International Journal of Scientific Research and Engineering Development-– Volume 4 Issue 3, May- June 2021

Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Flexural Behaviour of Beams with Polystyrene as Packing Material within the Reinforcement

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Abstract:

As concrete being one of the major constructional material, widely used in civil engineering. There is a need to develop alternative building materials due to rise in demand for conventional construction materials. We know that managing waste was the main topics mainly discussed for a very long time, so as a result many works and research has been done to bring this step into the construction industry. Many researchers have used many methods or experiments where they can replace Coarse aggregate. In this project, we have made use of expanded polystyrene to replace Coarse aggregate. Due to its lightweight Eps beads are used for making lightweight concrete. For waste management using polystyrene in construction is a method and it is one of the top second non – biodegradable waste. Concrete is said to be lightweight when it's density ranges from 160 – 1920 kg/m^3. Considering from the economical point of view these EPS beads will have a great impact where it has a sufficient strength as well the overall amount of coarse aggregate is replaced by the polystyrene beads in this plant. Fresh concrete properties are tabulated, with and without the addition of polystyrene beads. For cubes and cylinders with and without cement coating, workability, density, compressive force, break tensile strength are measured. Flexural strength is computed for Conventional beams and Polystyrene beams. Comparison of these properties observed later with normal concrete of M25 grade.

Keywords —Expanded polystyrene beads, Reinforcement, Self-Weight

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I. INTRODUCTION

Concrete, which is widely used material in the world especially on the construction industry has a total annual production of whopping two million cubic metres. For the optimum design of the building structures, it is very necessary to analyse the natural materials being used because of the extinction of these natural materials.So, our project has a main role in sustainable development as well as reducing the negative impact of concrete to the environment.

Materials like cement, coarse aggregate, fine aggregate and water are used inside the rectangular beams in this project. Steel reinforcement is used concrete in order to prevent the cracking of the structure. Concrete can hold strength in compression but in tension zone it is very weak. Tensile force will be generated at the bottom part of a reinforcement below the neutral axis and compressive force will be developed above the neutral axis as soon as a point load is applied. There is no much importance for the reinforcement section in the middle because it doesn't get affected by the force, so as these parts are not much important, we make use of some waste called as EPS beads instead of concrete.

To handle the limitations mentioned above, we need concrete with low density and the one which doesn't compromise in terms of its strength. These concretes are Lightweight concrete. Lightweight natural aggregates and the lightweight aggregates made of artificial aggregates are its classification. These concrete which are made up of lightweight aggregates are known as lightweight concrete.

In this project, we deal with replacement of concrete with polystyrene beads inside the reinforcement which is not so structurally important to reduce the self-weight it imparts to the structure. The wastes such as polystyrene are present in plenty which are not degraded in the environment.so we make use of this polystyrene in our project in the reinforcement part and care is taken very much so that the entire performance of the structure does not have any effect. Another idea of using polystyrene waste is that the entire weight of structure can be reduced to a good extent.

The substance used for partial replacement of coarse aggregate inside the reinforcement is polystyrene beads (EPS).Another property of this material is that when it is heated it melts and appears as solid in room temperature. Less weight is the reason by which we make use of it as a filling material in our project.

In the construction industry reinforced cement concrete has a big role. For structures there is a wide use of concrete. So, in our project we have made an attempt to decrease the self-weight of beam and the amount of concrete being used by replacing concrete with EPS beads. When a concrete is subjected to flexural load there is a high chance of failure of concrete because its tension part is not strong enough to resist. Taking into consideration the environment our project is useful where cement usage has decreased and as a result to this carbon dioxide production also has gone down too much. As the density of concrete is 2,400 kg per cubic meter in comparison to the density of EPS beads which is between 960-1050 kg per cubic centimeter, the entire weight of structure will be reduced to a greater extent.

In this study we have made use of Extended Polystyrene (EPS) beads, a material which is in the form of small round balls which otherwise creates a big problem as to where it has to be stored or managed. Because of its non-bio degradable characteristics it can't be wasted naturally, so we make use in our experiment as a solution to the above problem. In this analysis, EPS beads are partially replaced in the concrete where it does not have structural importance. From our history the knowledge we have is that Port of Cosa built around 273 BC is the first light weight concrete (LWC).

