GEOPOLYMER BASED LIGHT WEIGHT MASONRY BLOCKS USING WASTE EXPANDED POLYSTYRENE AND P.E.T. BOTTLE FIBERS

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Abstract : The demand of house for residential purpose increases with increasing population, Mass housing targets cannot be achieved by conventional burnt clay brick Due to its high production cost, environmental polluting production process and raw material obtained from natural resources and due to all that reason this conventional burnt clay brick become un-sustainable.

To develop a sustainable choice we have to develop a material whose production doesn't causes pollution and utilizes waste material. the following material was identified as waste but works perfectly as raw material for masonry blocks are:-

1. Geopolymer binder
2. Expanded polystyrene
3. PET bottles

The geopolymer is one which is the most sustainable replacement for cement because production of ordinary Portland cement releases a very high amount of carbon di oxide, during production more than fifty percent of carbon di oxide releases in calcination of lime out of total carbon di oxide release during whole production process, the amount of carbon di oxide released is approximately equal to amount of cement produce.

Expanded Polystyrene (EPS) is a lightweight, rigid cellular plastic that is made from the polymerization of styrene monomer while styrene is a liquid hydrocarbon that is commercially manufactured from petroleum. The expanded polystyrene is a single use plastic it does not have any scrap value therefore after use it is dumped in a dump yard or disposed in land fill. It is considered as possible human carcinogenic by International Agency for Research on Cancer and it also have ability to soak chemicals.

Beverage bottles made from polyethylene terephthalate (P.E.T.) is also a single use plastic producing trash and possible human carcinogenic. It is not decomposable it exists in environment for more than 500 years.it makes land barren it pollutes ocean and disturbs marine ecosystem.

In this research work the light weight masonry blocks was developed using all materials discussed above and using geopolymer as base binding material and crushed expanded polystyrene as filler and fibers of p.e.t. bottle to provide toughness. Due to expanded polystyrene filled matrix of geopolymer the product gains sound and thermal insulating properties, the product becomes light weight due to which its transportation cost reduces, imposed load on structure reduces which leads to cost reduction, the effect of lateral load can also reduce, it reduces trash, and does not causes pollution

Index Terms **– Lightweight Brick, Lightweight Blocks, Geopolymer Bricks, Geopolymer Blocks, P.E.T. fibres, PET Fibres, Polyethylene Terephthalate Fibres, Waste Thermocol, Waste Expanded Polystyrene, Waste Styrofoam, and Waste EPS.**

1. INTRODUCTION

India is a developing country and its infrastructure is developing rapidly but these different development activities are leaving huge negative impacts on environment such as:-

- Different type of Pollution's
- Decreasing green cover
- Generation of Waste
- Greenhouse gases emission
- Deforestation
- Ozone depletion
- Global warming

For solving all this issues without interrupting the development of our country, we have to work out smartly for decreasing these negative effects on environment causes due to different development activities takes place in our country.

While studying master of engineering at samrat ashok technological institute we identify a solution for decreasing these negative effects on environment caused due to development I decided to develop a light weight masonry blocks which is light weight, provides thermal insulation, economical and eco-friendly these blocks are made up of waste expanded polystyrene, geopolymer binder, fibers of PET bottle and sand.

1.1. Characteristics of GPC Based Light Weight Blocks

Light-weight : For protecting our green cover and fulfilling demand to increasing population we have to move toward multi storied building and in multi storied building dead load is an factor of key importance due to high dead load on top story the structure start oscillating due to seismic action and to counteract these forces a high percentage of reinforcement is required, while The typical

structure of these blocks having expanded polystyrene balls enclosed in geopolymer matrix resulted in light-weight blocks. Their weight is only half the density of clay bricks which makes them easy to handle on-site. Reduced weight of the brick decreases the dead weight on the structure, hence these bricks are ideal for low load bearing soil and for seismic zones. Even for building additional floors in an existing building, these blocks are perfect choice as their light weight will not affect the stability of the structure. Using these bricks from the foundation stage of the building helps to save substantial amounts of concrete and steel. Using these light weight blocks decreases dead load on structure and thus less reinforcement required which makes our structure economical.

Fire resistance: Walls build with these bricks, with a minimum thickness of 100 mm can resist fire for up to four hours because it is made up of geopolymer mortar which makes them the safe choice in construction. Especially for commercial, industrial and restaurants, where vulnerable to fire accidents, these blocks are of much help.

Sound insulation: One more interesting characteristic of these bricks is their sound insulation. Which made them ideal for wall construction in hotels, auditoriums, hospitals, etc., where sound insulation is quite essential?

