Comparative Study of Perlite as Additional Construction Materials with Conventional Materials

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Abstract : Building material is any material which is used for a construction occasion. Many naturally occurring constituents such as rocks, sand, clay, wood even twigs and leaves have been used to construct buildings. Apart from natural materials, many man-made products are in use, some more and some less synthetic. Light weight construction materials can be a great choice when it comes to building a home. Use of Perlite in construction has been introduced in this research project and the compressive strength and other properties of concrete mix of conventional material and concrete mix with perlite has been analyzed. The compressive strength of conventional concrete block has been resulted as 22 KN/m^2 where as the compressive strength of concrete block with perlite mix has been resulted around 35 KN/m^2.

Index Terms **- Perlite, Construction Material, Aggregates.**

I. INTRODUCTION

The use of traditional building materials and design is often initiated itself in a difficult situation that is either being under the risk of perished under the force of transformation or being newly implemented to meet modern building standards and living conditions. Traditional building materials and design have gained renewed attention thanks to the use of locally approachable resources that address local conditions in a cost effective way.

Many traditional building materials have benefited from innovative technologies in both manufacture and application. These developments have made several traditional building materials more financially feasible, environmental friendly and technically sound. In recent decades, material development in response to a call for more durable infrastructures has led to many exciting improvements. Even concrete and steel are being steadily improved to have better properties such as strength, durability etc.

Advanced civil infrastructure materials provide an up-to-date review of some incipient construction materials that may have a major impact on repairs of existing infrastructures or new constructions. Each chapter explores the 'materials design concept' which leads to the creation of advanced composites by combining two or more constituents. Such design methodology is made possible by several key advancements in materials science and mechanics. Each chapter is concluded with discriminating examples of real world applications using these advanced materials. This includes appropriate structural design guidelines and mechanics to aid readers in understanding the uses of these advanced materials.

Perlite is nontoxic and non-flammable; however, the nature of the material and the large quantities involved require the use of handling safety procedures and special operations. This publication provides guidance for reducing the risks of unplanned perlite releases and incidents that could have potential for personal injury, property damage, downtime, and environmental impact. It covers the use of perlite in cryogenic cold boxes and cryogenic bulk storage vessels and focuses on safety, perlite handling procedures, and emergency perlite management. It is directed to industrial gas plant manufacturers, owners, and operators of facilities that utilize and maintain perlite as an insulation medium for cryogenic equipment.

Figure 1 Perlite pellets

2. MATERIALS USED:

The naturally available materials and basic materials which must be needed for construction work it's called as traditional construction materials. These are the essential materials to construct any type of structure. Such as stone, wood, sand, clay, cement, aggregate, bricks, bitumen, lime, concrete (cement + sand + aggregate + water + admixture + air) etc.

1. Cement:

It is a binding material or a substance used in construction that sets, hardens and adheres to other materials. It is manufactured through a closely controlled chemical combination of calcium, silicon, aluminium, iron and other ingredients. The most significant use of cement is production of concrete and mortar.

Applications:

- Cement mortar can be used for masonry work, plaster, pointing, etc.
- Cement concrete can be used for laying floors, roofs, constructing lintels, beams, weather sheds, stairs, pillars, etc.
- It is used for construction of important engineering structures such as bridges, dams, culvert, storage reservoirs, tunnels, docks, light houses, etc.
- It can also be used for construction of water tanks, tennis courts, septic tanks, lamp posts, roads, telephone cabins, etc.
- It is used for making joints for pipes, drains, etc.
- It can be used for manufacturing precast pipes, garden seats, artistically designed urns, flower pots, dust bins, fencing posts, etc.
- It can be used for preparation of foundations, watertight floors, footpaths, etc.
- It can be used for creating fire-proof structures in the form of concrete. Also, it can be used for making acid-resistance and waterproof structures.
- Coloured cement can be used for decorating or colouring the structures.
- It could be used for shortcreting the geological walls or tunnel to achieve more strength of the structure.

