STRENGTH AND PROPERTIES OF LIGHTWEIGHT CONCRETE

THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

MASTER OF TECHNOLOGY

(Structural Engineering)

Submitted by

UJJWALDEEP SINGH

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October 2023

I.K. GUJRAL PUNJAB TECHNICAL UNIVERSITY

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CANDIDATE'S DECLARATION

I hereby certify that the work is being presented in the thesis entitled "STRENGTH AND PROPERTIES OF LIGHTWEIGHT CONCRETE" by "UJJWALDEEP SINGH" in partial fulfillment of requirements for the award of degree of M.Tech. (Structural Engineering) submitted in the Department of Civil Engineering at GURU NANAK DEV ENGINEERING COLLEGE, LUDHIANA under PUNJAB TECHNICAL UNIVERSITY, JALANDHAR is an authentic record of my own work carried out during a period from July to October under the supervision of Dr. Harvinder Singh. The matter presented in this thesis has not been submitted by me in any other University/Institute for the award of M.Tech. Degree.

Signature of the Student

This is to certify that the above statement made by the candidate is correct to the best of my/our knowledge.

The M.Tech. Viva Â–Voce Examination of UJJWALDEEP SINGH has been held on _______________ and accepted.

Signature of Supervisor(s)　　　　　　　　Signature of External Examiner

Signature of H.O.D.

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UJJWALDEEP SINGH

ABSTRACT

Lightweight Concrete has a history of more than two thousand years, and its technical development is still proceeding. The aim of this review is to know about the lightweight concrete (LWC), to study the effects of several factors on the strength of lightweight aggregate concrete composites: aggregate strength, w/c ratio. It also covers the study of use of Expanded Polystyrene (EPS) , un-expanded Polystyrene (UEPS) and thermally modified EPS (MPES) as lightweight aggregate in concrete and studying their effects on the properties of the concrete. The results indicate that EPS aggregate concrete with small EPS aggregates showed higher compressive strength and the concrete show gradual failure as compared to the concrete with UEPS aggregate which shows brittle failure.

CONTENTS

CHAPTER 1 - INTRODUCTION

Lightweight Concretes are not a modern invention or achievement of concrete technology. They have been known since ancient times and are basically the predecessors of today's concrete. The use of lightweight Concrete (LWC) can be traced to as early as 3000 BC, when the famous towns of Mohenjo-Daro and Harappa were built during the Indus Valley Civilization. In Europe, Romans built the Pantheon, the aqueducts, and Colosseum in Rome with the help of LWAC. The uses of Lightweight Concrete have been increased with time in the construction of high-rise buildings, offshore structures, and long span bridges due to the advantage of its low density, which is beneficial in terms of load bearing elements of small cross section and a corresponding reduction in the size of foundation.

The lightweight concrete can be produced by introducing:

i. Gassing agents like aluminum powder or foaming agents.
ii. Lightweight mineral aggregate such as perlite, vermiculite, pumice, expanded shale, slate, clay, etc.
iii. Plastic granules as aggregate e.g., polystyrene, or other polymer materials

Pumice is still used today as an aggregate for structural concrete in certain countries such as Germany, Italy, Iceland, and Japan. Palm Oil shells are used for making lightweight aggregate concrete in some countries like Malaysia.

Natural lightweight aggregates are mostly of the volcanic origin like pumice, scoria, tuff, etc. These have been used both as fine and coarse aggregates. They function as pozzolanic materials when used as fine aggregates. They interact with calcium hydroxide and produce calcium silicate which strengthens the structure.

Lightweight Concrete has many advantages such as –

i. Due to its low density its thermal insulation is very high, so these are used as thermal insulators in buildings, in walls and roofs.
ii. LWCs are fire resistant in nature.
iii. Using LWCs, the overall weight of structures can be reduced by a significant value.
iv. In framed structures, considerable cost savings can be brought by using LWCs for the construction of floors, partition, and external cladding.

The natural light weight aggregates (LWA) like pumice, perlite, vermiculite, expanded shale and slate are highly porous in nature as compared to the artificial LWA like expanded polystyrene (EPS), which are relatively less porous.

