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EXPERIMENTAL INVESTIGATION OF LIGHT WEIGHT CONCRETE (LWC) USING PUMICE AND EXPANDED POLYSTYRENE BEADS (EPS)

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Abstract

It is very significant to mention about Light Weight Concrete (LWC) which is very popularly used in in multi-story building frames, shell roofs, prestressed or precast elements because of its light weight or lower dead load compared to normal concrete. Because of other reasons such as high cost, lack of proper standards, etc., it is less popular in practice. This research work analyses and presents the best experimental study of preparation of LWC in different proportions (50%, 60% & 70%) with the mixture of pumice and Expanded Polystyrene Beads (EPS) to provide the best results. This research work aims at producing LWC of density 1850 kg/m^3 and compressive strength of greater than 20 MPa. Partial replacement of pumice in place of coarse aggregates and partial replacement of EPS beads in place of fine aggregates is the essence of the experimentation here. Compressive, flexural, and tensile strengths, among other mechanical attributes were calculated based on the experiments carried out. It is satisfying that the LWC can be prepared at 60% replacement of pumice and EPS beads in providing the expected density of 1850 kg/m^3 and strength. Therefore, it is concluded that challenges in producing LWC having adequate density and strength parameters can be overcome by new materials used such as pumice and EPS beads.

Introduction

For any type of infrastructure to be erected, concrete is an important component which can erect a huge development in the form of multi storey buildings and skyscrapers. Concrete, which we use every day, has always been a fragile material that breaks when subjected to tensile stress. Due to continuous usage of concrete, several studies have revealed that huge amount of cement, aggregates have been used posing heavy threat to the society. Recently there has been number of alternative researches carried out to replace the conventional concrete or to replace the cement material by adding different other materials and wastes available in the society. Owing to the number of attempts made in the recent past, several number of alternative concrete studies have piled up showing fruitful results.

Some of the important materials used in the past varies from plastics, PET, granulated slag, fly ash, GGBS, etc., Using different available materials and waste products, some of the newly created concrete paves the way for modern construction industries. One such type of concrete is

Light Weight Concrete (LWC). Proper guidelines are not set in the Indian standards and very less amount of work related LWC is conducted in India. Moreover, previous researches carried out in LWC focussed on producing light weight concrete whose density has to be less than 1850 kg/m^3 the reason being, i It is highly effective at lowering the structure's dead load. From the earlier results, it becomes very challenging to prepare LWC with certain criteria. This study is an attempt to work on the challenging area to assess the LWC with partial replacement of fine as well as coarse aggregates. Hence it is very important to analyse the need and identify the utilisation of such type of concrete in India. The objective of this investigation is to establish the mechanical properties of light-weight aggregate concrete. For the present research work, LWC is prepared using pumice and EPS beads.

Light Weight Concrete

LWC has a different density range than regular concrete as 1600 to 1900 kg/m^3. It is identified that for the usage in large structures, the strength of the concrete should be greater than 17.0 MPa. Significantly, light weight aggregates are used for the preparation of LWC. The aggregates varies from shale, clay or slate, pumice materials from different kilns. Some of the other materials used are air-cooled blast furnace slag, hematite, etc., Some of the important studies related to LWC are highlighted because of its advantages in the construction industry. Domagala (2020) insisted its limited use because of the high water absorption, high cost and various other parameters while designing and execution of LWC. ACI Committee (2013) mentions the role of aggregate size and the relationship with its strength parameters. The aggregates which were used in the studies related to LWC are light weight which is entirely a new material. The density of such aggregate is very lower than the normal concrete. Some of the advantages are it has fire resistance, thermal conductivity and it can be casted easily.

Materials

For the present study, in order to produce light weight concrete, Pumice is used as an interim replacement for coarse aggregate, and Expanded Polystyrene Beads (EPS) are used as a partial substitution for fine aggregate. Some of the important studies carried out by the researchers using pumice and EPS beads are reviewed and highlighted for reference.

