International journal of advances in engineering and management (IJAEM)
Volume 3, issue 6 June 2021, pp: 2412-2421 www.ijaem.net ISSN: 2395-5252

Experimental Study on Behaviour of Cement Replacement by Partial Replacement of Cement with Perlite

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Submitted: 05-06-2021 Revised: 18-06-2021 Accepted: 20-06-2021

ABSTRACT: For structural application of light weight concrete, the density is more important than the strength. A low density for the same structural level reduces the self-weight foundation size and construction cost. Structural lightweight aggregate concrete was designed with natural perlite aggregate that will provide an advantage of reducing dead weight of the structure.

KEYWORDS:cement, perlite, fine aggregate, coarse aggregate

I. INTRODUCTION

For structural application of lightweight concrete, the density is more important than the strength. A low density for the same strength level reduces the self-weight, foundation size and construction cost. Structural lightweight aggregate concrete was designed with natural perlite aggregate that will provide an advantage of reducing dead weight of the structure also compared the strength of normal concrete with perlite concrete by partially replacing of perlite with cement as a percentage of 10%, 20%, and 30% in normal concrete mix. Perlite is an amorphous volcanic glass that has a relatively highwater content, typically formed by the hydration of obsidian. It is an industrial mineral and a commercial product useful for its low density after processing. Small quantities of perlite are also used in foundries, cryogenic insulation, and in ceramics as a clay additive. It is also used by the explosives industry. Due to thermal and mechanical stability, non-toxicity, and high resistance against microbial attacks and organic solvents, perlite is widely used in biotechnological applications. Perlite was found to be an excellent support for immobilization of biocatalysts such as enzymes for bioremediation and sensing applications.

Perlite is an amorphous volcanic glass that has a relatively highwater content, typically formed by the hydration of obsidian. It occurs naturally and has the unusual property of greatly expanding when heated sufficiently. It is an industrial mineral and a commercial product useful for its low density after processing. Perlite softens when it reaches temperatures of 850– 900 °C (1,560–1,650 °F). Water trapped in the structure of the material vaporises and escapes, and this causes the expansion of the material to 7–16 times its original volume. The expanded material is a brilliant white, due to the reflectivity of the trapped bubbles. Small quantities of perlite are also used in foundries, cryogenic insulation, and in ceramics as a clay additive. It is also used by the explosives industry. Due to thermal and mechanical stability, non-toxicity, and high resistance against microbial attacks and organic solvents, perlite is widely used in biotechnological applications. Perlite was found to be an excellent support for immobilization of biocatalysts such as enzymes for bioremediation and sensing applications.

S.NO	PROPERTY	RESULT
1	Specific gravity	2.2
2	Physical state	Micronized powder
3	Colour	White
4	Water absorption	1.5%

II. DIRECTION OF USE(PERLITE)

Add the perlite in the mixer with little water. Keep mixing and add add sand, cement , and balanced water. Mix it for few minutes and stir well and mix in mortar. Perlite is meant for improving the strength in construction.

III. LITERATURE REVIEW

Yu et al. (2003)studied the changes in the 15 compressive strengths of samples containing 0 to 40% perlite powder at the ages of 3, 28, and 90 days. Results showed increases of 34, 24, and 8% in the compressive strengths of samples consisting of 20, 30, and 40% perlite, respectively, at 90 days, compared to the control samples, representing the significant pozzolanic activity of perlite. They also found that the optimum replacement percentage of OPC with calcined perlite powder is equal to 15% and 20% for the strengths at 28 and 91 days, respectively. It was demonstrated that perlite powder, of which only 5.6% remains on the 80-µm sieve, had the highest activity. In addition, they detected that perlite powder makes a greater contribution to the improvement of compressive strength at a higher w/c ratio.

Bektas et al. (2005) investigated the influence of calcined perlite powder (CPP) in suppressing the expansion resulting from Alkali–Silica Reaction (ASR). They found that CPP can effectively limit the expansion of mortars.