II. LITERATURE REVIEW

1.Ismail,LatifSaleh, et al. (2003)conductedastudytowhere they determined the hardened concrete properties of bricks containing. A total of five different specimens were created andthey named it as PC, P1, P2, P3, and P4 respectively in order. The researchers after thorough investigation mentioned that workabilitycharacteristicsofthe all themixesaredifferent fromthat of thenormalconcrete. Vibration or rodding was not effective as the mixes were cohesive. They concluded that the mix named P2 with compressive strength of 14 N/mm2 is most applicablefor internal walls ofload bearing type, mixes P3 and P4 can be used as non-load bearing typefalse walls.Potential use of polystyreneconcrete bricks can bedone here is the final inference.

2.Delsye C. L. Teo1, Md. Abdul Mannan,et al. (2010),did an investigation on the flexural behaviour of reinforced concrete beams that are produced from oil palm shell (OPS) aggregates. Natural resource conservation and disposal of solid wastes are the advantages they found by utilizing OPS in concrete production. The test procedure consisted of taking 6 reinforced beams with varying ratios of 0.52% to 3.90%. The main data noted include the ductility indices, end-rotations, cracking behaviour and deflection characteristics. From the experiments conducted the results showed that the flexural behaviour other lightweight concretes of reinforced was comparable to that of OPS concrete beams. The ductility behaviour of OPS concrete beams was also good. Finally, it was noted that with a minimum warning of failure, all beams exhibited a good rate of deflection.

3. Jamal Khatib, Adrian Jefimuk, et al. (2011), This research mainly dealt with reinforced concrete beams which consists of expanded glass as a partial fine aggregate and finding out their flexural properties. To further go deep into the experiment, they took four concrete mixes. In the increasing volume of 0%, 25%, 50% and 100% of expanded glass they replaced the fine aggregate. From the results they obtained, it was found that replacement of fine aggregate with 50% expanded glass suggest that the incorporation of 50% expanded glass increased the workability of the concrete. On the

other hand, as the amount of expanded glass kept on increasing, the compressive strength was decreasing simultaneously. Another advantage was that increasing the amount of expanded glass, the ductility of the concrete beam also increased. It was also found that the load at which first crack occurred on the beam was decreased linearly. The study was finally concluded that using of expanded glass in concrete is allowed but the only problem seen was that, as the expanded glass content increased the compressive strength decreased.

4. **Ade S. Wahyuni2 and Hamid Nikraz, et al. (2012),**this investigation is mainly based on how to reduce the weight of a structure by keeping in mind that there is no effect on its strength. Here by using lightweight concrete as a material which can be used as infill has been developed to create a lightweight sandwich reinforced concrete section. They found similar results for solid beam and LSRC beams on the basis of its flexural capacity. Due to the low compressive strength of the material which is used as infill, there was a significant decrease in shear capacity of the LSRC beams. By conducting the shear tests, it was also the shear capacity of equivalent solid beam was higher than that of LSRC beam. From the design point of view, the reduction in shear capacity was found to be 22%. From this study the authors concluded that the flexural capacity of solid beam is actually less than that of two LSRC beams. The main reason for this result was due to the fact that the self-weight of tested beam was reduced slightly by about 10% to 20% of the corresponding solid beam.

5. **M A Mansur2 and K H Kong, et al. (2013),** here the study is conducted to obtain the flexural capacity response of LWAC beams. Here a total of 11 beams are designed to check various factors like crack width, stiffness and deflection. They came to a result that LWAC beams with a density of 1850 kg/m3 used in this study shows similar characteristics as that of NWC beams. The results obtained here gives the building authorities a courage to use LWAC beams to use in the construction considering its potential advantage.

6. **Dr. Amrutha Kulkarni, et al. (2014),** here they present the observations of Expanded polystyrene which is partially replaced with coarse aggregate. It was stated that due to huge difference in densities (1680 kg/m3) EPS has not given the expected results although there was a replacement of 5%,10% and 15% of coarse aggregates. The author finally concludes in this study that this type. of concrete which is used in the study can be used as separation walls or for cladding of walls.