Due to highly porous nature of LWA, the major problem of using LWAs, especially natural LWAs, is the high-water demand to produce concrete with adequate characteristics including fresh and mechanical properties. Therefore, in order to attain an adequate consistency without adding chemical admixtures, more water is required which necessitates the use of more cement, to keep the W/C ratio constant. This will eventually lead to an increase in cost without enhancing the mechanical and durability properties of concrete. In order to solve these problems, use of modified or unmodified raw or waste EPS is one of the ways to produce LWCs.

This review paper focuses on the effects of aggregate properties on lightweight concrete, effect of polystyrene aggregate size on strength and moisture migration characteristics of lightweight concrete and effect of thermally modified waste EPS foams (MEPS) as aggregate in lightweight concrete.

EPS is a low density, hydrophobic, thermal insulated, non-absorbents, closed cellular and low-cost material mainly used as packaging material and for insulating material in various industries. A large quantity of EPS ends up as waste materials and are either sent to landfill or illegally dumped in open areas especially in developing countries. Due to this reason, the use of EPS in construction applications as partial or full substitution of quarried aggregates in production of concrete materials would be a distinct advantage. This would reduce the amount of waste sent to landfill, produce lightweight concrete materials, and preserve natural materials for use.

CHAPTER 2 - LITERATURE REVIEW

(Dixit et al., 2019) studied the effects of aggregate properties on lightweight concrete. They carried out study to understand effects of various factors on strength of the resulting concrete like aggregate strength, w/c ratio. They compared concrete samples with different water cement ratios such as, 0.4, 0.44, 0.48. They measured the crushing strength of three grades of expanded clay lightweight aggregates (i.e., 25, 15, 5 mm) and pore distributions of the hardened cement pastes were measured.

Effect of aggregate strength on concrete strength

The bulk density and aggregate strength of lightweight aggregate of size 25, 15, 5 mm is 440, 830, 620 kg/m^3 and 1.69, 5.79, 4.27 MPa respectively. Which means aggregate strength does not depend upon the size of the aggregate but somehow related to its density. When they test the concrete crushing strengths for different w/c ratio on 7 , 28, and 56 day, they found out that concrete using the 15 mm aggregate has achieved a greater highest strength than that of the 5 and 25 mm aggregates. It appeared as the strength achieved was directly proportional to the aggregates crushing strength as well as the aggregate density. Irrespective of w/c ratio, the interfacial zone is influencing facto on concrete strength. As the LWA are porous in nature, they absorb more water as compared to the normal aggregates and therefore exhibits self-curing function at the interfacial zone.

The effect of w/c ratio on concrete strengths at 7, 28, and 56 days.

The crushing strength of concrete decreases with an increase in w/c ratio, which is like the trend followed by normal weight concrete. Therefore, strength of LWC is depends upon the strength of LWA used and on the bonding of the aggregate and cement paste.

(Fernando et al., 2017) studied the effect of Polystyrene aggregate size on strength and moisture migration characteristics of lightweight concrete. They made Polystyrene concrete made from mixture of cement, sand, and polystyrene aggregate (EPS or UEPS aggregates). Polystyrene is a thermoplastic polymeric material initially in the solid form (UEPS) and it can be expanded by the use of steam and expansive agents. They test the different samples of light weight concrete made up of different sizes labelled as P, Q, and U. The P and U has me aggregate grading; however, the type U is UEPS aggregate, and type P is EPS aggregate. They made specimens of different concrete densities such as 1050, 1430, and 1820 kg/m^3 for each type of aggregate.

Compressive Strength

There is increase is compressive strength as the size of the EPS aggregate decreases. The increase is consistent for all the concrete densities. However, the increase in compressive strength with decrease of EPS aggregate size is significant in lower density concrete. They concluded that it might be since the lower density concrete gradually has high amount of EPS aggregate as compared to the higher density concrete lower amount of EPS aggregate, therefore the benefit obtained with the use of small size aggregate in lower density concrete is significant. The types P and U have same aggregate size, but the concrete containing UEPS (type U) aggregate showed about 70% higher Compressive strength as compared to EPS (type P) aggregate. This is since EPS has 60% lower density than UEPS.