Kotwica et al. (2013)showed that replacing OPC with expanded perlite powder, which is an industrial waste material, results in increasing the day 1 and day 28 strength of mortar and concrete mixtures, when studying replacement ratios of up to 35%. Investigation of the microstructures of the mixtures revealed that the main reason for the increased strength of the cement-based materials is the pozzolanic reaction of waste expanded perlite powder.

On the other hand, another study on NPP indicated that early age strength loss is possible as a result of replacing a portion of OPC with perlite powder in the mixture design; however, the results for compressive strength of mixtures containing NPP get 16 closer to control mixtures over time, but the pozzolanic reactions of NPP has a lower rate than of the control mixtures.

Dinesh. A et al. (2016) This study states that in the design of Concrete Structures, Light weight concrete plays a prominent role in reducing the density and to increase the thermal insulation. Structural light weight aggregate concrete was designed with the use of Perlite aggregate, Vermiculite aggregate and expanded clay aggregate. With respect to Compressive strength and Split tensile strength they concluded that the replacement of Vermiculite and Perlite aggregate by 50% of weight of aggregate increases strength with increase in age of concrete and obtain early strength.

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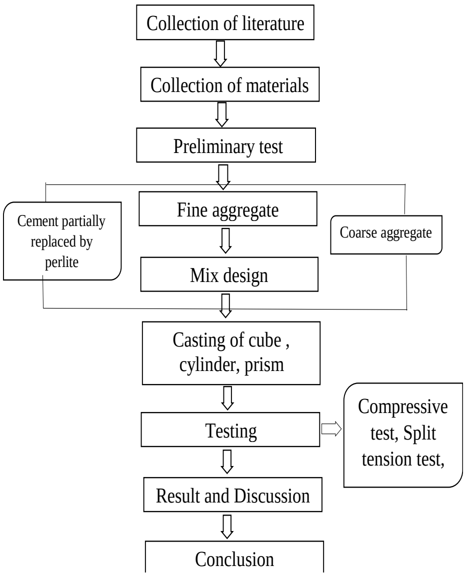
IV. METHODOLOGY



V.CONCRETE INGREDIENTS

The concrete mixture consists of the following ingredients,

1. Cement
2. Coarse aggregate
3. Fine aggregate
4. Water
5. Perlite

CEMENT

Cement is a well known building material and has occupied an indispensable place in construction works. There are variety of cements available in the market and each type is used under certain conditions due to its special properties. Cement in a general sense is adhesive and cohesive materials are capable of bonding together particles of solid matters into a compact durable mass.

TYPES OF CEMENT

Cement comes in various type and chemical composition. For general concrete construction IS :456-2000 permits the following types of cement.

Ordinary or low heat Portland cement conforming to IS :269-1976

Rapid hardening Portland cement conforming to IS:8041-1978

Portland slag cement conforming to IS :455-1976

Portland pozzolona cement conforming to IS:1489-1976

High strength ordinary Portland cement conforming to IS: 8112-1976

Hydrophobic cement conforming to IS: 8043- 1976

High alumina cement conforming to IS: 6452-197217

Super sulphated cement conforming to IS: 6909-1973.

Chemical composition	**Percentage**	**Average**
Lime CaO	60-65	63
Silica SiO2	17-25	20
Alumina Al_2	3-8	6.3
Iron oxide Fe_2O_3	0.5-6	3.6
Magnesia MgO	0.5-4	2.4
Sulphur trioxide SO_3	1-2	1.5

PHYSICAL PROPERTIES OF CEMENT

1. Fineness
2. Setting time
3. Soundness
4. Strength
5. Heat of hydration
6. Specific gravity
7. Chlorine
8. Flyash

Chemical composition of cement

AGGREGATE

Aggregate is a collective term for the minerals such as sand, gravel and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime etc,) to form compound materials. Aggregate is also used for base and sub base course for both flexible and rigid pavement.

Aggregate can either be natural or manufactured. Natural aggregate are generally extracted from larger rock formation through an open excavation. Extracted rock is typically reduced to usable sizes by mechanical crushing. Manufactured aggregate is often the by product of other manufacturing industries.

