage pipe and water supply system etc. are passed through the transverse opening in the floor beams. When such type of design is adopted, it reduces the height of the structures and it tends to a most economical design. Whenever an opening is provided in beams, it possess problems pertaining to stress concentration at the corners of the opening, deformation and excessive deflection under service load, hence a special consideration on design of the beam around the opening. According to ACI code is carried out, in order to counteract the negative effects of the premature failure of the beams due to Vierendeel Truss Action. When diagonal reinforcements are provided it improves the load carrying capacity of the beam. The aim of this study is to investigate the behaviour of foundry sand reinforced concrete beams with duct openings.

B. Foundry Sand

Foundry sand has high quality properties and has the physical characteristics which are uniformly found. Foundry sand is a byproduct of non ferrous and ferrous metal casting which is obtained in industries. This waste foundry sand can be recycled and reused. When the sand can no longer be reused it is called as “Foundry sand”.

Using the foundry sand as fine aggregates in the concrete instead of using it for the land filling can reduce the environmental issues. The volume of waste sand going to landfill can be reduced.

The raw sand is normally has a higher quality than that of the natural sand or typical bank sand used in fill construction sites. The sands form the outer shape of the mold cavity. These sands contains upon a small amount of bentonite clay that acts as a binding material. These chemical binders are used to create sand "cores". Depending upon the geometry of the casting, sands cores are incorporated into the mould cavity in order to form internal passages for the molten metal. The casting is separated from the molding and core sands in the shakeout process when the metal has solidified. In this casting process, molding sands are recycled and reused for multiple times. Eventually, the recycling processes have got a peak point where the recycled sand degrades and that sand cannot be reused again. At the peak point the new sand is incorporated and the old sand is disposed from the cycle and named as byproduct, and the cycle begins again.

C. Openings

Transverse openings in beam may be classified based on the shape and size of the openings. Openings that are of square, rectangular and circular shape may be considered as small openings, depending on the depth or diameter of the opening which should be proportional to the depth of beam size, which is usually less than 40% of beam depth. In this case there may be beam action which exists and beam with small opening behaves same as that of solid beam. If the openings size is more than 40% of the depth of the beam, it is taken as large openings.

D. Significance of Present Study

It is due to economical and growing trend towards the use of more systematically and advanced approach to building design that structural engineers are often used to provide transverse openings in beams. For low-rise buildings the saving in cost may not be predominant compared to high-rise buildings where any savings in wall height multiplied by number of stories will reduce the consumption of concrete and increase profit, the length of service pipes, computer network cables, water supply pipes which reduces inversely increasing effective use of waste materials(Foundry Sand) and minimizing cost of construction, by providing opening in beam we will not only reduce length of service pipes, height of floor but we will also reduce the overall service ducts. Weight of building which will lead to more effective earthquake design and also lesser load on foundation. Many designers permit the embedment of small pipes by providing few additional reinforcement around periphery of opening. But when large openings are provided, particularly in RCC and pre-stressed concrete members, they show a general reluctance to deal with them due of lack of technical details not readily available. There is also a lack of particular guidelines in building codes which are being practiced namely (ACI, 1995 & BS 8110-97), but they contains detailed treatment for slabs with opening. Therefore structural engineers are frequently based on intuition which may lead to improper design and disastrous consequences. There has been at least one event in which the building has failed due to provision of large opening in beams, which is described by Merchant(1967). Hence it is essential to understand the behaviour of beam with opening in order to use it in practice for construction of building and also give more prominence for stress locations of beams during the designing stage only.

II. MATERIALS AND METHODOLOGY

A. Materials

Foundry Sand was collected from Emerald factory Kannur, different sizes 2mm foundry sand, processed rough foundry sand, plastering fine foundry sand was available. Foundry sand of processed rough sand was best and used for the current exploration. 40% replacement of processed foundry sand was done for this exploration. Coarse aggregate of 20mm & 12.5mm sizes were utilised in ratio of 60:40. The most favourable ratio of fine aggregate to coarse aggregate was made a trial. Ratio and best fixed ratio was 43:57 is fixed to keep up density- IS 383:1970.

Dalmia Cement OPC 53 grade was adopted for the experiment - IS 12269:2013. Concrete mix of 369kg/m3 was taken corresponding to grade of M30- IS2156:2000. Admixture dosage was taken as 0.25 to 0.4% by mass of cement content as per codal provision.
Fe 500 Steel for normal reinforcement confirming to IS 1786.

