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COMPARATIVE STUDY OF DESTRUCTIVE AND NON-DESTRUCTIVE TEST ON LIGHTWEIGHT CONCRETE USING EXPANDED POLYSTYRENE

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Abstract:

One practical way to lessen the weight of big, massive structures in modern construction is to employ lightweight concrete. This technique substitutes lighter materials that yet offer high-strength construction components for conventional coarse aggregates. This study produced a concrete mix that retained the same volume as traditional dense concrete by substituting expanded polystyrene (EPS) beads for coarse particles. A water-to-cement ratio of 0.56 was maintained while 15% to 20% of the coarse aggregate was replaced with EPS beads to create the M20 grade mix. The specimens were cast with a normal 150 x 150 mm dimension.Density and compressive strength exhibit a strong correlation. Specifically, as density decreases, there is a noticeable decline in compressive strength. After 14 days, the material demonstrates a compressive strength of 16.29 MPa. The study examines density values ranging from 2340 to 2044 kg/m³, with corresponding compressive strength measurements after 28 days falling between 26.37 MPa and 17.77 MPa..Destructive tests revealed greater compressive strength than non-destructive tests, according to the data. When up to 15% of the coarse aggregate in the M20 mix was substituted with EPS beads, the greatest compressive strength was noted.

Introduction

In the modern construction industry, lightweight materials are the most crucial building components. Cement, sand (fine aggregate), coarse aggregate, and water are the primary ingredients of concrete. These days, technical developments are centre on sustainability, and concrete's qualities are being improved by partially replacing its basic materials. The need for concrete in the building sector has grown dramatically as a result of national development. Large amounts of concrete are currently needed to build a variety of structures, including flyovers, dams, bridges, and many more.

Normal concrete is frequently used in construction and has a density between 2200 and 2500 kg/m³. In order to emphasize sustainability, the use of ultralightweight materials—such as EPS beads—in concrete is being investigated. Standard specimens are used for both non-destructive testing (NDT) and destructive testing (DT). In order to comprehend the distinctions between lightweight concrete and regular concrete with aggregate partially replaced in regular concrete, the relationship between these characteristics will ultimately be examined and graphical representations will be produced.

The objective of the project:

- To compare the properties of concrete.
- To imply a connection between UPV, rebound hammer, and concrete's compressive strength.

Literature Review

The literature on the comparison of destructive and non-destructive testing on lightweight concrete using expanded polystyrene is discussed below:

1) Shanshan Shi, Nan Yuan, Rong Ma, Jinhong Yu, Tao Jiang, Ying Wang, Compressive behaviour of lightweight concrete with expanded polystyrene foams reinforced with aerogel, ELSEVIER, Accepted on October 10, 2022; Received on August 4, 2022; Concrete is changing as a result of the construction industry's ongoing evolution. Concrete that is both strong and lightweight is becoming more and more crucial.

2) Engineering Journal, volume 25, issue 8, Hendro Suseno, Ming Narto Wijaya, and Ananda Insan Firdausy, Correlation between Destructive and Non-destructive Characteristics of Pumice and Scoria Lightweight Concrete; Accepted August 2, 2021; Using Medium-K basaltic Andesitic pumice and scoria gathered from the Kelud Volcano, this study empirically correlates the destructive and non-destructive properties of structural lightweight concrete.

3) Comparison of destructive and non-destructive tests on concrete by Junaid Kameran Ahmad and Muhammad Tareq Shukri, Eurasian Journal of Science & Engineering, online publication, December 1, 2017. This study illustrates the drawbacks of assessing concrete's compressive strength using the ultrasonic pulse velocity test. Rebound hammer and ultrasonic pulse velocity (UPV) tests are used in tandem to evaluate the strength of concrete in more dependable buildings.

4) Non-destructive testing techniques for material surface examination, T. Jayakumar, B. P. C. Rao, and S. Trinavukkarasu, International Conference on Surface Techniques (INSURE-2001), Chennai, India; published in February 2001.With appropriate attention to capability, applicability, and constraints, this paper examines the specifics of several traditional and cutting-edge NDT techniques for material surface characterization.