CLASSIFICATION

1. On the basis of geological origin
i. Natural aggregate
ii.Artificial aggregate
2. On the basis of size
i. Coarse aggregate
ii. Fine aggregate
3. On the basis of shape
i. Round aggregate
ii. Irregular aggregate
iii. Angular aggregate
iv. Flaky aggregate
4. On the basis of unit weight
i. Normal weight aggregate
ii. Heavy weight aggregate
iii. Light weight aggregate

Properties of fine aggregate

1. Strength
2. Particle size
3. Specific gravity
4. Bulk density
5. Voids
6. Porosity
7. Moisture content
8. Bulking

Physical property of aggregate

S.No	Property	Coarse aggregate	Fine aggregate
1	Specific gravity	2.65	2.78
2	Water absorption	1.3%	0.5%
3	Dry loose bulk density	1322 kg/cum	1468 kg/cum
4	Soundness	0.55%	0.90%
5	Finess modulus	5.87%	3.75%
6	Zone	-	I
7	Silt(volume)	-	2%
8	Abrasion value in %	22	-
9	Impact value in %	13.76	-
10	Crushing value in %	23	-

WATER

It is the most important and least expensive ingredient of concrete. A part of the mixing is utilization in the hydration of cement to form the building matrix in which the inert aggregate are held in suspension until the matrix has hardened. The remaining water serves as a lubricant between the fine and coarse aggregate and makes the concrete workable. The water used for the mixing and curing of concrete should be free from deleterious materials. The portable water is generally considered satisfactory for mixing concrete. The quantity of water used should be just for hydration and 27 suitable workability of concrete. The insufficient quantity of water makes the concrete mix harsh and workable. The excess quantity of water causes bleeding and segregation in concrete. The strength and durability of concrete is reduced due to the presence of impurities in the mixing water. The presence of sodium carbonate and bicarbonate in water has an adverse effect on the setting time of cement. The presence of calcium chloride in water accelerates setting and hardening of cement. The quantity of calcium chloride is restricted to 15% by weight of cement.

PERLITE

Perlite is an amorphous volcanic glass that has a relatively highwater content, typically formed by the hydration of obsidian. It occurs naturally and has the unusual property of greatly expanding when heated sufficiently. It is an industrial mineral and a commercial product useful for its low density after

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specification of perlite

S.NO	PROPERTY	RESULT
1	Specific gravity	2.2
2	length	1.5-3.0 mm
3	Physical state	Micronized powder
4	Colour	White
5	Water absorption	1.5%
6	Compressive strength	39.67N/mm^2
7	Density	1100 kg/m^3

VI.EXPERIMENTAL INVESTIGATION

GENERAL

Testing of hardened concrete plays an important role in controlling and conforming the quality of cement concrete. Systematic testing of raw materials fresh concrete and hardened concrete are inseparable part of any quality control programme for concrete, which helps concrete with regard to both strength and durability. Test on hardened concrete confirms that the concrete that the concrete used at sites has developed the required strength.

MIXING PROPERTIES

The mixing properties is developed as per IS code method for characteristic strength of 50Mpa. The process of selecting suitable ingredients of concrete and determining their relative amount with the objective of producing concrete of the required strength, durability and workability as economically as possible is termed as concrete mix design.

The common method of expressing the properties of ingredients of a concrete mix is in term of parts or ratio of cement, fine and coarse aggregate. For example, a concrete mix of properties 1:2:4 or the mix contains one part of cement, two parts of fine aggregate and four parts of coarse aggregate.

The properties are either by volume or by mass. A constant properties of perlite are added to the concrete by 10%, 15%, 20%, 25%, and in addition to cement.

TYPES OF MIXES

1. NOMINAL MIXES

In the past, the specifications for concrete prescribed the properties of cement, fine and coarse aggregate. These mixes of fixed cement aggregate ratio which ensures adequate strength are termed as nominal mixes. These offers simplicity under normal circumstance, have a margin of strength above the specified. However, due to the variability of the mix ingredients, the nominal concrete for a given workability varies widely in strength.