Pumice Stone

It is a naturally occurring light weight aggregate that resembles a sponge that is created when molten lava cools and solidifies quickly. These are lightweight materials which are tried and tested to add for the preparation of different types of concrete. It can be used as an aggregate in lightweight concrete or as a cementitious material in blended cement or geopolymer after proper preparation. Many studies highlighted the properties of pumice light weight aggregate concrete. Some works indicated that pumice lightweight aggregate concretes can satisfy the requirements of lightweight structural concretes. Higher compressive strengths were also achieved by using pumice stones.

Initial studies were carried out by Muralitharan and Ramasamy, 2015 and suggested that the investigation of mechanical properties can be ascertained of pumice LWC. For their study, it was used as a coarse aggregate and the preparation of LWC was continued and different properties were tested at various stages of curing. Eventually, it was determined that the compressive strength was nearly equal to that of the typical aggregate. Further, it is confirmed that it can be used for light weight structures.

Further, Suba Lakshmi et al., 2017 used the LWC which includes pumice aggregate. Coarse aggregate was replaced with the thought of reducing the self-weight of the building. Compressive strength and split tensile strength was determined for the LWC having less density for various replacements of pumice aggregates and tested for 7 and 28 days. It is experimentally verified that beyond 50% of addition of pumice aggregate would reduce the strength of the building.

Pumice stones were used in the study of Devi Pravallika and Venkateswara Rao, 2016 to identify the strength and durability properties of M40 concrete by replacing coarse aggregates by pumice stones. Strength was identified to be better compared to normal concrete and relatively light weight on the structures.

Expanded Polystyrene (EPS)

It is a material that is widely available and has some distinguishing properties such as very low density, high impact absorption capacity, low thermal coefficient, insignificant water absorption capacity, and so on. These are lightweight materials which helps in reducing the overall weight of the structure. Some of the important characteristics of EPS is that it has 98% air and 2% polystyrene and are fine circular shaped particles.

Rosca (2021), in his study developed LWC embedding both recycled brick and polystyrene beads as coarse aggregates. Investigation of the LWC showed the density and compressive strength varied positively. For each replacement percentage of natural aggregate by EPS beads, it has been found that when recycled brick particles replace the coarse aggregate, the resulted concrete is lighter with 200 kg/m^3 and has a strength very close to concrete made entirely with natural aggregate.

Moon et al., 2020 examined the relationship between the compressive strength of conventional concrete and LWC that contains 30% fly ash and EPS. Studies carried out for the cubes consisting of 5%, 10%, 15%, 20%, 25% and 30% EPS. Results show that 5% EPS provided the high compressive strength.

In addition to pumice stones and EPS beads, nano silica is used which could enhance the strength parameters. Super plasticizer is used for enhanced workability.

Experimental Procedure

To investigate the various properties of LWC, concrete cubes with dimensions that measured 150 x 150 x 150 mm, cylinders with a diameter of 150 mm and a height of 300 mm, and beams with dimensions of 100 x 100 x 500 mm were cast. In the previous section, different materials used in the experiments and their research importance are explained through some literature papers. It is important to note the size of pumice stones and EPS beads in the range of 2-8 mm so as to occupy the gap between coarse aggregate, which suits the logic of gap graded aggregates. Batching was done by volume.

Figure 1 Materials used in the present research (Pumice stones and EPS beads)

Mix Proportioning

The mix design for LWC slightly differs from normal concrete when light weight aggregates are used. Different proportions were planned to measure for which proportioning of LWC which should consider the properties such as strength, density and durability. Detailed analysis and considerations are also to be thoroughly studied to have proper preparation of LWC. It is important to have proper mix proportioning as it will have good workability in the preparation of LWC. It is measured by carrying out the slump test to determine the fresh concrete's consistency. Slump cone test is done in compliance with IS:1199-1959.