7. **Shahrul Moza Nikhatar, Ismail Mat, et al. (2016),**in this study they deal with using infill material as foamed concrete for reinforced concrete. Here there is advantage forcomposite-based-concrete-structure due to its lightweight which was initially produced by joining of normal concrete with foamed concrete. This study also shows a method of saving the material retaining its strength

and specimen properties. Final result here was found that the reinforced concrete was subjected to ultimate load as compared to foamed concrete but the deflection of the beam was lying well within the certain limit.

8. **Muhammad U. Rashid, et al. (2017),**here the author discusses about testing under four-point loading of lightweight concrete beams by keeping them as simply supported beams. Due to the presence of weak lightweight aggregates used, LWC beam found a low modulus of rupture. The study aims at providing some toughness characteristics using DSSF. According to certain properties like ultimate deflection,flexural strength, stiffness, energy absorption these beams were evaluated.It was found that due to the presence of holes in LWC beams, its water absorption is very high. It was concluded that there would be a chance of internal cracking in LWC due to more contact zone and less spacing between the aggregate and the paste, and due to the availability of more water in the pores of aggregates.

9. **Ari Wibowo, Indradi Wijatmikon et al. (2017),**in this study the author tries to replace steel which is a regular member inside the reinforced concrete with bamboo. The main aim here was to obtain weightless and eco-friendly concrete by using bamboo bars inside the reinforcement instead of steel and along with the mixture of EPS beads as a material which is used as infill. The results obtained was that there was a reduction in weight of about 27% by using bamboo bars instead of steel, but there was a decrease of flexural strength of about 6%. showed that the flexural strength decreased marginally of about 6%. The main idea promoted here is that of sustainable development which has become most important in a century where there is no importance given to conserve natural resources. This is the importance of using bamboo as main material instead of steel inside the reinforcement.

10. **Arpit Sharma, et al. (2017)**, here the studied is carried out which discusses about obtaining a lighter concrete by replacing of traditional aggregates are replaced by light weight aggregates. Comparing standard cement concrete with lightweight concrete was done by using different amounts of materials like aggregates and certain other materials. By using different quantities of lightweight aggregates and pumice stones three lightweight mixtures were made. From the results they obtained it was discovered that aggregate such as pumice stone would produce a good strength concrete. It was also clearly mentioned that there would be a lightweight concrete developed due to the reduction of heavy dead load but it affects the strength of the concrete compared to the normal weight concrete. These can also be used as separation walls.

11. **J. Durga Chaitanya Kumar, et al. (2018),** In this paper, there is a complete comparison of

performance of normal weight concrete (NWC) beam with that of fiber reinforced concrete (FRC) beams which is obtained using certain fibers inside the concrete and lightweight aggregate concrete (LWAC). Here they are replacing coarse aggregate with an amount of 10% and 50% by inserting pumice and palm oil shell which are lightweight aggregate. Here 0.5% and 3% of concrete of fibers are used by volume.It was inferred that the surface hardness has increased very much on adding glass fibers and steel.

12. Danson Tan Tzet Lung, Ling Jen Hua, et al. (2020), in this study different alignments of polystyrene beads are combined together with the reinforced concrete with an aim to find out the flexural behaviour. This study was important because knowing the flexural behaviour of concrete would help in reducing the dead load. Under a static load polystyrene block combined with reinforced concrete was kept and flexural behaviour was learned. Polystyrene blocks of different alignments were tested. In order to finally obtain the efficiency of the specimen the ultimate load which is obtained per unit volume of concrete is calculated.