2. STANDARD MIXES

The nominal mixes of fixed cement aggregate ratio (by volume) vary widely in strength and may result in under or over rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed as standard mixes. IS 456-2000 has designed the concrete mixes into a number of grades as M10, M20, M25, M30, M35, M40. In this designated the letter 'M' refers to the mix and the number specifies 28 days of cube strength in N/mm2 . The mixes of grade M10, M20, M25 corresponds approximately.

3. DESIGN MIXES

In these mixes, the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is the most rational approach to the elections of mix proportions with specific materials more or less unique characteristics. The approach results in the production in the concrete with the appropriate properties more economically. For the concrete with undemanding performance nominal or standard mixes.

DATAS FOR CONCRETE MIX DESIGN

Degree of workability desired. Limitations on water/cement ratio and minimum cement content to ensure adequate (refer IS 456-2000).

Type and maximum size of aggregate to be used and standard deviation of compressive strength of concrete.

TYPICAL MIX DESIGN FOR M25 GRADE OF CONCRETE1.STIPULATIONS FOR PROPORTIONNING

Grade designation : M25
Type of cement : OPC 43 grade conforming to IS 8112
Maximum nominal size of aggregate : 20mm
Minimum cement content : 300 kg/$m3$
Maximum water cement ratio : 0.5
Workability : 75mm (slump)
Exposure condition : Moderate
Method of concrete placing : manual
Degree of supervision : Good
Type of aggregate : Crushed angular aggregate
Maximum cement content : 450 kg/$m3$
Chemical admixture type : Nil

2.TEST DATA FOR MATERIALS:

Cement used : OPC 43 grade conforming to IS 8112
Specific gravity of cement : 3.15
Chemical admixture : Nil
Specific gravity of
i)Coarse aggregate : 2.80
ii)Fine aggregate : 2.65
Water absorption
i) Coarse aggregate : 1.0percent
ii) ii) Fine aggregate : 2.0percent
Free (surface) moisture
i) Coarse aggregate : Nil (Absorbed)
ii) ii) Fine aggregate : Nil
Sieve analysis
i) Coarse aggregate : Conforming to all in aggregate
ii) Fine aggregate : Conforming to grading zone II of table 4 of IS 383

3.TARGET STRENGTH FOR MIX PROPORTIONING

fck′ = fck+1.65 x S
where,
fck′ = target average compressive strength at 28 days
fck = characteristic compressive strength at 28 days, and
s = standard deviation From table 1 of IS 10262:2009,
standard deviation = 4.0N/$mm2$
Target strength = 25 + 1.65 x4 = 31.6N/$mm2$

4.SELECTION OF WATER- CEMENT RATIO:

From table 5 of IS 456, maximum water cement ratio = 0.50
Based on experience, adopt water cement ratio as 0.40
0.40<0.50
Hence ok.

5.SELECTION OF WATER CONTENT:

From table 2, maximum water content for 20mm aggregate = 186litre (for 25 to 50mm slump range for 20 mm aggregate). Slump here is 75 mm ,Table read water content 50mm.hence correction at rate of ± 3% for change of ± 25mm slump to be adopted
Estimated water content for 75mm slump = 186 × 1.03
= 1972 litre

6.CALCULATION OF CEMENT CONTENT:

Water cement ratio = 0.50
Cement content = 192/0.50 = 384 kg/$m3$
From table 5 of IS 456, maximum cement content for moderate exposure condition =300 kg/$m2$
384 kg/$m3$ > 320 kg/$m3$
Hence ok

7.PROPORTION OF VOLUME OF COARSE AGGREGATE & FINE AGGREGATE CONTENT:

Volume of coarse aggregate = 0.62
Volume of fine aggregate = 1- 0.62
= 0.38

8.MIX CALCULATIONS:

a)Volume of concrete = 1$m3$

b)Volume of cement $= \frac{\text{Mass of cement}}{\text{specific gravity of cement}} \times \frac{1}{1000}$

$= \frac{384}{3.15} \times \frac{1}{1000} = 0.122\ m^3$

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c)Volume of water $= \frac{\text{Mass of water}}{\text{specific gravity of water}} \times \frac{1}{1000}$