5) ANKESH, JAIKANT And SANJEEV GOYAL, Properties Of Expanded Polystyrene And Its Environmental Effects, Advances and Applications in Mathematical Sciences, August 2021 This paper highlights the manufacturing of EPS, its properties, scope of improvement within the properties that lay effect on major applications within the scope of the topic.

6) Compare destructive and non-destructive concrete testing: A review by Malik Arooj and Gopendra Yadav, International Journal of Engineering Research & Technology (IJERT), ISSN 2278-0181, Vol. 6, Issue 11, November 2017.This research examined each of these approaches in detail and contrasted them, highlighting the benefits of each method and recommending NDT for concrete strength.

7) Correlation between non-destructive and destructive tests of concrete's compressive strength, Duna Samson, Omoniyi, and Tope Moses, International Journal of Engineering Science, Issue 91, September 2014. This study compares and contrasts the destructive and non-destructive methods (rebound hammer) of determining the concrete's compressive strength.

Applications:

Lightweight concrete is used in a variety of buildings, such as non-load-bearing walls, insulation, and geotechnical applications.

Materials And Methods

1. materials

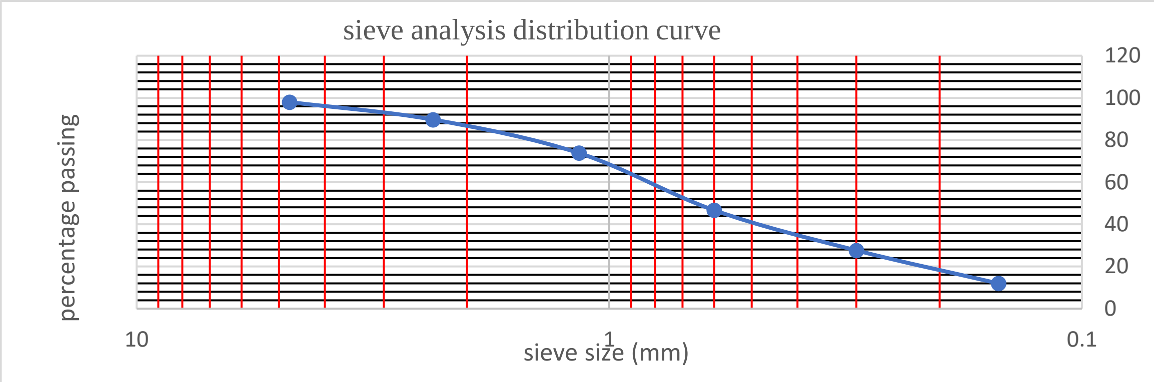
Cement fine aggregate, coarse aggregate, EPS beads, and water are the ingredients required to make lightweight concrete.

1.1 Cement

The Ultra Tech company's regular Portland cement, grade 53, has a short setting time and quickly gains strength.

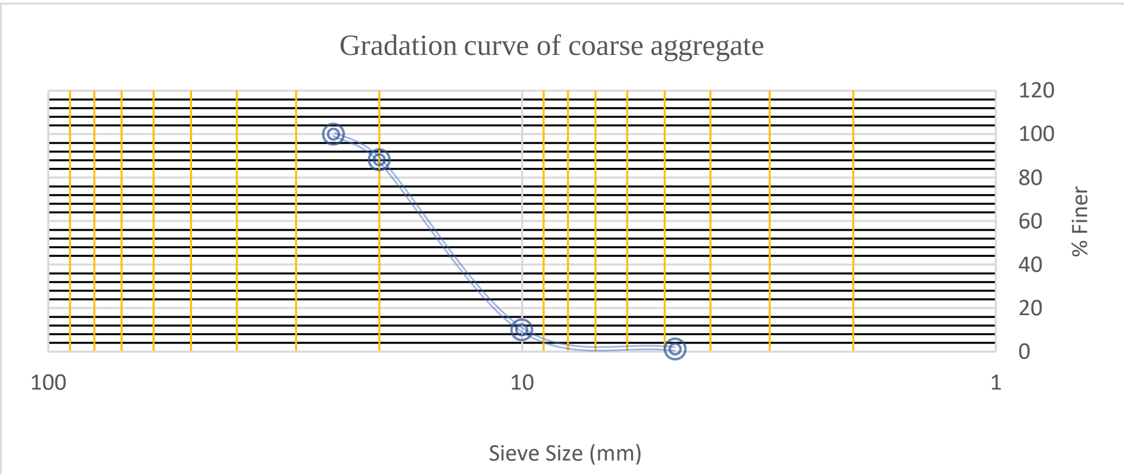
1.2 Fine Aggregate

The size distribution curve in the picture below illustrates the sand's retention on a 4.75mm passing sieve. The sand is zone 2 river sand.