Thermal insulation: Due to the closed cell structure of these blocks, they provide excellent thermal insulation. They help interiors to remain cooler during summer and warmer during winter which further aid the user to save electricity bills and thus help in conserving natural resources.

Curing: Geopolymer does not require water curing; the curing of this type of blocks should be done at ambient room temperature for 7 days or in hot air oven for 24 hours at 60-70 degree Celsius. This makes it the most appropriate for production in hot climate regions where availability of water is less or faster production rate should also be obtained.

Eco friendly : The major portion of raw material used in this blocks are industrial discards, which decreases its cost and utilizes pollution causing industrial waste such as expanded polystyrene, fly ash, fibers made up of discarded P.E.T. bottle.

1.2. Problem Statement

Environment Vs Cement: Concrete is one of the generally used artificial development materials and its uses is second just to water. Portland cement is the most preferable cementitious ingredient in concrete. Production of cement is not only energy intensive, but also responsible for emission of carbon dioxide (CO2) in environment. The production of one ton of cement releases approximately an equal quantity of CO2 to the atmosphere and for the production of one ton of cement approximately 94.76 x 106 Joules of energy is required.

The Cement production has been increasing every year. An estimate according to IBEF (Indian brand equity foundation) shows that in year 2018 India was the second largest cement producer in the world with nearly 502 million tons per year cement production, and it may rises to 550 -600 million tons per year in year 2025 The world Earth Summits held in 1992 and 1997 expressed its concern about the unchecked and increased emission of greenhouse gases to the atmosphere., according to think tank Chatham House The quantity of CO2 produced due to cement manufacturing contributes to about 8% of the world's carbon dioxide (CO2) emissions. If an alternate material to ordinary Portland cement is used in concrete, the corresponding CO2 release to the atmosphere can be reduced.

In India, three fourth power generation is through coal fueled power plant and it's by product- fly ash- is an environmental threat to the public, if not disposed properly. According to mission energy foundation in year 2018 approximately 210 metric ton of fly ash generated in India but out of which only 59 percent is utilized and the rest quantity is disposed in ash ponds or lagoons. Deposition of the fly ash in storage places can have a negative influence on water and soil because of its 2-granulometric and mineral composition as well as morphology and filtration properties. Therefore the safe disposal of fly ash is still a major concern. There are various methods to reduce the consumption of cement in concrete, like the partial replacement of cement with cementitious materials. However, partial replacement of cement with supplementary materials in concrete reduces the release of CO2 gas only to a limited extent, and a complete replacement is always preferable.

Expanded Polystyrene Vs Environment: In 1941 scientist Otis Ray McIntire invented expanded polystyrene and it was marketed in United States under the name Styrofoam and in India it is popular as thermocol. It is basically polystyrene and it is a polymer made from the monomer styrene, styrene is a liquid hydrocarbon that is commercially manufactured from petroleum. In India there is a massive volume of Expanded Polystyrene generates every day and their major source is electronic appliances and fragile goods packaging accompaniment such as that of air conditioners, televisions, refrigerators etc. However, the drawback is that the material cannot be reused as it holds zero scrap value and is often dumped or burnt down. When it comes in contact of marine environments it contaminates water by leaching chemicals which is carcinogenic on other side marine creatures like fish, snake etc. eat these pallets of polystyrene in confusion of food which may leads to clogging of respiratory system. Chemically absorbent properties make Expanded Polystyrene more dangerous. It can also harm terrestrial animals that scavenge food from landfills. Styrofoam products have the tendency of easily breaking apart into small pieces making it a choke hazard to animals. In India water logging is the major problem in rainy season and expanded polystyrene is one of the major causes of water logging because it floats on water and storms water takes these waste expanded polystyrene from dumps to drains which may leads to water logging. Expanded polystyrene does not degrade or break down over time and it is also not known how long does it takes for polystyrene to biodegrade. Some experts estimate the decomposition of expanded polystyrene can takes up to 500 years. Expanded polystyrene can be disposed if it is incinerated at extremely high temperatures, this residues only a small amount of water and carbon as by products. However if it is burned in a normal fire instead of in a specialized incinerator, it releases pollutants such as carbon black, carbon monoxide and carcinogenic fumes.

International Agency for Research on Cancer considers styrene a "possible human carcinogen" and those materials can have serious impacts upon human health, wildlife, and aquatic environment, and the economy. When expanded polystyrene used with food products, especially when with hot food, expanded polystyrene releases toxic chemicals into the food causing a contamination which can be hazardous to human as well as animal health In addition, when exposed to sunlight, Styrofoam creates harmful air pollutants which contaminate landfills and deplete the ozone layer. Styrofoam is one of the most environmentally unfriendly types of waste that exist today. It remains on this earth forever as a piece of toxic trash to humans, to wildlife and marine life, food supply, and our environment while costing taxpayers millions in clean up and mitigation costs While Expanded

Polystyrene is technically "recyclable" there is, to date, no meaningful recycling of Expanded Polystyrene or Styrofoam due to high food contamination rates and a very weak market to clean, handle and process the material.