$= \frac{192}{1} \times \frac{1}{1000}$ =0.192 mm^2

d)Volume of all in aggregate = a – (b+c+d)

= 1- (0.122 + 0.192 + 0.00)

= 1 – 0.324

= 0.676 m^3

e)Mass of coarse aggregate = d × volume of coarse aggregate × specific gravity of coarse aggregate × 1000

= 0.676 × 0.42 × 2.8 × 1000

= 1176 kg/m^3

f)Mass of fine aggregate = d × volume of fine aggregate × specific gravity of fine aggregate × 1000

= 0.676 × 0.38 × 2.65 × 100

= 689 kg/m^3

9.MIX PROPORTION:

a) cement = 384 kg/$m3$
b) water = 192 kg/$m3$
c) Fine aggregate = 689 kg/$m3$
d) coarse aggregate = 1176 kg /m^3
e)Water cement ratio = 0.50

TESTING OF CONCRETE SPECIMENS
COMPRESSION TEST

Compression test is the most common test on hardened concrete. Concrete is strong in compression and weak in tension. Partly because it is an easy to perform, and partly because most of the desirable characteristics properties of concrete are quantitatively related to its compressive strength.

The compression test is carried on specimens, cubical or cylindrical in shape. Prism is also sometimes used. Here compression test is carried out on specimens. The cube specimen is of the size 150x150mm.

$F_{ck}= \frac{P}{A}$ (N/mm^2)

Where, P= Failure load in compression (KN)
A= Loaded area of the cube(mm^2)

SPLIT TENSILE STRENGTH TEST

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tensile failure.

As there are many difficulties associated with the direct tension test a number of indirect methods have been developed to determine the tensile strength. In these test in general a compressive force is applied to a concrete specimen in such a way that the specimen fails due to tensile stress developed in the specimen. The tensile stress at which the failure occurs is termed as the tensile strength of concrete.

$F_{ck}= \frac{2P}{\pi LD}$ (N/mm^2)

Where, P= Failure load in compression(KN)
L= Length of the cylinder(mm)
D = Dia of the cylinder(mm)

3 FLEXURAL STRENGTH TEST

Flexural strength of concrete also known a modulus of rupture or bend strength is a material property defined as the stress in a material just before it yields in a flexure test. The transverse bending test is most frequently employed , in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a three point flexural test technique.

The flexural strength represents the highest stress experienced within the material at its moment of yield. Flexural strength test is done as per IS: 516: 1959. Prisms are testes for flexure in Universal Testing machine of capacity 500 kN. The bearing surfaces of the supporting and loading rollers are

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wiped clean before loading. The prisms are placed in the machine in such a manner that the load is applied to the upper most surface along the two lines spaced .The axis of the specimen is aligned with the axis of the loading device. The maximum load applied to the specimen during test is noted.

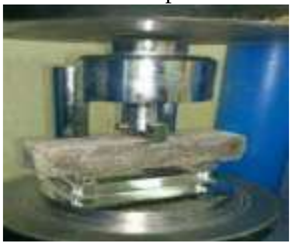
Flexural Strength = $\frac{PL}{b \times d \times d}$ **(N/mm^2)**

Where,

P = Maximum load in newton applied to the specimen

L = Length of the beam specimen in mm

D = Depth of the beam specimen in mm



VII. RESULT AND DISCUSSION

GENERAL

The result of specimens with varied fractions of perlite in addition to cement are compared with the results given by the control check specimens. The table gives the comparison of 28 day split tensile, compressive , flexural strength and Bond strength results.

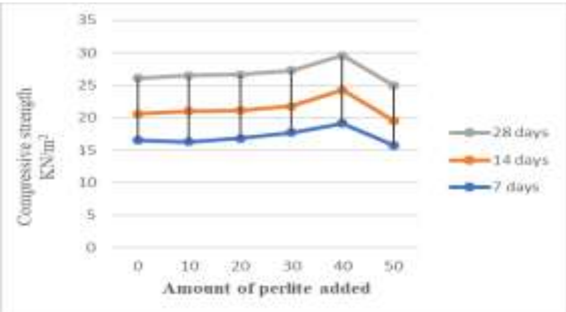
- Including perlite, the compressive strength of concrete progressively increases to a certain limit, but steadily decreases.
- Including perlite up to 2% increases the compressive strength inclusive of 28 days curing.
- Ultimate tensile strength is found with 0% replacement of marble powder and the strength gradually decreases by addition of WMD.
- Flexural strength of prism concrete increases upto 2% and then gets decreasing.
- Therefore, it was found that the optimum rate of perlite in concrete was almost 2% .