OBJECTIVES

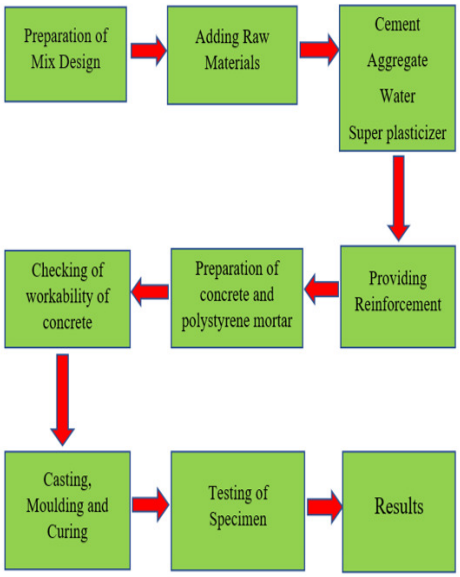
1) To determine the tensile strength of concrete beams, the flexural behaviour is checked.

2)Properties like compressive strength, creep is determined by finding out the mechanical properties of EPS.

3)To reduce the weight of a structure.

METHODOLOGY

The basic methodology and the steps carried out in our experiments mentioned below.



III. BASIC TESTS CONDUCTED

In this experiment we have made use of OPC 53 grade cement is used. It is one of the binding materials that is used in the mix. As per IS-12263:1987 basic properties for cement are tested and tabulated below. Some of the tests conducted during the process of experiments are as follows:

1) SPECIFICGRAVITYTESTONCEMENT
2) NORMAL CONSISTENCY OF CEMENT
3) INITIAL AND FINAL SETTING TIME OF CEMENT
4) SPECIFIC GRAVITY AND WATER ABSORPTION OFGIVENCOARSE AGGREGATE
5) SPECIFICGRAVITYOFFINEAGGREGATES

6) SEIVE ANALYSIS AND FINENESS MODULUS OF GIVEN FINE AGGREGATES:

EXPERIMENTAL DETAILS

Our experiment was carried out in three stages. Stage 1 was to determine workability of the concrete so we have done mix design for M25 grade concrete. Stage II involved works like casting and curing of hardened concrete. Stage III involved the testing of specimens.

STAGE 1:

CONCRETE MIX DESIGN

Before the concrete mix design was carried out the basic materials like coarse aggregate, fine aggregate, cement was obtained from the work site which was going on in our college. Next, we collected polystyrene beads from the and superplasticizers from the shop. The collected materials were tested first and then used in our experiment. The design mix for the materials was done according to IS456:2000 and IS 10262: 2009.

WORKABILITYTEST

On conducting the workability test such as slump test, it definitely helped us to arrive to a particular water-cement ratio. In order to obtain a slump for conventional concrete of 0-20mm and for polystyrene concrete of 130-150mm, the water-cement ratio obtained was 0.45 whereas the content of admixture was found to be 0.45%.

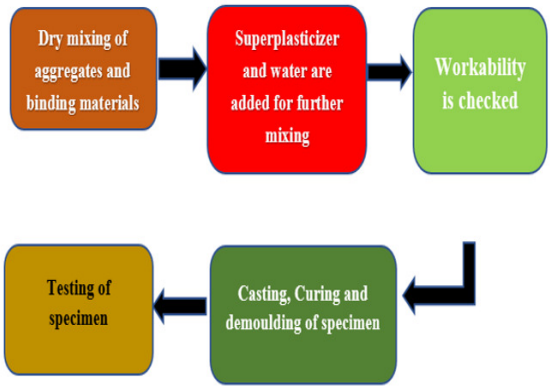
SLUMPTEST

In order to measure the consistency of the fresh concrete we will do slump test. In this test we will make use of an equipment called as slump cone where its base width is 20cm, height is 30 cm and top distance is 10cm.We have conducted slump test for both the normal concrete and polystyrene concrete. There are three types of slump namely True slump. Shear slump and Collapse slump.

STAGEII:

MIXPROCEDURE,CASTINGANDCURINGOFSPECIMENS

The detailed process of mix procedure, casting of all the 12 beams including 4 normal beams,4 beams with 25% addition of EPS beads and 4 beams with 50% addition of EPS beads and the curing of these beams are shown below:



PROCEDUREFORMIXINGANDPLACING:

Here we have done many trails, mixed and placed a conventional concrete and polystyrene concrete (full and half inside the reinforcement). These beams werecasted at firstand thentestedforthesetsofevery28 days. For polystyrene

concrete coarse agg is replaced by polystyrene beads within reinforcement.