Beverages Bottles Vs Environment : According to surveys approximately one million plastic bottles are bought every minute around the world and this value gets an increment of another 20% by 2021, if it is not controlled it creates an serious environmental crisis and it may be as serious as climate change and according to a news published in the guardian "This demand of about 20,000 bottles being bought every second, is driven by an apparently insatiable desire for bottled water and the spread of a western, urbanized "on the go" culture to China and the Asia Pacific region". According to estimates from Euromonitor International's global packaging trends report if we placed this bottles placed end to end, they would extend more than halfway to the sun and Around 13 million tons of plastic are dumped into the oceans across world each year and it is ingested by sea birds, fish and other organisms and this fishes are eaten by seafood lovers and with this seafood they ingest plastics also and according to an estimates in year 2050 the ocean will contain more plastic by weight than fish. Then landfills are another of major sink for plastic bottles globally but landfill is advantageous then dumping in ocean because plastic within them are stationary and accessible but it due to plastic land becomes barren. There are Millions of tons of plastic waste end up in our oceans, littering our beaches, suffocating marine life and contaminating our seafood.

The plastic pollution rivals the threat of climate change as it pollutes every natural system. A survey report shows The amount of plastic produced in a year is roughly the same as the entire weight of humanity plastic production has grown faster than any other material. Single-use packaging of beverages is a part of our daily life and significant contributor to the marine litter that has become a global crisis. These plastic bottles are commonly made from polyethylene terephthalate (Pet), and researches shows that it takes approximately 400 years to naturally decompose. Our goal is to work out to develop an useful material with this waste bottles to reduce the increasing risk of plastics in our environment and the harmful consequences that lie therein. These beverages bottles are made to stay in very high pressure therefore fibres made from these bottles have very high tensile strength thus its inclusion in concrete proves to be very effective because concrete is weak in tension.

Imposed Loads Vs Economy: There is different type of loads acting on a structure on horizontal and vertical direction. Imposed load is load which acts on vertical direction the load due to floor finish, partition walls, infill walls, furniture, false ceiling, person living there and any other equipment. This load may not be permanent. The Indian standard 875-1987 (part-2) gives us a brief estimation about imposed load. Every structure has some or more amount of imposed loads depending upon purpose of structure. The contribution of masonry work on imposed load is approximately fifty percentage or more. There is one more other secondary effect called p-delta. If imposed load on building increases p-delta effect also gets increases. Due to more imposed load building starts oscillating on application of lateral load or seismic effect which is known as seismic drift and to counteract all this effects the more percentage of reinforcement required which leads to un-economical design. To counteract this imposed load or the shear force, bending moment, and torsion due to imposed load structural designer have to provide some extra percentage of reinforcement depending on calculations this percentage of reinforcement gets increased or decreased with increase and decrease in intensity of imposed load respectively. And as we all knows the cost of reinforcement bars is highest among all construction material therefore the amount of reinforcement is governing factor for economy of construction.

2. OBJECTIVE OF STUDY

This study was carried out for the following objectives:-

1. For development of low cost, light weight and eco-friendly substitute for traditional bricks
2. For finding out most optimum proportion of material used.
3. For finding out required mechanical properties according to Indian standards.
4. For finding out required physical properties according to Indian standards.
5. For finding out advantages of developed product over traditional bricks.

3. MATERIALS USED

3.1. Fly Ash

The combustion gases which is going to exit through chimneys in environment, the dust collection system filter outs Fly ash with motive to protect environment from these dust, the dust collection system are of two types mechanical and electrostatic precipitators, The relative amounts of matter left incombustible from coal is responsible for chemical composition of fly ash. The chemical composition of fly ash mainly consist oxides of silicon (Sio_2), alumina (Al_2o_3), iron (fe_2o_3), and calcium (CaO), whereas magnesium, potassium, sodium, titanium, and sulphur are also present in a lesser amount**.** In the present experimental work, low calcium, fly ash (ASTM CLASS F) were collected from the Electrostatic precipitators of the SARNI THERMAL POWER PLANT IN M.P. (India), was used as the base material for geopolymer.