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In using LWC for our study, there are various guidelines of when and how to use these light weight aggregates. Some brief information can be seen below:

During the mix design, water added to the light weight aggregate should always disclose water added to the concrete (Bogas et al., 2012). An important observation to be noted in the LWC is the high absorption rate by the light weight aggregates. It should be taken into consideration while mix design is done (Sveindottir et al., 1997). The water cement ratio was set at 0.45 for each mix. Soaking of light weight aggregate is important and done as per the procedure. All the other ingredients were rightly mixed for the preparation of LWC.

Test results and discussions

Compressive Strength

It is an indication of its resistance to static load, which has the tendency to crush it. Compressive strength tests are the most often used tests on hardened concrete.

The equipment used for finding the compressive strength is compression testing machine and the procedure for finding the value is summarized below. The test procedure was in accordance to IS: 516 - 1959.

Concrete's compressive strength was calculated using standard 150 mm x 150 mm x 150 mm cubes. Adequate number of specimens were casted with 60% of replacement of pumice aggregate (in partial replacement of coarse aggregates) and EPS beads (in partial replacement of fine aggregates). Procedure is not much varied for the preparation of LWC. All the specimens after casting, it is kept for 24 hrs and then it is demoulded. It is then placed in curing tank and then taken out for different tests. Figures 1 and 2 shows the preparation of cubes with the suitable proportions for the preparation of LWC.

Figure 2 Preparation of moulds for determining compressive strength

Table 1 Compressive strength values for Conventional Concrete and LWC

Cube	Density & Compressive Strength of Conventional Concrete				Density & Compressive Strength of LWC			
	Density (kg/m^3)	7 days (N/mm^2)	28 days (N/mm^2)	90 days (N/mm^2)	Density (kg/m^3)	7 days (N/mm^2)	28 days (N/mm^2)	90 days (N/mm^2)
1	2563	44.34	58.51	61.36	1807	11.63	22.97	25.25
2	2603	41.63	54.57	58.18	1793	11.03	21.91	23.83
3	2535	42.32	56.62	58.47	1785	13.25	24.97	26.36
Ave	**2567**	**42.76**	**56.56**	**59.33**	**1795**	**11.97**	**23.95**	**25.14**