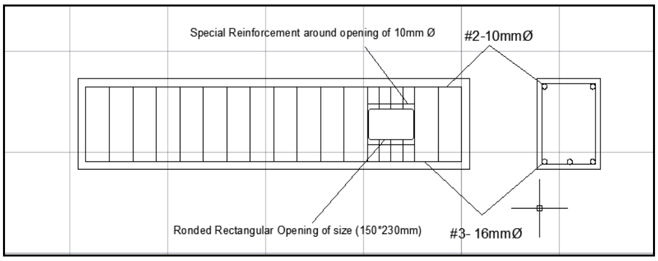
B. Methodology for Analytical Investigation

In the numerical method of analysis, beam with different shapes of duct openings and without any openings model was developed using three dimensional non-linear FE model using macro concept with the help of ANSYS 14.5.The concrete was modelled considering the replacement of steel slag sand adopting SOLID65, which is eight node element.Solid65 element is provisioned with simulating the cracking and crushing behaviour of brittle materials in all the three orthogonal direction. The steel reinforcement is modelled discreetly using LINK180, a 3D solid element and which consists two nodes three degree of freedom at each node. The link180 element is provisioned for simulating compressive and tensile stress in the reinforcement. The modulus of elasticity, stress-train characteristic etc. are concrete with replacement are taken from earlier research works. The ultimate failure compressive stress and crack pattern predicted by FE model is compared with experimental results.

C. Beam Specimens

For the present experimental study, two types of reinforced concrete beam specimens have been considered one with different shapes of openings in beam with replacements and another one is nominal conventional beam without openings. Initially the three different shapes of duct openings i.e. Rectangular openings are modelled and analysed in ANSYS and experimentally validated.
The following specifications have been adopted for this study:-

- The beams with rounded rectangular opening with 40% of foundry sand.
- The beams with rounded rectangular opening with 100% manufactured sand.
- The conventional beam.



D. Analytical Investigation on Beams

In order to get accurate results from numerical analysis, solid65 element is conidered andrectangular mesh is preffered other types of meshes.the beam beam element is primarily modeled by considerering volumes.the reinforcements are modelled using nodes created by mesh of the concrete volume.merge item command is used to merge separate elements that have similarlocation,these elements are then merged into single elements.in order to get the model,which behaves the same way as the experimental beam.boundary conditions are needed to get a unique solution and hence it is applied at the supports and loadings.

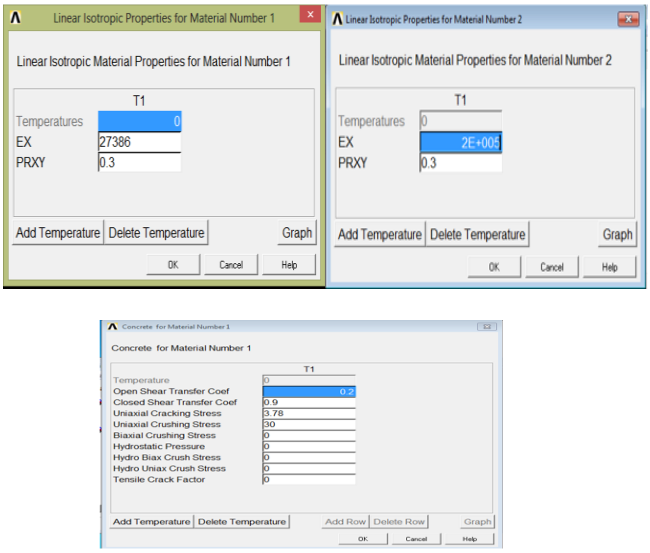


Fig.2: Material Property given to SOLID65, Reinforcement and Concrete Beam

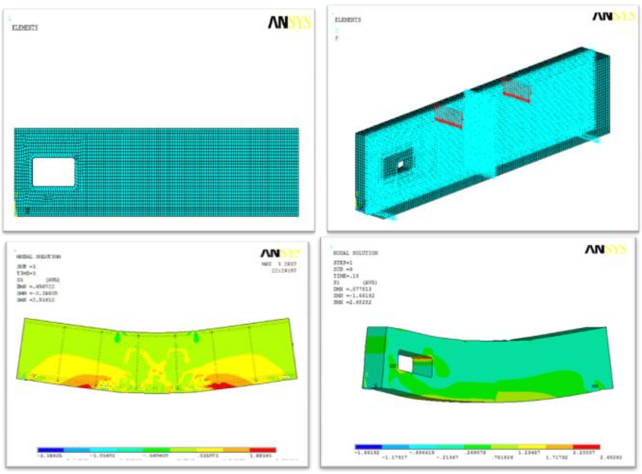


Fig.3: Modelling, Meshing, Deflection, Stress and Cracks of Beam with and without opening.