Dimensionofbeam=150mm*150mm*700mm

Dimension of reinforcement cage=110mm * 110mm *660mm

STAGE III

FLEXURAL STRENGTH TEST OF BEAMS

Once the beams are cured. Then the first test carried out is flexural strength test of beams which is done under two-point loading. This test is actually done so as to find out the tensile strength of beams. These tests can be carried out either by central point loading or two-point loading. In our experiment we are doing two-point loading.

Brief procedure of flexural strength test is given below:

- As the beams casted are cured, after 28 days these are taken for testing.
- This testing is carried out in a machine called as universal testing machine (UTM).
- First the testing points are marked on the specimen and then the beams are placed correctly on the machine.
- The base of the testing machine will have two steel rollers provided which will be 38mm in diameter.
- For 150mm specimen which we are using we will keep the steel rollers at a distance of 600mm from each other.
- Next slowly the load is applied at a rate of 400kg/min and the measurements were noted.
- The load at which the first crack and the deflection developed is noted down.
- The distance between the points at which crack is developed and the nearest support is noted down.
- Flexural strength of beam was calculated by applying the formula.

I V. TEST RESULTS

The test was conducted on three types of beams

- Normal beams
- Beams with concrete replaced with 25% polystyrene beads
- Beams with concrete replaced with 50% polystyrene beads

The results obtained is mentioned in the form of Load vs Deflection graph. Three types of beams have their own ultimate load where they failed. From the ultimate load obtained we have calculated the flexural strength.

Flexural strength is calculated by the formula:

$$F= \frac{P \times L}{b \times d \times d}$$

Where F= flexural strength of concrete in Mpa

P=failure load in N

L=length of beam

b=breadth of beam

d=depth of beam

TABLE I
LOAD VS DEFLECTION

Load (KN)	Deflection(mm)		
	Normal beam	Beams with addition of 25% EPS beads	Beams with addition of 50% EPS beads
10	0.060	0.089	0.092
20	0.090	0.54	0.68
30	0.12	0.98	1.12
40	0.15	1.35	1.72
50	0.30	1,87	2.37
60	0.52	2.42	3.54
70	0.63	3.29	4.74
80	1.09	4.51	5.81
90	1.32	5.11	6.74
100	1.72	5.24	8.90
110	1.98	5.98	
120	2.34	6.24	
130	2.57		
140	2.88		
150	3.24		
160	3.71		
170	4.05		

Calculations:

Length of beam (L) = 700mm

Breadth of beam(B) = 150mm

Depth of beam(d) = 150mm

From the table we have:

1)For Normal Beam

- Ultimate load (P)= 180KN

$$F=\frac{P\times L}{b\times d\times d}=\frac{180\times 1000\times 700}{150\times 150\times 150}=37.3\ \text{Mpa}$$

2) For beams with 25% addition of EPS beads

- Ultimate load (P)= 130KN

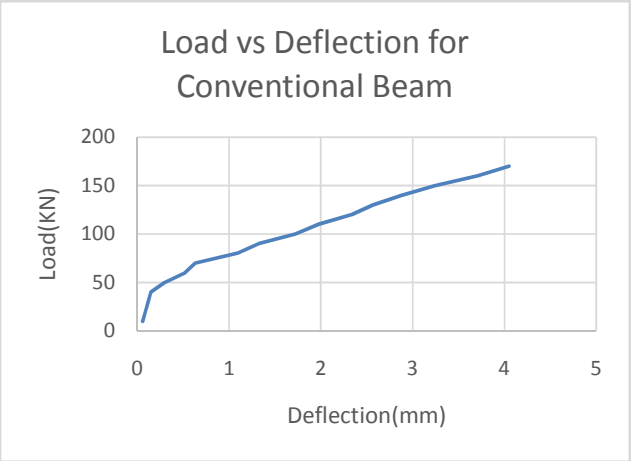
$$F=\frac{P\times L}{b\times d\times d}=\frac{130\times 1000\times 700}{150\times 150\times 150}=26.9\ \text{Mpa}$$