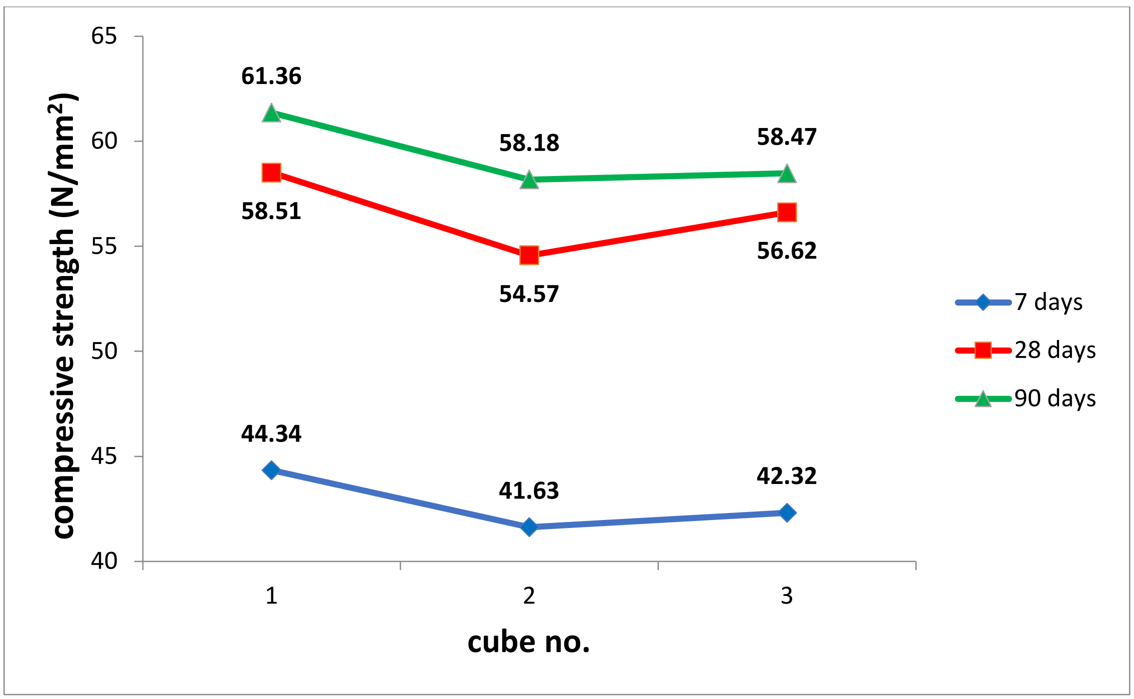

Figure 3. Compressive Strength results for Conventional Concrete

Figure 3 illustrates the compressive strength of conventional concrete for 7, 28 and 90 days for different cubes. As can be observed, the strength in compression is increasing. In the case of LWC, it is tested for 7, 28 and 90 days to know the actual strength it is gaining. It is very important to note that we were targeting for more than 20 N/mm^2 along with the density of not more than 1800 Kg/m^3.

Figure 4 shows the compressive strength of LWC. In such case also, in each of the cube, as number of days increased, compressive strength is also getting increased and gives a hope on the usage of LWC.

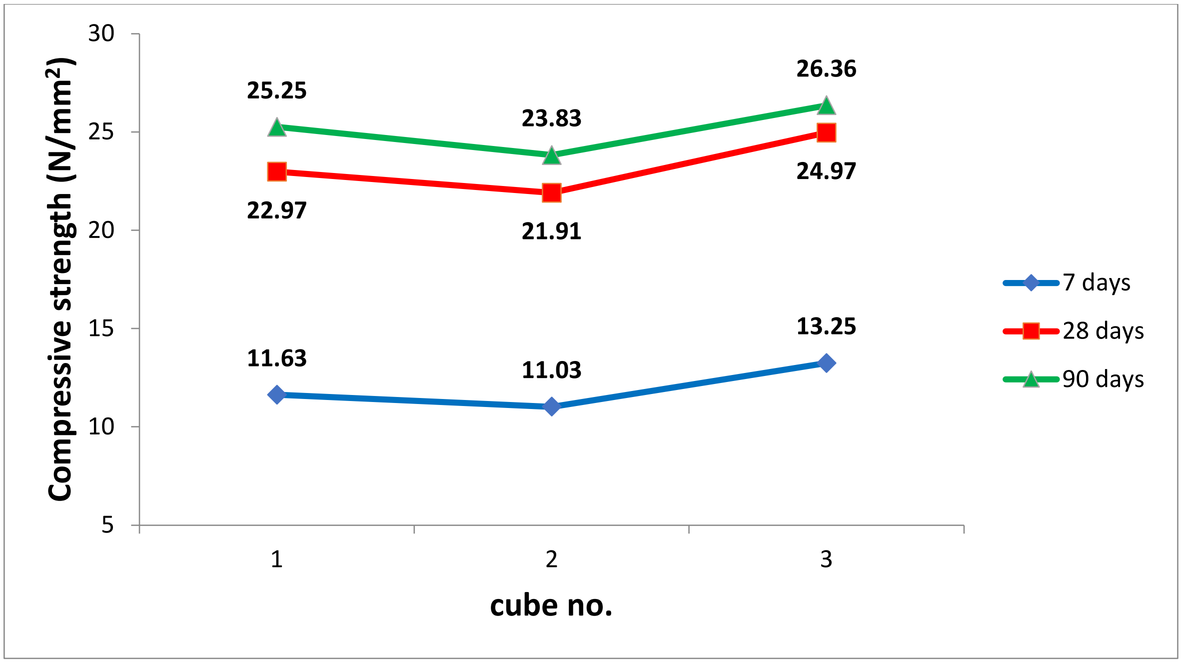

Figure 4. Compressive Strength results of 60% mix of LWC

Out of all the trials, 50%, 60% and 70%, only the important result of 60% mix is provided for compressive, flexural and split tensile strength. It is very conclusive that LWC provides better results and necessary density. Hereafter all the other tests will only be conducted for 60% mix and hereby all the future notions will be mentioned as LWC.