Sl. No.	Percentage of Foundry Sand variation	Weight of specimen (Kg)	Compressive Strength at 28days (N/mm^2)
1	0%	8.08	31.05
2	10%	8.10	32.52
3	20%	8.12	33.03
4	30%	8.12	35.72
5	40%	8.13	35.49
6	50%	8.13	35.08
7	60%	8.14	34.81
8	70%	8.14	34.64
9	80%	8.15	33.75
10	90%	8.13	33.28
11	100%	8.08	31.05

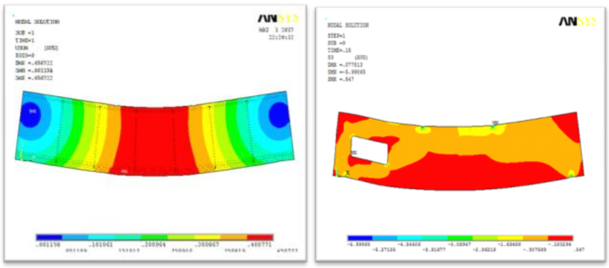


Fig.4: Stress in the Beams

III. RESULTS AND DISCUSSIONS

From the test conducted on cubes for 28days strength, it is seen that at 50% replacement of foundry sand with crushed stone sand, the compressive strength starts decreasing, 40% replacement of foundry sand gives the maximum compressive strength of 39.20N/mm^2.partial replacement of foundry sand with 40% has performed better compared to full replacement with crushed stone stand.

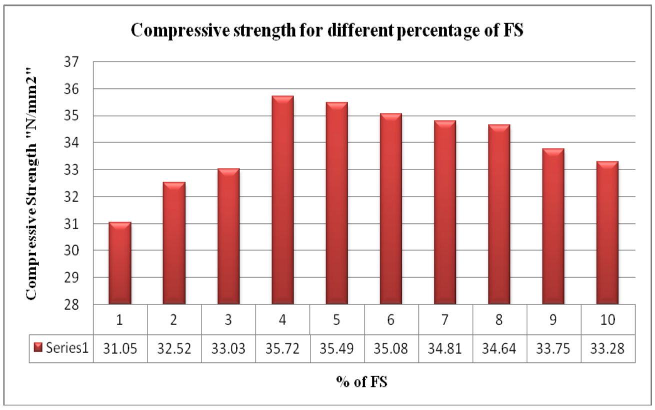


Fig 5: Indicates the maximum compressive strength for replacement of foundry sand for 28 days.

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After optimizing the appropriate percentage of foundry sand as fine aggregate in concrete i.e. 40%, primarily through compressive strength test. The beams of dimension 2000*450*230 are casted and tested in order to study the flexural behaviour of the reinforced concrete beam with various duct openings, under two point loading and simply supported condition in loading frame of capacity 100T.M30 grade concrete is used for the study and special reinforcement around opening is provided. For the experimental work steel foundry sand with 40% replacement with crushed stone sand with opening of the beam is casted, openings with 100% crushed stone sand is casted and beam without opening using 100% crushed stone sand.

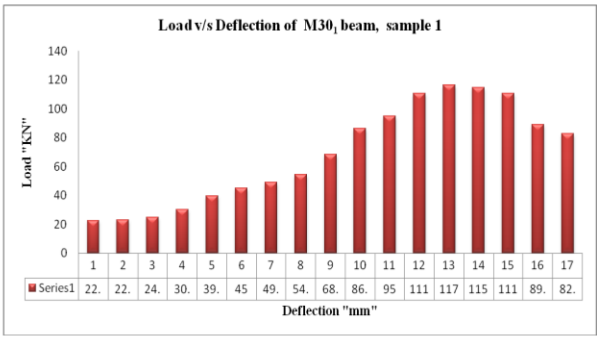

Fig.7: Load vs Deflection Curve for Beam with rounded rectangular opening with 40% of Foundry Sand.

