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MANAGEMENT OF PUMICECRETE AS LWC/LWA CONSTRUCTION MATERIAL WITH FLY ASH AS PART CEMENT SUBSTITUTE

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ABSTRACT

Lightweight concrete reduces the dead load of the huge concrete structures of low thermal conductivity. Recent advances in light weight concrete and light weight aggregates focuses on optimization of cost, material, labour and time of construction by use of undisposed industrial and dismantled wastes. Present study envisages design of light weight concrete of M25 grade and study of their mechanical properties like compressive strength, split tensile strength by replacement by 25% and 33% in volume of pumice stone as coarse aggregate and their different combinations with 10%, 20% and 30% fly ash which is an industrial waste as replacement of cement. The specially prepared concrete is compared with the properties of convention concrete of M25 grade. At 20% replacement of cement by fly ash the optimum compressive strength was observed but at 10% replacement of cement by fly ash the maximum split tensile strength was achieved when cured for at 28 days. The management of the type of pumicecrete for green house building is also discussed.

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INTRODUCTION

Lightweight concretes (LWC) are used for structural applications to reduce the overall load or weight of the concrete structure. Less dead loads, save in foundations, reinforcement, cost of transportation of material, improved thermal properties and fire resistance and reduction in cost of centering, centering and formworks, The structural designers can save in footings, columns, beams, reinforcement and other load bearing elements without destroying the strength, stability and longevity of the concrete structures. The structures are cost effective and also save labour and time. The LWC dates back to early eighteenth century and incorporated popularly with advances in building and construction materials and technology. LWC became popular in United States during 1930s and regularly used as replacement to common concrete to reduce cost of construction. LWC was used during First World War for construction of ships due to its low corrosion property, as railway platform in Japan, for many bridges in USA and Canada in 1980's.

The environment friendly, pumice as a material is of low specific gravity which is used in this in the study replacing ordinary coarse aggregates like hard granite chips in concrete.
The word pumice is derived from the Latin word "pumex", which means foam. Pumice is a light weigh coloured igneous, porous, sponge-like rock formed from volcanic eruption These materials are considered as alternatives to coarse aggregate in concretes because of its relatively high strength to unit weight ratio. The waste material can replace coarse aggregate in concrete and can maintain the stability and the durability.. Romans are the first country to use Pumice and pumicites as LW construction material. Pumice aggregate are abundant at the outskirts of volcanic mountains, particularly in Mediterranean area, Rocky Mountains in US, and most part of Turkey and Indonesia. The largest producer of pumice materials are Italy, Greece, Chile, Spain, Turkey, and the United States. During the World Wars the military engineers took advantage of the lightweight of concrete produced using natural lightweight aggregates notably pumice to produce concrete which was used in the construction and production of ships and barges.

At present the increased cost of cement, fly ash has been successfully added in pozolnna cement for nearly 60 years. The huge fly ash received from coal based thermal power plants as waste poses problem for their disposal as it is hazardous to the environment. These fly ash is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electrostatic precipitator. Fly Ash is the most commonly and widely used as replacement to pozzalonic material all over the world.

Review of literature

Swamy et. al.,(1984) [12] stated that the thermal efficiency of is more in the light weight concrete and the load carrying capacity is same as the normal concrete by using mineral and chemical admixtures. Banthia et. al., 1994, suggested that in lightweight fiber reinforced concrete with addition of fibers can increase in compressive strength of LW RCC. Compione et. al. (1999) (Compione et al., 1999; Campione et al., 1999; Calogero et al., 2004) reported that brittle nature of lightweight aggregate can be overawed by increasing the ordinary confinement of transverse reinforcement and/or by adding reinforcing fibbers to the concrete matrix and resulting in reduction in material decay with increasing compressive strength. They also advocated that the brittle behaviour and the ductility is required for seismic purposes by using adequate percentages of short fibbers. Also observed that, using fibers only moderate effects in terms of maximum and residual strength were increased. Balaguru et al., (1996) (Balaguru, 1987) found that lightweight fiber-reinforced concrete resemble that of normal concrete except for air entrainment which can reduces air content and increase workability by using high-range water-reducing admixtures.