2. Aggregate:

It is a granular material which is used with a hydraulic cementing medium to produce either concrete or mortar. It occupies about 75%of the volume of concrete and hence their influence on various properties of concrete is considerable. It greatly affects the properties of concrete such as strength, workability, durability and economy.

There are mainly two types of aggregates used in construction – coarse aggregate and fine aggregate. The most important function of fine aggregate is to assist in producing workability and uniformity in mixture and cement paste to hold the coarse aggregate particles in suspension.

Applications:

- For making concrete, light weight concrete, blast furnace slag
- The uses of aggregates can be summarized in to the following three categories
  - As a Load Bearing Material
  - As a Filling Material
  - As an Infiltrating Material
- To provide a rigid structure
- To reduce the shrinkage and cracking.
- Concrete aggregate is used in many structures and substructures e.g. different elements of a Building, bridges and foundations.
- The smaller the aggregate size the greater its surface area and the more binding material (cement) will be required, resulting in a higher cost.
- The greater the aggregate size the larger will be the voids, resulting in wastage of binding material (cement).
- Light weight aggregates are used as road metal, ballast for railway sleepers etc.

3. Sand

It is an important building material. It consists of small rounded or angular grains of silica SiO2 and is formed by the decomposition and disintegration of and stone under the actions of weather such as wind, rains frost etc. It forms a major ingredient in concrete, lime mortar, cement mortar etc.

4. Concrete

Concrete = Cement + Sand + Aggregate + Water + Admixtures + Air. Certain other materials are added to obtain specific effects it's known as Admixtures. By suitably adjusting the proportions of various ingredients, concrete with sufficient compressive strength for various purpose can be developed. The ultimate strength and other proportions of concrete depends on the materials used. It is the most important material used in the Civil Engineering Field.

Applications:

- Concrete is used extensively for construction of foundations, walls, beams, columns, slabs, roofs, false ceilings, lintels, staircase units etc.
- It is used to construct driveways, basement, sidewalks, parking areas, barn floors, curbs silos, skyscrapers, swimming pools etc.
- It is also useful in construction of dams, roads, bunkers, tunnels, water tanks, shells, domes, retaining walls, bridges, highways etc.
- It is required in construction of railway sleepers, electric poles, fencing poles, long span roots, industrial buildings etc.

5. Perlite & Perlite Aggregates

Perlite is a 100% natural siliceous volcanic glass mineral, which traps crystalline water into its mass. Perlite expands when rapidly heated in factory, in temperatures of 800°C– 1,000°C. The abrupt, controlled rise of temperature forms a white mass of minuscule glass bubbles. Perlite melts and expands in an extremely porous surface and increasing its volume thirteen times. Perlite Plaster lightweight aggregate has superior thermal and acoustic insulation properties, extreme lightness and it is non-combustible.

Advantages:

1. Lightweight – Weigh approximately 60% less than ordinary sand plasters, saving about one (1) ton for every 85 m2 of material applied in 13mm thickness.
2. Insulating – 4 to 7 times more resistant to heat transmission than sand plasters. Permit savings in heating and air conditioning costs, conserves energy.
3. Fire retardant – Non-combustible and non-toxic. Provide up to 5-hour fire protection with minimum weight and thickness, more than 50 fire tested designs by recognized laboratories.
4. Noise reduction – reduce sound transmission between partitions.
5. Adaptable – Perlite Plaster is packaged in 100 lit. Bags, easy to measure, mix and handle, job mixing permits proper proportioning to meet different plaster based materials specifications.
6. Durable – Cannot rot or decay, strong but not brittle, endure freeze thaw exposure, successfully used on major construction projects since 1946.