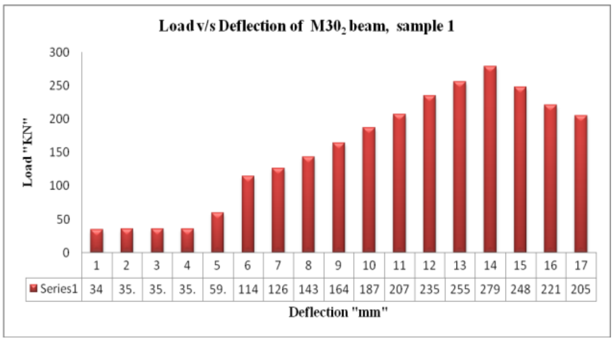

Fig.8: Load vs Deflection Curve for Beams with rounded rectangular opening with 100% manufactured sand.

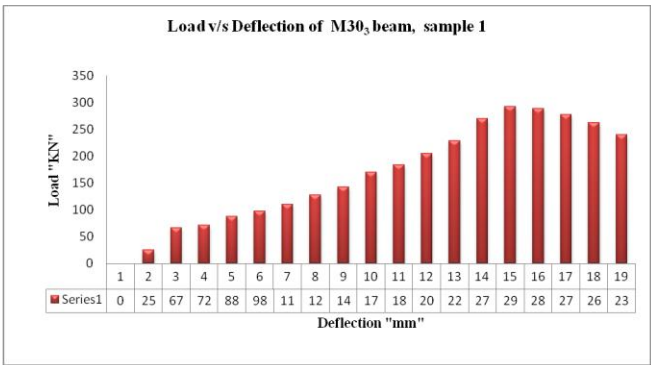

Fig.9: Load Deflection Behaviour of Conventional Beam

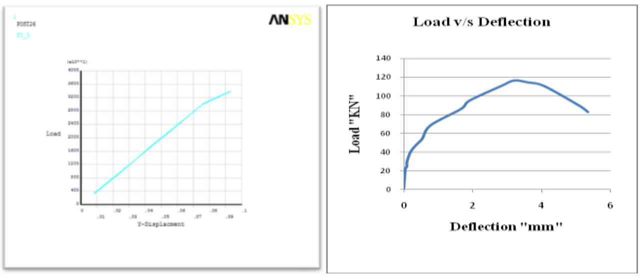

Fig.10: Comparision of Experimental and Analysis Results for Load v/s Deflection of beam with opening

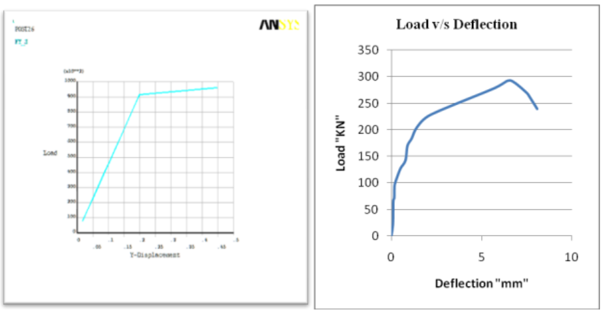

Fig.11: Comparision of Experimental and Analysis Results for Load v/s Deflection of beam without opening