Table 3.1. Chemical properties of Fly ash

S.No.	Particulars	Proportion (%)
1.	Silicon dioxide(SiO_2)	67.35
2.	Aluminium oxide ($Al2O_3$)	22.80
3.	Iron oxide($Fe2O_3$)	5.55
4.	Calcium oxide (CaO)	1.21
5.	Magnesium oxide(MgO)	0.07
6.	Potassium oxide(K_2O)	1.29
7.	Sodium oxide(Na_2O_3)	0.0001
8.	Titanium dioxide(TiO_2)	1.38
9.	Loss on ignition (LOI)	3.30

Fig 3.1. Fly Ash

Table 3.2. Physical Properties of Fly ash		
S.No.	**Particulars**	**Test Result**
1	Colour	Light grey
2	Fineness	430 m^2/kg
3	Particle size	5-10 µm
4	Specific gravity	2.15
5	Bulk density	1440 kg/m^3
6	Particle shape	Spherical

Fig 3.2. Water

3.2. Water

In this research work Ordinary potable water was used which is free from salt, turbidity and organic content this water is supplied through bore well present in campus to overhead tank of civil engineering department.

3.3. Fine Aggregate

Fine aggregates are responsible for decreasing shrinkage cracking it is one of the main ingredients of the geopolymer concrete it act as filler material, it decreases quantity of fly ash required which ultimately increases economy. As per IS:383 1970 sand which will passes through 4.75 mm IS sieve and retained over 75 µM IS sieve is known as fine aggregate. The grain size of sand used in this research work is lower than 4.75 mm and grater then 75 µM. In this research work locally available river sand was used which was obtained from river Narmada, locally it is known as Narmada sand.

Table 3.3. Physical properties of fine aggregate (IS: 2386-1963)		
S.No.	**Properties**	**Results**
1	Type	Natural
2	Shape	Rounded
3	Size	4.75 mm below
4	Specific gravity	2.60
5	Bulk Density (Kg/m3)	1570 kg/m^3
6	Moisture content	1.0%
7	Fineness:% retained on 45 mm sieve	28
8	Water absorption	0.5%
9	Fineness modulus	3.182

Fig 3.3. Sand

Table 3.4. Fineness modulus of fine aggregates Sieve					
S.No.	**size**	**Weight retained**	**Weight retained**	**Cumulative weight retained**	**Cumulative weight passing**
	(mm)	**(gm)**	**%**	**%**	**%**
1	10	0	0	0	100
2	4.75	6	0.6	0.6	99.4
3	2.36	6	0.6	1.2	98.8
4	1.18	10	1	2.2	97.8
5	0.6	375	37.5	39.7	60.3
6	0.3	423	42.3	82	18
7	0.15	103	10.3	92.3	7.7
8	0.075	77	7.7	100	0
Fineness modulus = 318.2/100 = 3.182					

3.4. Waste Polyethylene Terephthalate Bottle Fibres

The waste Polyethylene terephthalate (p.e.t.) bottle are collected from different sources such as college canteen, restaurants, marriage party after collection they are washed to remove oil and debris from surface then they are cut into strips and fibres with the help of scissors

Table 3.5. Physical properties of Polyethylene terephthalate		
S.No.	**Parameters**	**Properties**
1	colour	transparent
2	density	970 kg/m^3
3	Melting point	260 ^0c
4	size	2 mm x 4 mm, 1.5 mm x 4 mm
5	Aspect ratio	6-8
6	Shape	Rectangular strips

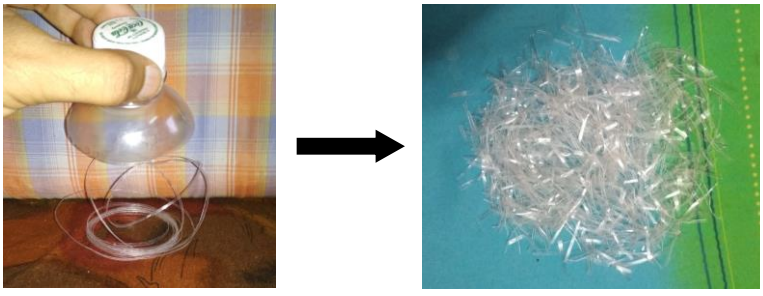

Fig 3.4. How Pet Bottle Fibres Are Made

3.5. Waste Expanded Polystyrene

The waste packaging of expanded polystyrene are collected from different sources such as electronic shop, crockery shop, etc. after collection they are washed to remove oil and debris from surface and then they are grinded in mixer grinder in order to obtain small pallets of expanded polystyrene.

Fig 3.5. Preparation Process For Eps Pallets From Waste Eps

Table 3.6. Physical properties of expanded polystyrene pallets		
S.No.	**Parameters**	**Properties**
1	colour	white
2	density	67 kg/m^3
3	Melting point	100 ^0c
4	diameter	2-4 mm

3.6. Alkaline Activators

The combination of sodium silicate and sodium hydroxide in water in a definite proportion is known as alkali activators. For purpose of economy Sodium-based solutions were preferred because they were cheaper than potassium-based solutions.