Flexural Strength Test

Concrete's flexural strength was determined using a size-specific beam, 100 mm x 100 mm x 500 mm. Flexural strength is a definite amount of a concrete of its ability to resist bending. The beams are subjected to bending and the test is performed to find the increase or decrease in the strength when the mixture of pumice and EPS beads were added. It is very crucial as it will evaluate the quantity of materials added in LWC. It was planned in such a way that the test on flexural strength was done for the concrete for 7, 28 and 90 days for the case of LWC and the results are tabulated below in Table 2.

Table 2. Flexural strength test results for Conventional Concrete and LWC

Beam	Flexural Strength of Conventional concrete			Flexural Strength of LWC		
	7 days (N/mm^2)	28 days (N/mm^2)	90 days (N/mm^2)	7 days (N/mm^2)	28 days (N/mm^2)	90 days (N/mm^2)
1	3.14	4.32	4.46	2.09	2.78	3.14
2	4.15	5.18	5.32	1.68	2.23	2.66

3	3.21	4.69	4.88	1.72	2.59	3.03
Ave	**3.5**	**4.73**	**4.88**	**1.83**	**2.53**	**2.94**

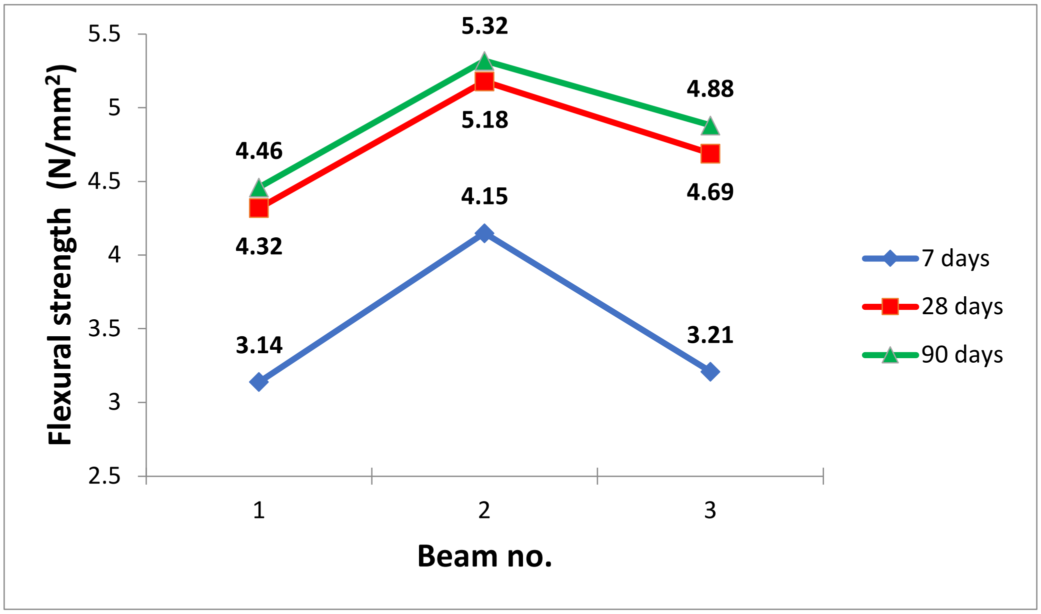

Figure 5. Flexural Strength results of Conventional Concrete

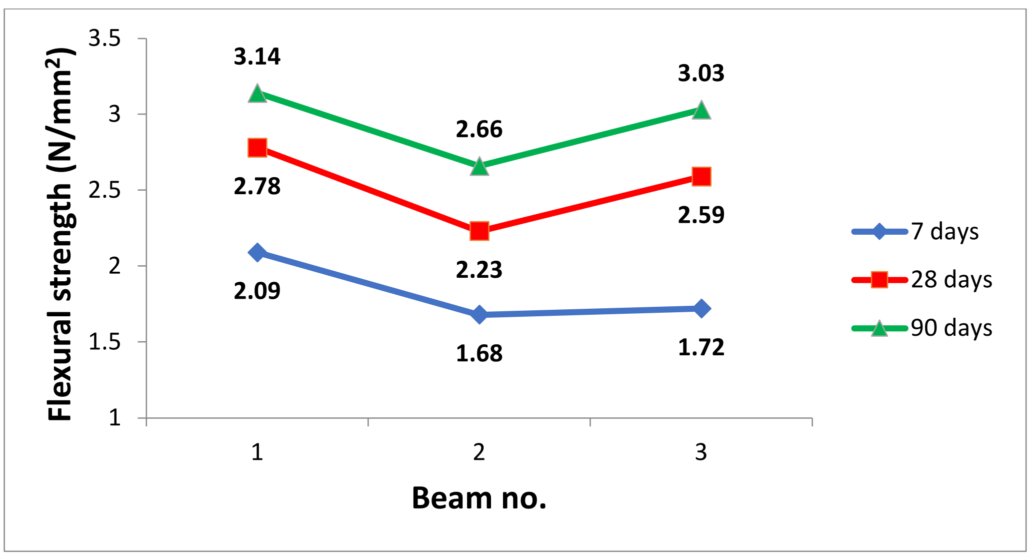

Figure 6. Flexural Strength test results of LWC

The test procedure was performed in accordance with IS: 516- 1959. Universal Testing Machine was used to determine the flexural strength test.