1.3 Coarse Aggregate

The gradation curve of coarse aggregate is depicted in the figure below. The maximum size of coarse aggregate is 20 mm, and lightweight concrete is prepared using well-graded crushed material.



1.4 EPS Beads

Expanded polystyrene (EPS) is a rigid, closed-cell, thermoplastic material produced from solid beads of polystyrene, which is polymerized from styrene monomer and contains an expansion gas dissolved within the polystyrene bead. EPS beads are easily available in the market and are commonly used in bean bag chairs. EPS beads are hydrophobic, meaning the molecules do not mix with water. The density of EPS beads ranges from 12 to 16 kg/m³. They are spherical in shape, with sizes ranging from 6 mm to 10 mm.

Expanded polystyrene beads

2.Testing Methodology

2.1 Ultrasonic Pulse Velocity Test

The ultrasonic pulse velocity test is a non-destructive method used to assess a structure's mechanical properties and evaluate its behavior without causing any harm to it. The pulse wave produced by an electronic transducer is the fundamental component of ultrasonic pulse velocity. Next, the pulse wave passes through the concrete specimen, and the amount of time it takes to do so is recorded. Next, the length-to-time ratio is computed. There are two types of transducers that are utilized: transmitters and receivers [9].

Ultrasonic pulse velocity test

The pulse velocity is calculated by the equation shown below:

$$V = L/T$$

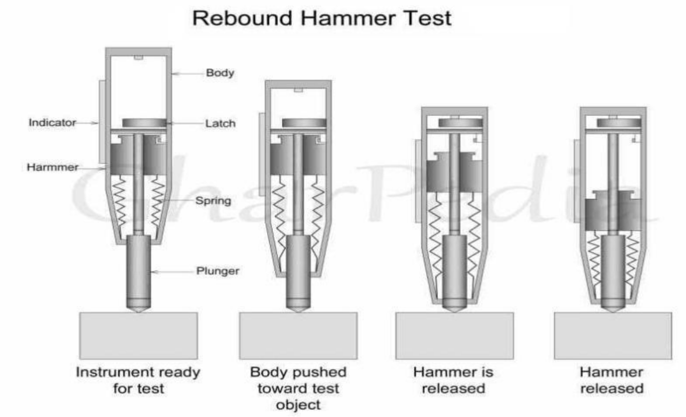
where

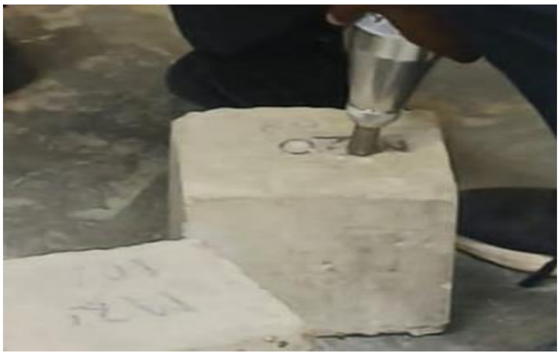
L= length of specimen (m), T=time (sec), V= Pulse velocity (km/s)

2.2 Rebound Hammer Test

One kind of non-destructive test for determining the compressive strength of concrete is the Schmidt rebound hammer test. Older constructions are typically subjected to this test to ascertain their strength without inflicting any harm. An elastic mass that depends on the hardness of the surface it hits is the foundation of the rebound hammer's operation. With its 1.8 kg weight, the hammer is suitable for both laboratory and field use. The sample cube is used to obtain six rebound readings, and the average of these values is computed.