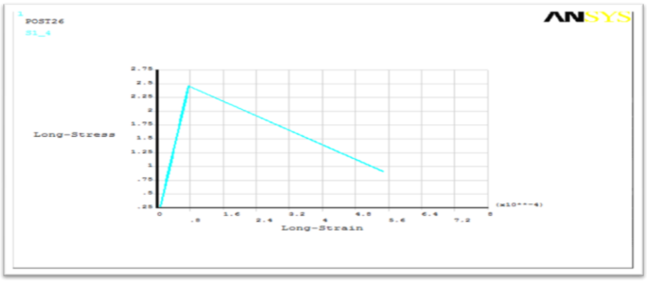

Fig.12: Stress Strain curve for beam with opening

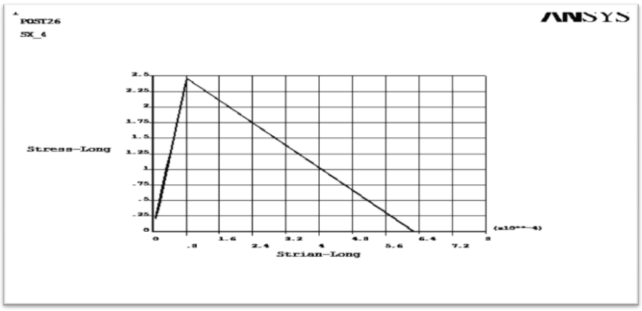

Fig.13: Stress Strain curve for beam without opening

- The beams with rounded rectangular opening with 40% of foundry sand.
- The beams with rounded rectangular opening with 100% manufactured sand.
- The conventional beam.

The beams with rounded rectangular opening with 40% of foundry sand showed increase in the flexural strength with 40% replacement of foundry sans with 60% of crushed stone sand for 28 days of curing. The beams with rounded rectangular opening with 100% manufactured sand showed increase in the flexural strength of yje beam with opening for 28 days. The conventional beam without replacement and without opening showed the maximum flexural strength for 28 days.

Comparing the conventional beam and the beams with rounded rectangular opening with 100% manufactured sand, there is maximum load showed for The beams with rounded rectangular opening with 100% manufactured sand than that of the beams with rounded rectangular opening
h 40% of foundry sand. Comparing beams with rounded rectangular opening with 100% manufactured sand and The conventional beam, the maximum strength showed for the conventional beam i.e., the beam without opening.

Now a day's deforestation is the major threat to the environment. Global warming is the first affect caused by deforestation. witHence, every action took which decreases deforestation will decrease the chances of threat to the environment. Decline in resource of natural available river sand have led to numerous problems and using them for construction purposes have become intricate. Cause behind difficulty is unavailability of natural sand in river beds, reasons in huge range constructing structures

A proper measure should be taken to accelerate the use of foundry slag sand as a building material in construction by the government and also it is very important to generate the awareness regarding importance of steel slag sand as fine aggregate.

IV. CONCLUSIONS

The beams with the rounded rectangular opening has more shear force compared to that of the conventional beam. The shear force acts more arround the opening in the diagonal patterns.

The bending moment is less in the rounded rectangular opening beam compared to that of the conventional beam.

There is no greater variation observed in the values obtained by experimentally and by the finite element analysis method i.e., ANSYS.

From the compressive strength of the foundry sand, the fine aggregates can be replaced upto the optimum level of 40% in the concrete.

There is optimum percentage of increase of the strength of the concrete by the replacement of the fine aggregate from the foundry sand.

The conventional beam has greater strength than the beam with rounded rectangular opening. Since the shear has more concentration surrounding the opening that reduces the strength of the beam.

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REFERENCES

1. Deepak Chaurasiya, Kiran Koli, Suraj Chaudhari "Replacement of fine aggregates with in concrete"– International Journal on Theoretical and Applied Research in mechanical Engineering. Volume 5, Issue 1, February 2016.
2. Umashankar A, Shashikumar A "Flexural behavior of RC beams using as partial replacement of fine aggregates". International Journal of Research in Engineering and Technology. Volume 5, Issue 8, August 2016.
3. G.Ganesh Prabhu, Jung Hwan Hyun, Yun Yong Kim "Effects of as a fine aggregate in concrete production" entitled - Science Direct, September 2014.
4. Rafat Siddique, Geert de Schutter "Effect of on the mechanical properties of concrete"– Science Direct.
5. Gurpreet Singh, Rafat Siddique as "Effect of waste as partial replacement of sand on the strength,ultrasonic pulse velocity and permeability of concrete" – Science Direct.
6. Mahima Ganeshan, Dr.Sreevidya V "Waste foundry sand as a replacement for fine aggregate in high strength solid masonary blocks",. International Journal of Innovative Research in Science ,Engineering Technology.
7. Rafat Siddique, Yogesh Aggarwal "Strength, durability and micro structure properties of concrete made with used "– Science Direct, Volume 4, Issue 3, December 2010.
8. Saeed Ahmed Sheikh "Flexure behavior of reinforced concrete beams with opening", Concrete Research, Volume 5(2), June 2014.
9. Saeed Ahmed Sheikh "Flexure behavior of reinforced concrete beams with opening", Concrete Research, Volume 5(2), June 2014.

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