A. sodium hydroxide (Naoh)

Generally, the sodium hydroxides are available in solid state in form of pellets and flakes. The cost of the sodium hydroxide is mainly dependent on purity of the substance. The sodium hydroxide (NAOH) solution was prepared by dissolving the flakes in water. The mass of NAOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar (M).

For 12.5 molarity solution = (12.5 X 40) = 500 gm of NAOH flakes/lit water.

Fig 3.6. Sodium Hydroxide

Table.3.7. Properties of sodium hydroxide (NAOH)		
S.No.	**Parameters**	**Properties**
1	Chemical formula	NAOH
2	Molecular weight	40 gms
3	Specific gravity	2.12
4	PH	12
5	Color	White opaque

Table.3.8. Chemical properties of sodium hydroxide		
S.No.	**Chemical Properties**	**Percentage (%) By Mass**
1	Carbonate (Na_2CO_3)	2
2	Chloride(Cl)	0.001
3	Sulphate(So_3)	0.05
4	Potassium(K)	0.1
5	Silicate(SiO_2)	0.05
6	Zinc(Zn)	0.02
7	Heavy Metals as(Pb)	0.002
8	Iron(Fe)	0.002
9	Minimum Assay	97
10	Molarity	30

Fig 3.7. Alkali Activator Solution

B. sodium silicate (Na2Sio3)

Water glass or liquid glass is other common names of Sodium silicate, it is available in liquid (gel) and solid both form. In this study sodium silicate in solid crystalline form is used.

Table.3.9. Chemical and Physical properties of sodium silicate(Na2SiO3)		
S.No.	**Parameters**	**Properties**
1	Chemical formula	NA_2SIO_3 colour less
2	Na_2o	15.9%
3	Sio_2	31.4%
4	H_2o	52.7%

Fig 3.8. Sodium Silicate

Table.3.10. Physical properties of sodium silicate (Na_2SiO_3)		
S.No.	**Parameters**	**Properties**
1	Appearance	SOLID CRYSTILLINE
2	Specific gravity	1.6
3	Molar mass	122.06 g/mol
4	Colour	Light yellow
5	Boiling point	102^0C

4. METHODOLOGY

4.1. Proportioning

The following proportion of mix design was used in this research work

Table.3.12. MIX PROPORTION FOR 1 M^3

Material	Unit	With Sand		Without Sand		Without E.P.S, P.E.T. And Sand
		SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5
Fly ash	kg	350	450	600	890	1100
Sand	kg	250	450	0	0	0
EPS volume	Cum	0.45	0.35	0.45	0.35	0
EPS weight (dry)	kg	26.9	23.45	27.9	23.45	0
PET fibre	kg	10.5	15.9	10.5	15.9	0
NA_2SIO_3	kg	87.5	132.5	123.8	182.5	240
NAOH	kg	35	53	49.5	73	96
water	litre	70	106	99	146.2	192
Solution in litre	Litre	140	212	198	293.4	384
fly ash to Solution	ratio	0.40	0.40	0.33	0.33	0.32

4.2. Batching and Mixing

Raw materials such as Waste pet bottle fibers, fly ash, fine aggregates, pallets of waste expanded polystyrene, and alkali activated solution was prepared and weighted according to the design mix. Then these materials were mixed either in mixer machine or by hand mixing. Mixing was continued for until it becomes homogeneous. After when mixture achieved their homogeneity, firstly it is tested for workability by means of Slump Cone Test & then the mold was cleaned and a layer of oil is applied on inner surface of molds and then the mixture was poured into the molds.

4.3. Casting

The fresh concrete is poured, tampered and compressed in molds. Further compaction was done by vibrating table. The procedure of mixing and casting is similar to conventional concrete Cubes. Size of cube specimen is 15 cm x 15 cm x 15

4.4. Vibrating

Vibration are generally provided to concrete in order to remove void spaces present in fresh mixture these void may leads to decrease in strength of concrete. The cube was vibrated on vibration table but in this research the compaction was obtained using tempering rod because due to vibration of more than 1 minute on vibrating table causes the expanded polystyrene pallets to floats upward and fly ash slurry settles down.

4.5. Curing

After demoulding the cube the next step is curing. The curing method of geopolymer based concrete is completely different than conventional concrete because it does not requires water for curing, it requires heat for curing. The following ways are adopted for curing of geopolymer based concrete:-

1. Hot air oven curing
2. Ambient temperature curing

In this research work the specimen was tested for both type of curing. Both type of curing has its own advantage and disadvantage. Hot air oven curing provides full strength gain in just 7 days curing but it requires hot air oven.