Operational diagram of rebound hammer and sample testing





2.3 Compressive Strength Test

The compressive strength test is the most common type of destructive test. The compressive strength is determined by crushing concrete cubes that are tested after 7, 14, and 28 days of curing using a compressive testing machine. The maximum strength is achieved at 28 days of curing. The compressive strength is calculated by the ratio of the maximum load the cube can withstand before failure to the area of the specimen

.Compressive Strength = P/A

Compression Testing Machine

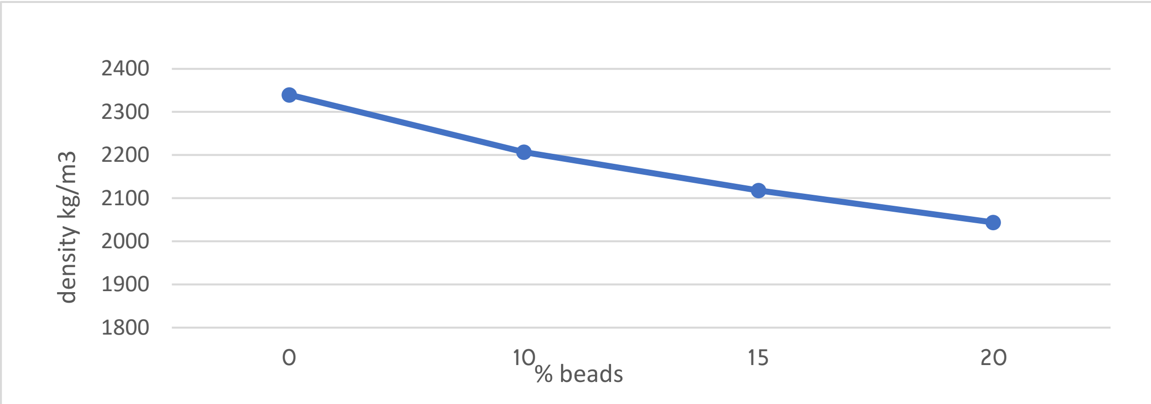
RESULT AND DISCUSSION

EPS beads were used to partially replace the aggregate in various concrete mixtures, ranging from 0% to 20% of the aggregate by volume. Both destructive and non-destructive tests were used to evaluate the cubes.

1.Effect Of Eps Beads vs Density

In this project, EPS beads were used in place of coarse aggregate at volumetric intervals of 0%, 10%, 15%, and 20%.
Expanded polystyrene (EPS) beads can lower the concrete's density and make it lighter. The following illustrates how EPS beads affect cube weight.

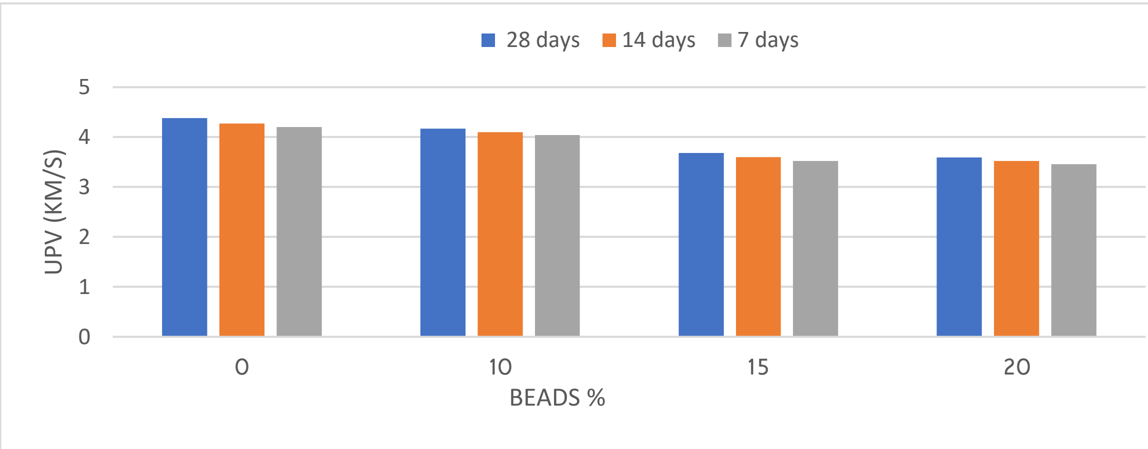
density vs beads %



The study identifies the maximum and minimum densities as 2340 kg/m³ and 2044 kg/m³, respectively, corresponding to 0% and 20% aggregate replacement with beads. The density and the percentage of beads, which lowers the weight of the concrete, are directly correlated in this figure.