3. TEST METHODS FOR CONVENTIONAL AND ADDITIONAL CONSTRUCTION MATERIALS

1. Standard Consistency Test (IS-4031 (Part – V) 1995)
2. Slump Cone Test (IS-4031 (Part – V) 1995)
3. Compression Strength (IS-4031 (Part – V) 1995)

4. CONCRETE MIX DESIGN USING M-25 GRADE CONCRETE

(A) Design Stipulations:

Table 1 Mix Design

1	Characteristic Compressive Strength Required in the field at the age of 28 days :	31.6 N/mm^2
2	Maximum Normal Size of Aggregates	20 nm
3	Degree of Workability	Medium
4	Method of Compaction	Vibration
5	Degree of Quality Control	Good
6	Type of Exposure	Moderate

(B) Test Data for Material Used:

Table 2. Test Data for Material Used in Normal Concrete Mix Design

Sr. No.	Test Method As per IS	Parameters	Results	Limits as per IS: 12269 - 1987
1	-	Type of Cement	Ultratech 53 Grade	-
2	4031-Part 4	Consistency	28.0%	-
3	4031 – Part 11	Sp. Gravity	3.15	-
4	4031 – Part 1	Fineness by Blain Air Permeability	287 m^2/kg	Min. 225 m^2/kg
5	4031 – Part 5	Setting Time		
		Initial	68 min.	Not less than 30 min
		Final	196 min.	Not more than 600 min
6	4031 – Part 3	Soundness by Le-Chatelier Method	1.3 mm	< 10mm
7	4031 – Part 6	Compressive Strength kg/cm^2 (Avg. of 3 Cubes)		
		3 days	273 kg/cm^2	Min. 270 kg/cm^2
		7 Days	377 kg/cm^2	Min. 370 kg/cm^2
		28 Days	241 kg/cm^2	Min. 530 kg/cm^2

(C) Fine Aggregate:

Table 3 F.A in Normal Concrete Mix Design

Sr. No	Type of Test	Test Method	Test Parameter	Test Result	Specification IS:383
1	Particle Size Distribution	IS:2386 (P-1)	Fineness Modules	2.41	-
2	Sp. Gravity and Water Absorption	IS:2386 (P-3)	Sp. Gravity	2.62	-
			Water Absorption (%)	1.46	-

(D) Coarse Aggregate

Table 4 C.A in Normal Concrete mix Design

Sr. No	Type of Test	Test Method`	Test Parameters	Test Result		Specification IS:383
				20 mm	10 mm	
1	Particle Size and Shape	IS:2386(P-1)	Flakiness Index & Elongation Index (%)	23.6	25.4	-
2	Sp. Gravity	IS:2386(P-3)	Sp. Gravity	2.86	2.75	-
3	Water Absorption	IS:2386(P-3)	Water Absorption (%)	0.69	0.86	-
4	Mechanical Properties	IS:2386(P-4)	Impact Value (%)	15.4	12.8	Max. 30.00

- Targeted Mean Strength of Concrete : 31.6 N/mm^2
- Max W/C Ratio by Weight : 0.48

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(E) Material Required

Table 5 Material Required in Normal Concrete Mix Design

Sr. No	Type of Material	Per m^3 of Concrete (kg)
1	Cement	365
2	Fine Aggregate – Sand	713
3	Coarse Aggregate – 10 mm	495
	Coarse Aggregate – 20 mm	729
4	Water	175

(F) Proportion of Material

Water : Cement : FA : 20mm : 10mm = 0.48 : 1 : 1.95 : 2.00 : 1.36

(G) Compressive Strength

Table 6 Compressive Strength at 7 days

Sr. No.	Kind of Specimen	Identity Mark	Size (cm*mc*cm)	Load (KN)	Compressive Strength (N/mm^2) (7 Days)
1	Concrete Cube	M – 25	15 * 15 *15	525.37	23.35
				550.80	24.48
				527.85	23.46
		Average of 3 Cubes			**23.76**

Table 7 Compressive Strength at 28 days

Sr. No.	Kind of Specimen	Identity Mark	Size (cm*mc*cm)	Load (KN)	Compressive Strength (N/mm^2) (7 Days)
1	Concrete Cube	M – 25	15 * 15 *15	723.38	32.15
				739.35	32.86
				745.20	33.12
		Average of 3 Cubes			**32.71**