Figure 5 and 6 shows the comparative graphs of flexural strength of conventional concrete and LWC. There seems to be gradual increase of flexural strength in all the cases of beams tested.

It was tested for 7, 28 and 90 days for conventional concrete and LWC. It seems minor changes in increase and decrease of flexural strength of LWC.

Split Tensile Strength

Split tensile strength of concrete was found out using cylinder of size 100 mm diameter and 200 mm height. Split tensile test was also conducted through Universal Testing machine. Different cylinders were cast to determine the split tensile test. Here in the present analysis, the category belonging the addition of 60% of pumice and EPS beads are shown for reference. Table 3 represents the combined value of split tensile strength of conventional concrete and LWC. Figure 3 shows the split tensile strength carried out on a sample.

Table 3. Split Tensile strength test values for Conventional Concrete and LWC

Cylinder	Split Tensile Strength of Conventional concrete			Split Tensile Strength of LWC		
	7 days (N/mm^2)	28 days (N/mm^2)	90 days (N/mm^2)	7 days (N/mm^2)	28 days (N/mm^2)	90 days (N/mm^2)
1	2.34	3.4	3.54	1.01	1.44	1.75
2	2.15	3.8	3.88	1.23	1.98	2.26
3	2.96	4.1	4.3	1.44	1.92	2.12
Ave	**2.48**	**3.77**	**3.9**	**1.23**	**1.78**	**2.04**