2. Effect of EPS beads vs UPV

Concrete specimens are also subjected to non-destructive testing in this investigation. This test often yields data regarding the concrete's quality and uniformity. One crucial factor in the building sector is the quality of the concrete. The data for various percentages of aggregate replacement with beads are displayed in the figure below.



Ultrasonic pulse velocity (km/s)

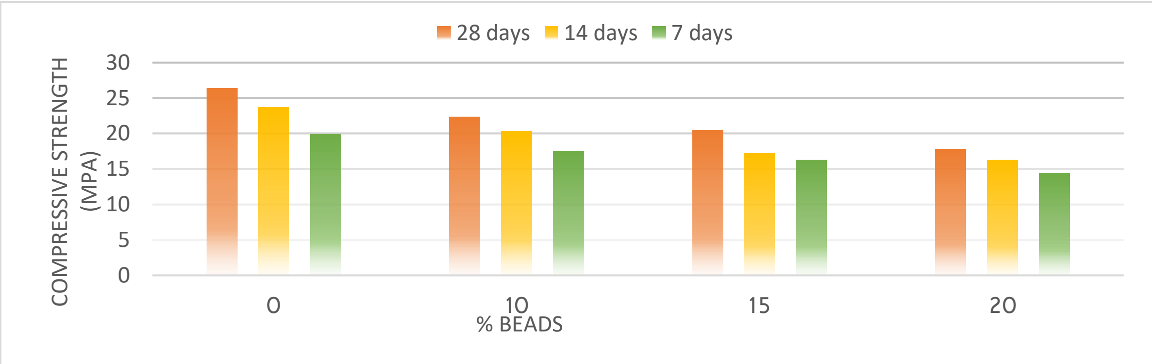
The obtained pulse velocity decreases as the fraction of beads replaced increases. The pulse velocity measurements for the 7-day and 14-day curing periods are shown in the above figure. The curing period also affects the velocity; similarly, the longer the curing period, the higher the pulse velocity.

According to quality standards, the maximum pulse velocity value is 4.20 km/s at 7 days and 4.27 km/s throughout 14 days of curing. The pulse velocity is 4.38 km/s after 14 days, which is around 2% quicker than it was at 7 days. The overall quality and homogeneity of the concrete specimen are satisfactory following 28 days of testing.

3. Compressive Strength vs Beads %

The partial replacement of aggregate of 0%- 20% of Eps beads, the compressive strength is noted. The below table shows the strength at 7 ,14 and 28 days of curing.

Sr no	% beads	Density	strength at 7 days (N/mm2)	strength at 14 days (N/mm2)	strength at 28 days (N/mm2)
1	0	2340	19.88	23.70	26.37
2	10	2207	17.48	20.29	22.37
3	15	2118	16.29	17.18	20.44
4	20	2044	14.37	16.29	17.77



% beads vs compressive strength test

The dead load falls as the aggregate replacement percentage rises. As a result, concrete's compressive strength likewise declines. Density and compressive strength exhibit a strong correlation. Specifically, as density decreases, there is a noticeable decline in compressive strength. After 14 days, the material demonstrates a compressive strength of 16.29 MPa. The study examines density values ranging from 2340 to 2044 kg/m³, with corresponding compressive strength measurements after 28 days falling between 26.37 MPa and 17.77 MPa.The increased percentage of beads causes the EPS beads to have a lower strength, which in turn reduces the strength of the lightweight concrete.

4. Rebound hammer vs Eps beads %

The rebound hammer test was used in this experiment. Every cube underwent the rebound hammer test, and strength analysis and the same proportion of beads were carried out. The strength numbers derived from the rebound hammer test are displayed in the table below.