Fig 3.9. Mixture Poured In Cube

Fig 3.10. Hot Air Oven Curing

Fig 3.11. Ambient Temperature Curing

4.6 Testing Specimen For Compliance With Indian Standard2185 (Part 4) 2008 And 2185 (Part 3) 2008

To test the product for compliance with indian standard, We have tested these blocks for following mechanical properties

1. Compressive Strength Test According To Is 516-1959
2. Workability According To Is 1199-1959
3. Water Absorption According To Is 3495-2-1992
4. Density

Fig 3.12. while conducting compressive strength test

Fig 3.13. cube floats on water

Fig 3.14. Cubes After Compressive Strength Test

Fig 3.15. Weight Of Cube Size 150mm X 150mm X 150mm

Fig 3.16. Brick of Size 190mm X 90mm X 90mm

5. RESULTS AND DISCUSSION

5.1. Compressive Strength (IS 516-1959)

Concrete cubes of size 150 mm x 150 mm x 150 mm were casted for different proportion of waste expanded polystyrene. Then after 24 hours, the specimens were demoulded and the curing of cube was started here two method for curing was employed.

1. Ambient Heat Curing
2. Hot Air Oven Curing

In ambient curing the curing should be done in sunlight available in open ground at day time for 28 days. While for hot air oven curing the curing of cubes is done in hot air oven for 24 hours and tested this cubes on 7th day. Results obtained after compressive strength tests of cubes are as follows:-

Table 5.1. Compressive strength of cube cured for 28 days in ambient temperature

S. No.	Sample no.	Avg. load at failure	Cross-Sectional Dimension of specimen	Compressive strength at 28 days
		(KN)	(mm)	(N/mm^2)
1.	SAMPLE 1	85	150 X 150	3.77
2.	SAMPLE 2	210	150 X 150	9.33
3.	SAMPLE 3	90	150 X 150	4.00
4.	SAMPLE 4	190	150 X 150	8.44
5.	SAMPLE 5	890	150 X 150	39.5

Table 5.2. Compressive strength of cube after 7 days of 24 hour oven curing

S. No.	Sample no.	Avg. load at failure	Cross-Sectional Dimension of specimen	Compressive strength at 7 days
		(KN)	(mm)	(N/mm^2)
1.	SAMPLE 1	80	150 X 150	3.55
2.	SAMPLE 2	215	150 X 150	9.55
3.	SAMPLE 3	100	150 X 150	4.44
4.	SAMPLE 4	210	150 X 150	9.33
5.	SAMPLE 5	930	150 X 150	41.33

Conclusion

From the above result it has been concluded that,

- The compressive strength decreases with increase in volume proportion of expanded polystyrene.
- The compressive strength decreases with increase in proportion of sand but simultaneously shrinkage cracking increases.

- The pet fibres acts as bridge in crack they are protecting cube from splitting.
- The compressive strength also increases with decrease in diameter of expanded polystyrene pallet.
- The compressive strength gain after hot air oven curing is comparatively more than 28 day ambient curing.
- The compressive strength obtained is in permissible limit according to Indian standard 2185 (part 4) 2008.

5.2. Workability (IS 1199-1959)

Slump cone test was performed to determine the workability of mortar made for geopolymer based light weight masonry block using waste expanded polystyrene & p.e.t. bottle fibres. The slump test was performed using standard sizes of slump cone apparatus as per Indian standard: 1199 – 1959.

Table 5.3. Slump test results

S. No.	Sample no.	Slump(mm)
1.	SAMPLE 1	68
2.	SAMPLE 2	64
3.	SAMPLE 3	82
4.	SAMPLE 4	70
5.	SAMPLE 5	55

Conclusion

From the above result it has been concluded that,

- The workability increases with increase in percentage of expanded polystyrene.
- The workability decreases with increase in percentage of pet fibres.
- The workability decreases with increase in percentage of sand.
- The workability decreases as the time lapse between alkaline activation solution preparation and mixing increases.

5.3. Water Absorption (3495-2-1992)

Water absorption of cube should be tested to determine permeability and porosity of cube it is expressed in percent by mass, the sample is immersed in water at ambient temperature for 24-hour and after that the weight gain is calculated by following formula:-

$[(M_2 - M_1)\backslash M_1] \times 100$

Where,

M_1 =dry weight before immersion

M_2= weight after 24 hour immersion

Table 5.4. water absorption test results

S. No.	Sample no.	Weight of sample before immersion in water (Kg)	Weight of sample after 24 hour of immersion in water (Kg)	Percentage water absorption
1.	SAMPLE 1	2.715	2.920	7.55
2.	SAMPLE 2	3.755	4.000	6.52
3.	SAMPLE 3	2.535	2.715	7.10
4.	SAMPLE 4	3.480	3.695	6.17
5.	SAMPLE 5	5.635	5.970	5.94

Conclusion

From the above result it has been concluded that,

- The water absorption increases with increase in proportion of sand.
- The water absorption increases with increase in proportion of expanded polystyrene.
- The water absorption percentage obtained is in permissible limit for all samples according to Indian standard 2185 (part-4) 2008.