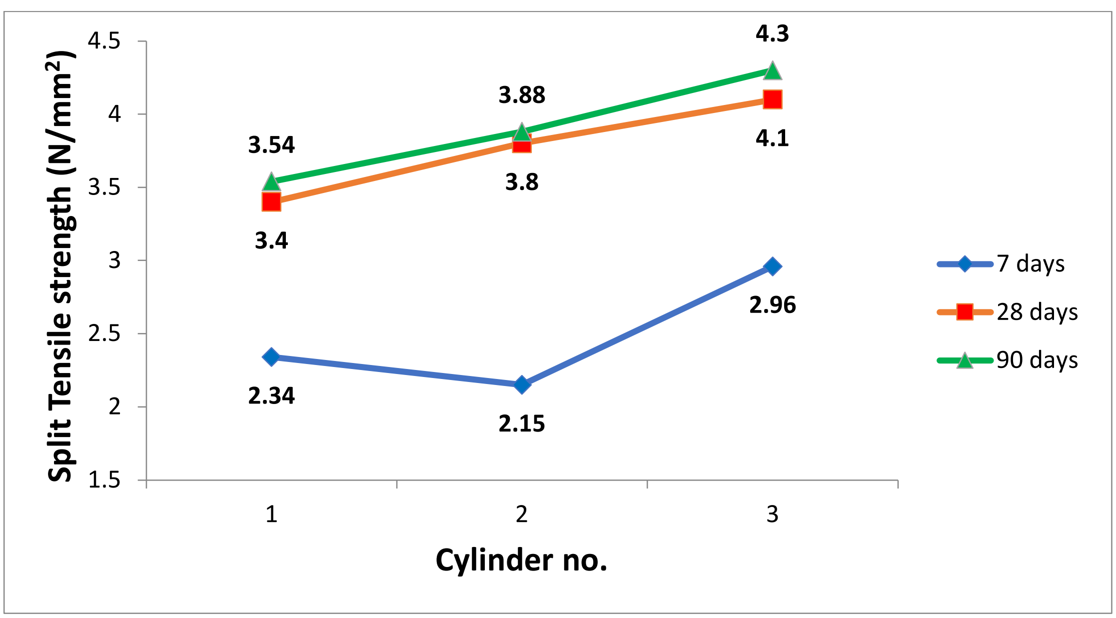

Figure 7. Split Tensile Strength results of Conventional Concrete

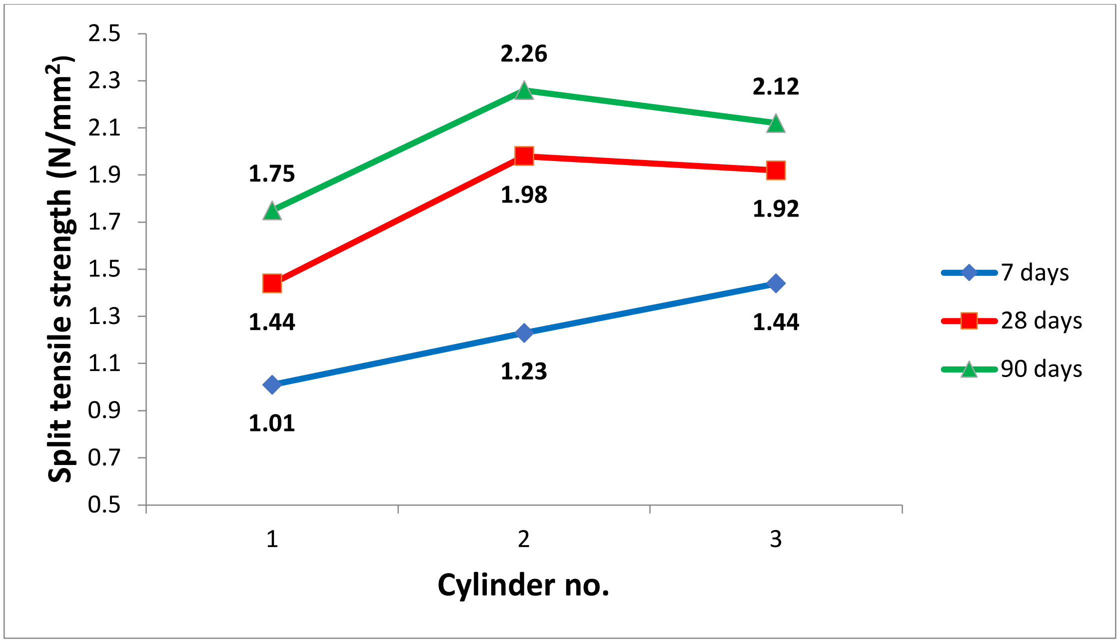

Figure 8. Split Tensile Strength test results for LWC

It is observed from Table 3 and Figures 7 and 8 of split tensile strength, that the results of conventional concrete as well as LWC (addition of 60% pumice and 60% of EPS beads) is seen to increase w.r.t increasing number of days i.e 7, 28 and 90 days. Similar observations were found in LWC. As the number of days were increased, in all the cylinders, split tensile strength was found to increase for LWC.