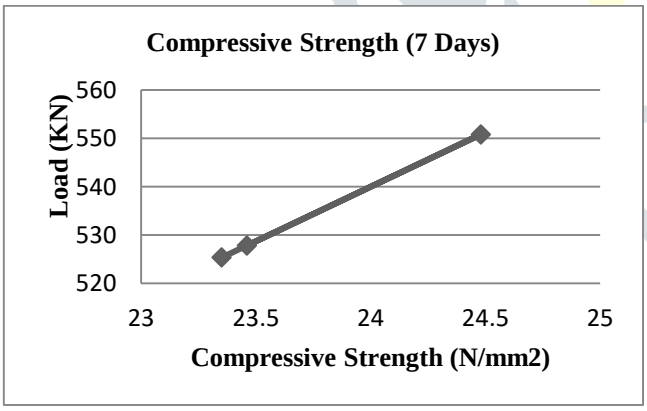

Figure 2 Compressive Strength at 7 days

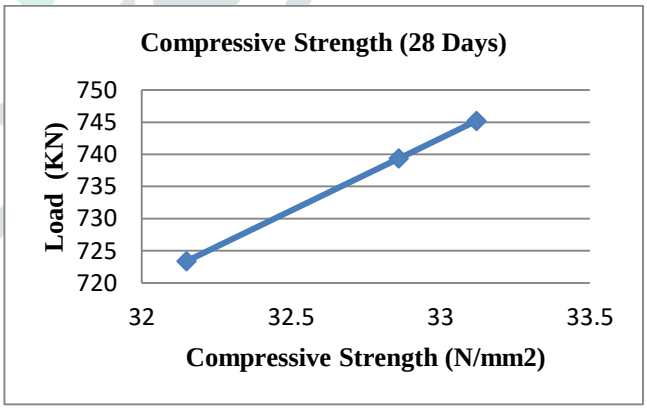

Figure 3 Compressive Strength at 28 days

5. CONCRETE MIX DESIGN USING PERLITE POWDER AS 20% REPLACEMENT OF M-25 GRADE CEMENT

(A) Design Stipulations:

Table 8 Mix Design

1	Characteristic Compressive Strength Required in the field at the age of 28 days :	31.6 N/mm^2
2	Maximum Normal Size of Aggregates	20 nm
3	Degree of Workability	Medium
4	Method of Compaction	Vibration
5	Degree of Quality Control	Good
6	Type of Exposure	Moderate

(B) Test Data for Material Used:

Table 9. Test Data for Material Used in Concrete mix with perlite powder

Sr. No.	Test Method As per IS	Parameters	Results	Limits as per IS: 12269 - 1987
1	-	Type of Cement	Ultratech 53 Grade	-
2	4031-Part 4	Consistency	28.0%	-
3	4031 – Part 11	Sp. Gravity	3.15	-
4	4031 – Part 1	Fineness by Blain Air Permeability	287 m^2/kg	Min. 225 m^2/kg
5	4031 – Part 5	Setting Time		
		Initial	68 min.	Not less than 30 min
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7	4031 – Part 6	Compressive Strength kg/cm^2 (Avg. of 3 Cubes)		
		3 days	273 kg/cm^2	Min. 270 kg/cm^2
		7 Days	377 kg/cm^2	Min. 370 kg/cm^2
		28 Days	241 kg/cm^2	Min. 530 kg/cm^2

(C) Fine Aggregate:

Table 10 *F.A in Concrete mix with perlite powder*

Sr. No	Type of Test	Test Method	Test Parameter	Test Result	Specification IS:383
1	Particle Size Distribution	IS:2386 (P-1)	Fineness Modules	2.41	-
2	Sp. Gravity and Water Absorption	IS:2386 (P-3)	Sp. Gravity	2.62	-
			Water Absorption (%)	1.46	-

(D) Coarse Aggregate

Table 11 C.A in Concrete mix with perlite powder

Sr. No	Type of Test	Test Method`	Test Parameters	Test Result		Specification IS:383
				20 mm	10 mm	
1	Particle Size and Shape	IS:2386(P-1)	Flakiness Index & Elongation Index (%)	23.6	25.4	-
2	Sp. Gravity	IS:2386(P-3)	Sp. Gravity	2.86	2.75	-
3	Water Absorption	IS:2386(P-3)	Water Absorption (%)	0.69	0.86	-
4	Mechanical Properties	IS:2386(P-4)	Impact Value (%)	15.4	12.8	Max. 30.00