3) For beams with 50% addition of EPS beads

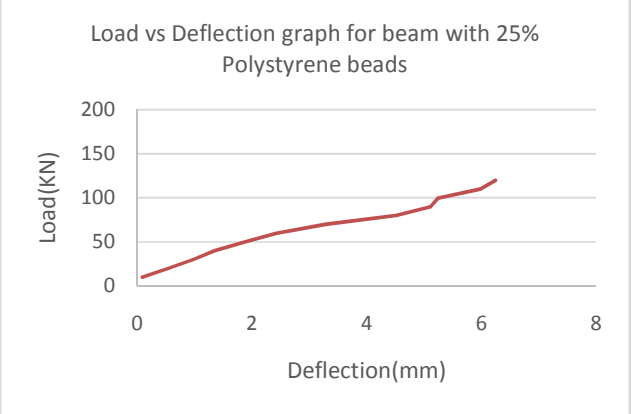
- Ultimate load (P)= 110KN

$$F=\frac{P\times L}{b\times d\times d}=\frac{110\times 1000\times 700}{150\times 150\times 150}=22.8\ \text{Mpa}$$

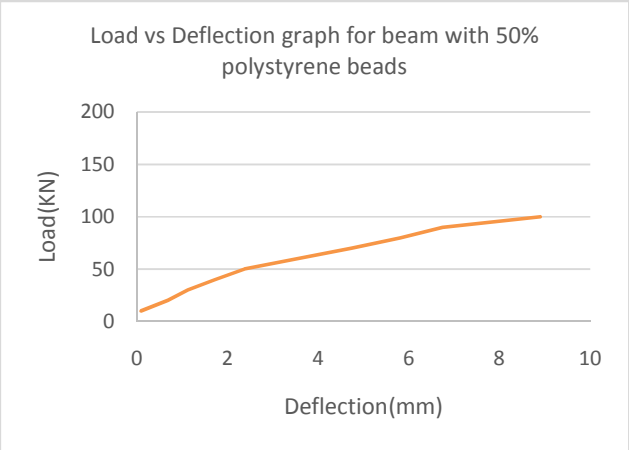
GRAPH 1
LOAD VS DEFLECTION GRAPH FOR CONVENTIONAL BEAM



GRAPH 2
LOAD VS DEFLECTION GRAPH FOR BEAMS WITH 25% POLYSTYRENE BEADS



GRAPH 3
LOAD VS DEFLECTION GRAPH FOR BEAMS WITH 50% POLTSTYRENE BEADS



V. CONCLUSIONS

This paper has presented the use of lightweight concrete inside the reinforcement so as toreduce the weight of the overall structure. Various materials like expanded glass, traditionalaggregates, palm oil shell has been used in different experiments as a replacement for coarseaggregate partially, thereby aiming to reduce the self-weight of the structure and keeping inmindthattheoverallperformanceofthestructureshouldnotgetaffected.Followingconclusionsaremade from theabovestudies

1. Expanded polystyrene beads are advantageous as lightweight concrete. It mainlyreduces the dead load, self-weight and mainly improvises the thermal insulatingproperty of a structure. Polystyrene being top second non – biodegradable waste nexttoplastic, usingpolystyrenein constructionhelpsapartofwaste management.
2. The compressive strength was decreasing linearly with the increasing amount ofexpandedglassand alsotheductilityof theconcretebeam hasalso improved.
3. Using oil palm shells in the production of concrete not only solves the problem ofdisposing the waste which is coming from the palm shell and also helps to conservenaturalresources.
4. Bytheusageoflightweightconcrete,thedeadloadsproducedbytheconcretereducesonthestructureandhenceithelpsinsavingthecostsinfoundationsandreinforcement.

RESEARCHNEEDS

Inthepresentcenturythereisawideuseofconcreteformakingthestructuresandmostofthestructures carry heavy loads. In our experiment we have tried to reduce the self-weight of thestructurebyusingexpandedpolystyrenebeadsasa partialreplacementinsidethereinforcement.Manycomparisonsaremadebetweennormalconcreteandlightweightconcrete.

ACKNOWLEDGEMENT

We wish to acknowledge the contribution of authors of the papers referred in this review and for their impact in the former's research

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