Figure 9. Performance of split tensile test

Conclusions

The study's conclusions include the following:

- It is important to note that as a trial and error method, it was experimented with 50%, 60% and 70% of pumice and EPS beads and concluded that 60% mix of LWC provides the necessary density and strength required for LWC.
- Compressive strength for conventional concrete and 60% mix of LWC were done. Through observations, the strength of conventional concrete increases as usual. Similarly, gradual increase is seen in the results in 60% mix of LWC but not comparable with conventional concrete.
- Similarly flexural and split tensile strength also gradually increased for 60% mix of LWC.
- It is concluded that LWC can be prepared for the challenging density and strength. In our case, The range of LWC density is 1750–1800 kg/m3. and strength of about 24 N/mm^2.
- Since several studies mention about the high absorption capacity of light weight aggregates, it should be noted that adequate processes to be done before the preparation of LWC.
- When the voids are packed heavily it may lose its light weighing property and becomes heavy for the structure.
- As coarser aggregates are reduced in the mix, compressive strength increases. So, if curing gets more number of days, the compressive strength can be increased but not as effective as conventional concrete.
- Although split tensile strength is increasing, its rate of rise is different from compressive strength's.

On the whole, the present study elaborates the need to quantify the addition of pumice and EPS beads to be added for the preparation of LWC. Based on the present test results in compressive strength, Flexural strength and split tensile strength, it is very clear that all the quantity of conventional aggregates cannot be replaced with Light weight aggregates. Nevertheless more investigation is necessary to confirm the beneficial effects of other traits.

References

ACI Committee 213. (2003). Guide for structural lightweight-aggregate concrete. American Concrete Institute.

Bogas, J.A., Gomes, A., Gomes, M.G. (2012). Estimation of water absorbed by expanding clay aggregates during structural lightweight concrete production. *Mater. Struct.45*, 1565–1576.

Devi Pravallika, B., Venkateswara Rao, K. (2016). The Study on Strength Properties of Lightweight Concrete using Lightweight Aggregate, *International Journal of Science and Research*, Volume 5, Issue – 6,1735 – 1739.

Domagała,L.(2020).SizeEffectincompressivestrengthtestsofcoredspecimensoflightweight aggregate concrete. *Materials*, 13(5), 1187.

Moon, A.S., Selokar, L.S., Patle, A.I., Bhoyar, D.S., Kowale, S.D., Quaz, S.S. (2020). Light weight concrete by using EPS beads. International Research Journal of Engineering and Technology, 7(7), 2345-2351.

Muralitharan, R. S.., Ramasamy, V. (2015). Basic Properties of Pumice Aggregate, *Int. J. Earth Sci. Eng.* 8 (4) (2015) 256–258.

Rosca, B (2021). Comparative aspects regarding a novel lightweight concrete of structural grade containing brick aggregate as coarse particles and expanded polystyrene beads, *Materials Today: Proceedings*, 45(6), 4979-4986.

Suba Lakshmi, A., Karthick, S., Gasper Helden,Dinesh Boopathi, M., Balaji Pandian., V. (2017). Experimental Investigation on Lightweight Concrete using Pumice Aggregate,*International Journal of Innovative and Emerging Research in Engineering*, Vol 4, 3, 176 – 183.

Sveindottir, E.L., Maage, M., Poot, S., Hansen, E.A.,Bennenk, H.W.,Helland, S., Norden, G., Kwint, E.,Milencovic, A.,Smeplass, S. (1997). Light Weight Aggregates-Datasheets. *BriteEuramProj. Euro Lightcon, 132*.