- Targeted Mean Strength of Concrete : 31.6 N/mm^2
- Max W/C Ratio by Weight : 0.48

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(E) Material Required

Table 12 Material Required in Concrete mix with perlite powder

Sr. No	Type of Material	Per m^3 of Concrete (kg)
1	Cement	292
2	Fine Aggregate – Sand	713
3	Coarse Aggregate – 10 mm	495
	Coarse Aggregate – 20 mm	729
4	Water	175
5	Perlite Powder	73

(F) Proportion of Material

Water : Cement : FA : 20mm : 10mm : Powder = 0.48 : 0.80 : 1.95 : 2.00 : 1.36 : 0.20

(G) Compressive Strength

Table 13 Compressive Strength at 7 days

Sr. No.	Kind of Specimen	Identity Mark	Size (cm*mc*cm)	Load (KN)	Compressive Strength (N/mm^2) (7 Days)
1	Concrete Cube	M – 25	15 * 15 *15	408.60	18.16
				440.10	19.56
				436.05	19.38
		Average of 3 Cubes			**19.03**

Table 14 Compressive Strength at 28 days

Sr. No.	Kind of Specimen	Identity Mark	Size (cm*mc*cm)	Load (KN)	Compressive Strength (N/mm^2) (7 Days)
1	Concrete Cube	M – 25	15 * 15 *15	569.7	25.32
				632.7	28.12
				605.7	26.92
		Average of 3 Cubes			**26.79**

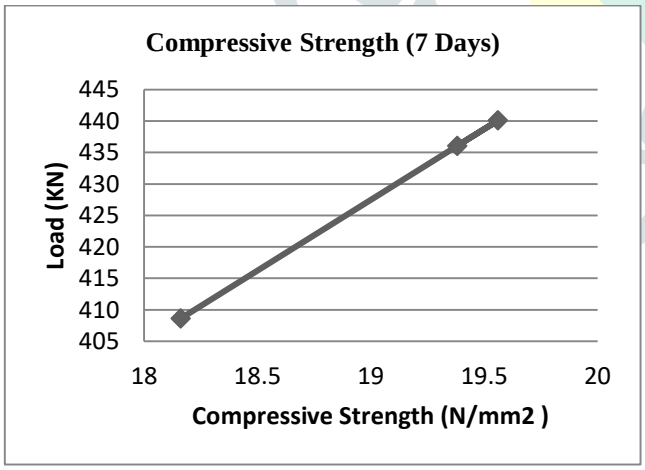

Figure 4Compressive Strength at 7 days

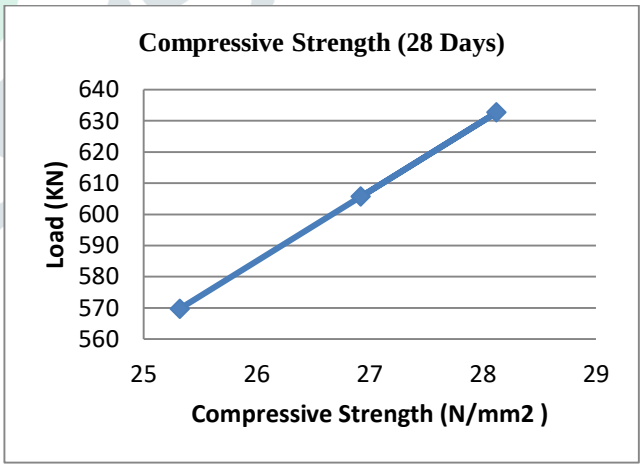

Figure 5 Compressive Strength at 28 days

CONCLUSION:

Compressive Strength in Perlite Concrete gives unsatisfactory results, because the bonding of cement and perlite powder is not strong enough rather than the Normal Concrete Mix Design. 80% replacement of cement by perlite powder can give better result and prediction can be done based on the derived results. So concrete mix with perlite can be use at small scale and temporary constructions.

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