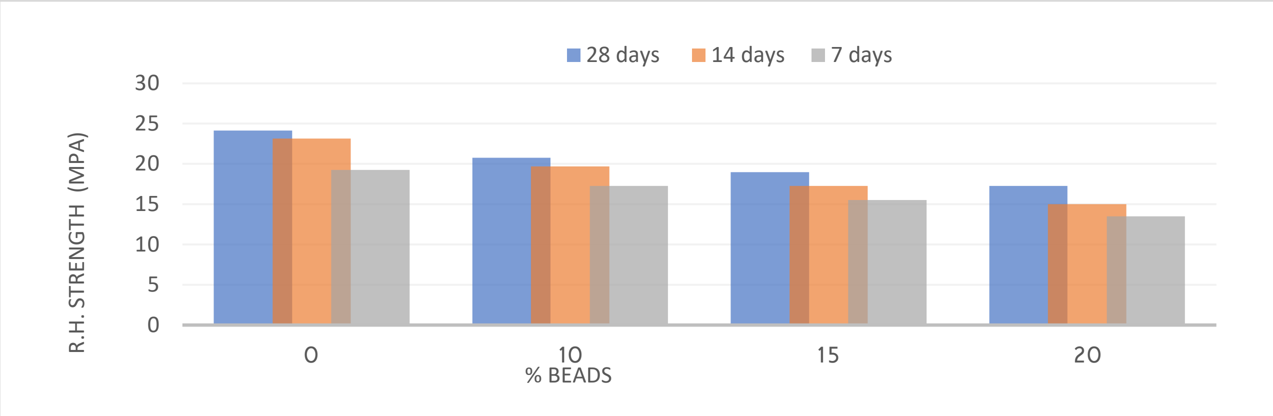
Rebound Hammer Strength Vs Beads %

Sr no.	%beads	Density (kg/m3)	7 days strength (MPa)	14 days strength (MPa)	28 days strength (MPa)
1	0	2340	19.5	23.10	24.15
2	10	2207	17.25	19.70	20.7
3	15	2118	15.525	17.25	18.97
4	20	2044	13.5	15.25	17.25

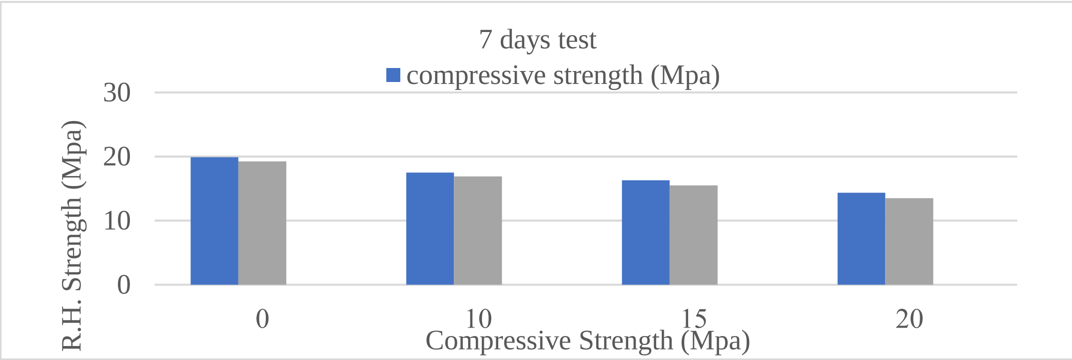
The above table shows the compressive strength values at 28, 14, and 7 days, which vary from 17 to 24 MPa at 28 days. Also, as density grows, so does strength. However, the non-destructive analysis yields poorer results than destructive testing. The figure below depicts the rebound hammer strength at 28, 14, and 7 days, as well as the proportion of beads.