TESTING ON HARDENED CONCRETE

In present study the compression test on cubes and split tensile test on cylinders of conventional concrete and incorporated concrete are carried out. The experimental results for various tests are described below.

Compressive strength test

Percentage of perlite added	7 days (KN/m^2)	14 days (KN/m^2)	28 days (KN/m^2)
0	16.5	20.6	26.1
10	16.3	21	26.5
20	16.8	21.1	26.6
30	17.1	21.75	27.25
40	19.1	24.25	29.75
50	15.75	19.52	25



Split tensile strength test

Percentage of perlite added	7 days (KN/m^2)	14 days (KN/m^2)	28 days (KN/m2)
0	4.31	5.57	6.58
10	4.34	5.6	6.62
20	4.37	5.67	6.69
30	4.37	5.69	6.68
40	4.4	5.71	6.74
50	4.38	5.58	6.46

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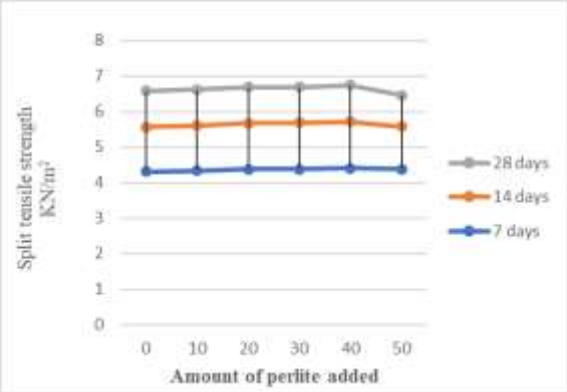
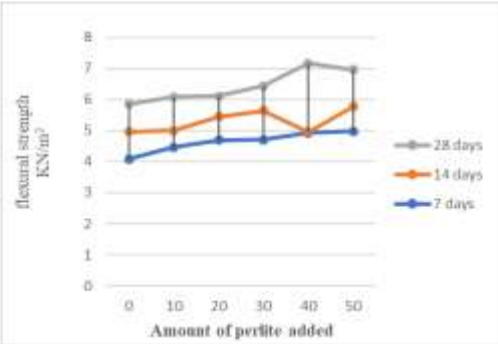


flexural strength test

Percentage of perlite added	7 days (KN/m^2)	14 days (KN/m^2)	24 days (KN/m^2)
0	4.09	4.96	5.85
10	4.46	5.01	6.09
20	4.69	5.45	6.11
30	4.71	5.64	6.44
40	4.93	4.69	6.90
50	4.98	5.78	6.97



CONCLUSION

- By increasing the addition of perlite dosages from 10% , 20% ,30% , 40% and 50% the workability decreases.
- When compared to conventional concrete, compressive strength for M25 for varying dosages of perlite at 10%,20%,30%,40%, and 50% and increased compressive strength respectively. The maximum percentage increase in compressive strength was achieved at 2% of dosage and was found to reduce for 2.5% of perlite content.
- It was also observed that there was an increase in split tensile strength for varying dosages of 10%,20%,30%, 40%, and 50% were found to be increased in split tensile strength than that of conventional concrete. The maximum percentage in split tensile strength was achieved at 2% of dosage and was found to reduce for 2% of perlite content.
- Flexural strength for M25 grade of concrete for different dosage of perlite at 10%, 20%,30%, 40%, and 50% when compared with conventional concrete was found to increased in flexural strength respectively. The maximum percentage increase in flexural strength was achieved at 2% of dosage and was found to reduce for 2.5% of perlite content.

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