5.4. Density of Geopolymer Concrete

Density of geopolymer concrete is a measure of its unit weight. The weight of geopolymer based light weight masonry block using waste expanded polystyrene & p.e.t. bottle fibres was measured two time firstly just after unmoulding and then after full curing.

Table 5.5. Density of different samples

S. No.	Sample no.	Avg. Mass after unmoulding (Kg)	Avg. Mass after curing (Kg)	Density (kg/m^3)
1.	SAMPLE 1	3.265	2.870	772.802
2.	SAMPLE 2	4.175	3.605	970.715
3.	SAMPLE 3	3.015	2.615	704.139
4.	SAMPLE 4	3.820	3.356	903.667
5.	SAMPLE 5	6.180	5.591	1505.49

Conclusion

From the above result it has been concluded that,

- The density decreases with increases in preposition of expanded polystyrene.
- The density decreases with decrease in alkaline activated solution ratio to fly ash.

6. CONCLUSION

Geopolymer is an ecofriendly binding Material. In production of geopolymer concrete carbon-di-oxide emission is comparatively very less as compared to concrete made using ordinary Portland cement. In these geopolymer based blocks fly ash gets utilized otherwise these fly ash creates trash and pollutes environment. The Beverage bottles and jars made up of (P.E.T.) polyethylene terephthalate which is responsible for leaching carcinogenic chemicals in water bodies and produces trash this polyethylene terephthalate bottles gets utilized. Expanded polystyrene which has no scrap value, which goes to landfill and produces trash it also leaches carcinogenic chemicals in water bodies, this expanded polystyrene gets utilized.

When the Ratio of Na2Sio3/NaOH increased then the strength of Geopolymer Based Light Weight Masonry Block also increases till an optimum ratio of 2.5. The 28 days compressive strength can be achieved in just 24 hours of hot air curing at 60-70 degree Celsius. Compressive strength of these blocks is 55-59 percent higher than Autoclaved Aerated concrete block of similar density prescribed in Indian standard 2185 part 4 : 2008 .

It does not requires water for curing therefore it saves water which is good for our environment. Due to its lightweight the imposed loads of masonry work on building gets reduced due to which less reinforcement required which leads to cost saving and due to its smooth and regular surface less mortar required in masonry work which also leads to cost saving. No plastering required on masonry wall and superior finish can also be achieved.

Due to its expanded polystyrene filled cellular structure this masonry blocks has good thermal insulation and sound insulation properties. The Manufacturing process of these blocks does not require any special equipment and special skills but precautions should be taken while handling sodium hydroxide and sodium silicate solution because this solution is highly caustic. Waste material gets utilized in its production which leads to cost saving and environment protection.

All the physical properties of this masonry blocks meets the criteria specified in Indian standard 2185 part 4 : 2008 and 2185 part 3 : 2008. As the waste material is used as raw material for these blocks therefore the cost of these blocks is rupees 5.75 for a brick of size 190 mm X 90 mm X 90 mm which is comparatively very low as compare to traditional burnt clay bricks (red bricks). Mass housing and low cost house under housing for all schemes can be achieved because of its light weight and low manufacturing cost.

This light weight block floats on water which shows that this block is lighter than water. These blocks are made up of geopolymer therefore these blocks are more durable in salty environment, it resists fire, it resists sulphate attack, it resists corrosion effectively then ordinary Portland cement based materials.

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8. REFERENCES

[1] S. S. Patil and A. A. Patil (2015) "Properties of polypropylene fiber reinforced geopolymer concrete" International journal of current engineering and technology , vol.5, no.4 (aug 2015).

[2] Mohammed rabbani nagral, Tejas ostawal Manoj kumar V. chitawadagi "Effect of curing hours on the properties of geo polymer concrete" International journal of computational engineering research(IJCER) vol 04.

[3] Subhash.v.Patankar et al ,"Mix design of Fly Ash based geopolymer concrete".

[4] Davidovits, J, "Soft Mineralogy and Geopolymers", Proceedings of the geopolymer 88 international Conference, the université detechnologie, compiègne, france, 1988.

[5] Davidovits, "what is a geopolymer? Introduction. Institute géopolymère, saint-quentin, france",2010.