They also observed that concrete containing EPS and UEPS aggregate shows different behaviour. The Concrete containing EPS aggregate does not show the typical brittle failure under compressive loading. The failure observed was more gradual and specimens could retain the load after failure without full disintegration. But contrary, the Concrete having the UEPS aggregate showed the typical brittle failure. They also observed that EPS aggregate sheared off along the failure plane whereas in UEPS no damage was observed by them. Due to this it can be observed that the bond between the UEPS and the matrix is weaker than the failure strength of UEPS aggregate and on the other hand the bond between the EPS and the matrix is stronger than the failure strength of the EPS aggregate.

Splitting Tensile Strength

The splitting tensile strength test was like the compressive strength test. The trend followed by the splitting tensile strength test was same as the compressive strength test. The splitting tensile strength of concrete increase with decrease in aggregate size. The failure behaviour of EPS and UEPS containing concrete was also like the behaviour exhibit by them in compressive strength test.

Moisture migration

As the durability of concrete also depends on its permeability. Concrete with greater porosity results in higher moisture migration.

It was observed by them that the EPS aggregate of same size shows higher moisture migration in concrete in which they are present more in volume. As the more volume of EPS is present in density concrete, if the aggregate shrink, then micro cracking can occur due to which higher moisture migration take place.

For the same EPS aggregate volume, the concrete made with bigger size Eps aggregate shows higher moisture migration. Because larger EPS aggregate shrink more, so more microcracks and hence more moisture migration.

The lower moisture migration in concrete containing UEPS aggregates was observed as compared to normal weight concrete.

(Lo et al., 2007) studied the effect of LWC using thermally modified waste EPS foams (MEPS). MEPS aggregate concrete mixture were obtained by partially replacing natural aggregate with the MEPS aggregate. MEPS aggregates were obtained from waste EPS foams by using a thermal treatment method in Laboratory.

They produced six different mixtures of different MEPS ratio (labelled as series from C1 to C6). MEPS aggregate was used as 25%, 50%, 75%, 100% of natural aggregate by volume.

Table 1 – Mixing details of the MEPS aggregates

Mix type	Total MEPS %age	MEPS Coarse Aggregate	MEPS Fine Aggregate
C1	100 %	50 %	50 %
C2	75 %	50 %	25 %
C3	50 %	50 %	0 %
C4	50 %	0 %	50 %
C5	50 %	25 %	25 %
C6	25 %	0 %	25 %

Workability

The workability of concrete mixture decreases as we increase the replacement of natural aggregate with MEPS. As the MEPS have many pores so the surface area of aggregate increased. It was observed that when MEPS aggregate content increased, the fresh concrete mix became rubbery, harsh, and difficult to place and compact.

The fine MEPS aggregate improved the workability of mixture due to its shape effect.

Compressive strength

The compressive strength of concrete mic increases as the decrease in the replacement of natural aggregates with MEPS.

It was observed that the strength of C3 was lower than that of the C4 and C5 even though their MEPS aggregate contents were all 50% by volume. It is because C3 have the coarser MEPS aggregates as compared to C4 and C5. So, it was concluded that coarse aggregates are more brittle and weaker because of their highly porous structure.

UPV of MEPS aggregate concrete

As the UPV is directly proportional to the density of concrete and compressive strength of concrete so UPV values increase as the strength of the concrete increases or decreased with the increase of MEPS content.

CHAPTER 3 - CONCLUSION

1) The usage of Lightweight Concrete is beneficial in superstructures, in bridges, decks, girders, piers, and high-rise buildings as their density is very less by virtue of which the dead load of structures can be reduced to great extent, hence the size of the foundation can also be reduced.
2) The strength of lightweight aggregate concrete depends on the strength of the lightweight aggregate used and the hardened cement paste as well as the bonding of the aggregate/cement paste.
3) The strength of the lightweight concrete decreases if the size of the LWA increases due to its high porosity and less density.
4) Less density LWA used in mixture means lightweight of the concrete will be received but at the same time the strength of the concrete will decrease.
5) The strength of the concrete also depends upon the strength of aggregates. More the strength of aggregates, more will be the strength of the concrete.

CHAPTER 4 - REFERENCES

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