5. Comparison of destructive and non- destructive test

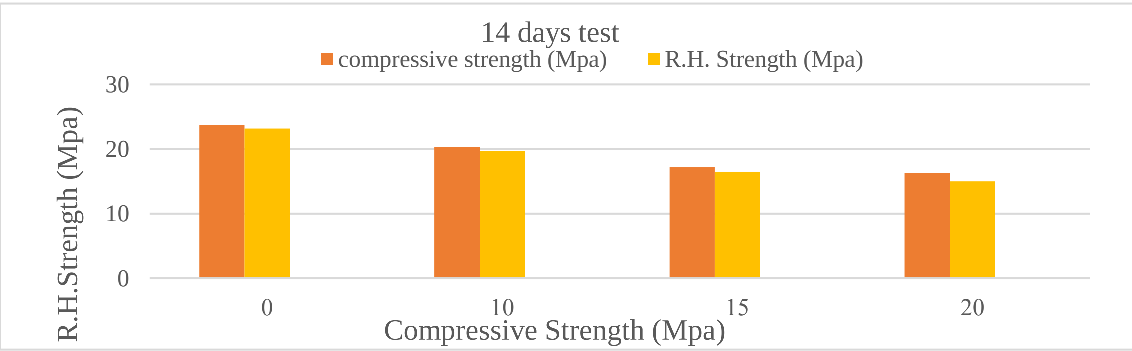
Compressive strength values from destructive and non-destructive methods are shown in Figures (a), (b), and (c).



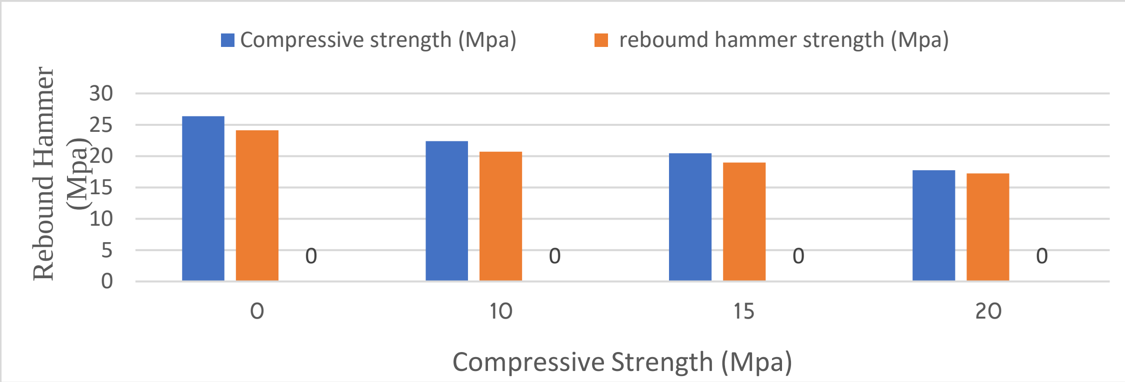
(a).7 Days Test Of Compressive Vs Rebound Hammer Strength (Mpa)



(b) 14 Days Test Of Compressive Vs. Rebound Hammer Strength (Mpa)



(c). 28 Days Test Of Compressive Vs. Rebound Hammer Strength (Mpa)



In the data shown in the graph, a comparison between destructive and non-destructive tests for strength is made using only the compression test and rebound hammer test, not the ultrasonic pulse velocity test. This is because the ultrasonic test only shows the homogeneity and quality of concrete, not its strength. The strength obtained from the destructive test is comparatively higher than the strength measured by the rebound hammer test.

Conclusion

- This study uses expanded polystyrene beads to investigate the relationship between destructive and non-destructive tests on lightweight concrete.
- The preparation of lightweight concrete is done by partially replacing the aggregate, ranging from 0% to 20%. In this work, we reduce the weight of concrete cubes using EPS beads.
- The data show that strength is directly related to the density of concrete. As the density increases, the strength also increases.
- The UPV test shows that the higher the percentage of beads, the lower the velocity of the concrete cube, and higher velocity indicates better quality concrete.
- According to the compressive strength, the strength rises as the proportion of EPS beads falls, and vice versa; that is, the compressive strength falls as the proportion of beads rises.
- The rebound hammer test also depends on the bead percentage; as the bead percentage increases, the rebound number decreases, which directly indicates a reduction in the strength of the concrete.
- When comparing destructive and non-destructive testing, it can be seen that the former quantify strength more accurately than the latter.
- The maximum strength for M20 grade concrete is achieved with up to 15% aggregate replacement by EPS beads, after which the strength decreases as the percentage of EPS beads increases.

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