[6] IS: 3812:1981 "Specification for fly ash for use as Pozzolana and admixture" code of practice Bureau of Indian standards, New Delhi.

[7] IS: 383:1970 "Indian standard specification for coarse and fine aggregates from natural sources for concrete" code of practice Bureau of Indian standards, New Delhi.

[8] IS 516:1959 "Indian standard methods of tests for strength of concrete" code of practice Bureau of Indian standards, New Delhi.

[9] IS 2386 (part 3) :1963 "Methods of test for aggregates for concrete: part 3 specific gravity, density, voids, absorption and bulking" code of practice Bureau of Indian standards, New Delhi.

[10] Dr. S. S. Amritphale, Navin chandra, Priya sharma, G. L. Pashkov, E.N. Voskresenskaya, Narendra S. Baghel "Coal fly ash utilization: low temperature sintering of wall tiles".

[11] Dr. Alka Mishra , Giriraj S. Mandloi, Anam khan, Ravi patidar, Avinash Singh, Asokan Pappu "Characterization of thermal power plant coal combustion residues".

[12] IS: 3495 (part 1) :1992 "Methods of tests of burnt clay building bricks" code of practice bureau of indian standards, new Delhi

[13] T.Subramani, A. Fizoor Rahman "An Experimental Study on The Properties of Pet Fibre Reinforced Concrete" International Journal of Application or Innovation in Engineering & Management (IJAIEM) Volume 6, Issue 3, March 2017 ISSN 2319 – 4847

[14] Subhash V. Patankar, Yuwaraj M. Ghugal and Sanjay S. Jamkar "Mix Design of Fly Ash Based Geopolymer Concrete" Springer India 2015,V. Matsagar (ed.), Advances in Structural Engineering

[15] B. Singh, M. Gupta, Monika Chauhan and S. K. Bhattacharyya "Lightweight Geopolymer Concrete with EPS Beads" CSIR-Central Building Research Institute; Roorkee-247667, India

[16] IS 10262:2009 "Concrete mix proportioning – guidelines" code of practice Bureau of Indian standards, New Delhi.

[17] IS 10262:2019 "Concrete mix proportioning – guidelines" code of practice Bureau of Indian standards, New Delhi.

[18] IS 2185 (part 3) : 2008 Indian standard concrete masonry unit specification for autoclaved aerated cellular blocks code of practice Bureau of Indian standards, New Delhi.

[19] IS 2185 (part 4) : 2008 Indian standard concrete masonry unit specification for preformed foam cellular blocks code of practice Bureau of Indian standards, New Delhi.

[20] Muhd Fadhil Nurruddin, Sani Haruna, Bashar S. Mohammed, Ibrahim Galal Sha´aban "Methods of curing geopolymer concrete: A review" International Journal of Advanced and Applied Sciences 5(1) 2018, Pages: 31-36.

[21] Ali Sadr Momtazi, Mir Alimohamad Mirghozar Langrudi, Akbar Khodaparast Haggi, Hadi Rasmi Atigh "Durability of Lightweight Concrete Containing EPS In Salty Exposure Conditions" ISBN 978-1-4507-1488-4.

[22] Partha Sarathi Deba, Pradip Natha, Prabir Kumar Sarkera 'Drying shrinkage of slag blended fly ash geopolymer concrete cured at room temperature" The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5) .

[23] Showkat Maqbool, Hemant Sood "Effect of PET fibers on the Performance of concrete" IJSRE Volume 4 Issue 12 December 2016.

[24] IS:456 : 2000 "Plain and reinforced concrete code of practice" code of practice Bureau of Indian standards, New Delhi.

[25] M. Krishnamoorthy, D. Tensing, M. Sivaraja, A.R. Krishnaraja "Durability studies on polyethylene terephthalate (pet) fibre reinforced concrete" International Journal of Civil Engineering and Technology (IJCIET) Volume 8, Issue 10, October 2017, PAGE 634-640.

[26] R. N. Nibudey, P. B. Nagarnaik, D. K. Parbat, A. M. Pande "Compressive strength and sorptivity properties of pet fiber reinforced concrete" International Journal of Advances in Engineering & Technology, Sept., 2014, ISSN: 22311963, Vol. 7, Issue 4, pp. 1206-1216.

[27] Sarika S, Dr. Elson Jo hn "A Study on Properties of Reactive Powder Concrete" International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 4 Issue 11, November-2015

[28] Monita Olivia, H. Nikraz "Corrosion performance of embedded steel in fly ash geopolymer concrete by impressed voltage method" incorporating sustainable Practice in Mechanics of structures and Materials Fragomeni, Venkatesan, Lam & Setunge (eds) @ 2011 Taylor & Francis Group, London, ISBN 9780415616577