Parhizkar et al., (2011) have reported that the compressive strength, tensile strength and drying shrinkage properties of lightweight concretes are compatible with the requirements of normal concrete when pumice were used as lightweight fine and coarse aggregates. Rao et al., (2013) reported that the fiber reinforced natural pumice stone used as LW aggregate have strength as that of M 20 concrete by (20% and 1.5%) or (40% and 0.5%) replacement of pumice aggregate and fibber respectively. Taylor (Banthia, 1994) reported that addition of fly ash enhances the compressive strength and splitting tensile strength by >20% and addition of silica fume enhances the compressive strength by 25%. Calaveri et al have noted that lightweight pumice stone concrete (LWPSC) can be an alternative to common artificial light weight aggregates using loading tests. Desai et al., [16] stated that 30% replacement of conventional granite chips by light weight aggregate with 15% replacement of cement (metakoline + pumice powder and silica fume + flyash) the strengths were found to be of standard and cost effective.

MATERIALS AND METHODS

LWC can be light weight aggregate concrete (porous), aerated, cellular, foamed or gas concrete (air entrained large void concrete blocks) and no fine concrete. The concrete can be Low weight concrete (LWC) or low weight aggregate (LWA). Present study deals with a concrete of LWC and LWA. The alternate LWA can be *Pumice, Foamed Slag, Clays and Shales and Sintered Pulverised – fuel ash aggregate.* LWC follows ASTM C 330-82a, ASTM C 331-81, and insulating concrete ASTM C 332-83.

Compressive strength: as per ASTM C 330-82a, after 28-days curing the cylinder should exceed 17 MPa, the unit weight (when) should be less than 1840 kg/m³ and lies between 1400 and 1800 kg/m³. For LWC masonry, the density should lie between 500 to 800 kg/m³ and 7 and 14 MPa should be its compressive strength. Present study attempts to prepare a combined M25 grade concrete which shall behave as both LWA by replacement of coarse aggregate by light weight pumice and LWC by substituting fly ash in place of cement and the 28days compressive strength and flextural strength has be tested in the laboratory. The management of the type of pumicecrete for green house building is also discussed.

The Materials

Pumice

However, pumice is far from being fully utilized in lightweight concrete at the time being. Concrete structures are generally designed to take advantage of its compressive strength. Light weight aggregate (pumice) is procured from Turkey. The size of light weight aggregate is 20mm, Specific gravity = 1.06 and Water absorption = 30.15%.

Fig 1. a. pumice aggregate

Fig 1. b. Image of fly ash

During mixing pumicecrete need, less cement to be used as it defeat the air entrainment of concrete either to natural colour of the stones or prepared surface to adher plaster over it.

Fly ash

Fly ash, the common and widely used pozzolanic material, a waste product of the thermal power plants. The fly ash is light weight and results from the combustion of coal and extracted from the exhaust gases by electrostatic precipitators before the flue gases reach the chimneys of coal-fired power plants. At early ages fly ash exhibits very little cementing properties.

Table 1. The sieve analysis results 10mm, 20mm and blended coarse aggregate

Sl. no	Sieve size		Weight retained (mg)	Cumulative wt. retained (mg)	weight passing (mg)	wt. passing (%)
For 20 mm coarse aggregate						
1	80mm		Nil	Nil	5000	100
2	40mm		Nil	Nil	5000	100
3	20mm		1038	1038	3962	79.24
4	10mm		3249	4287	713	14.26
5	4.75mm		689	4976	24	0.48
6	Pan		24	5000	0	0
For 10mm coarse aggregate						
1	80mm		Nil	Nil	2000	100
2	40mm		Nil	Nil	2000	100
3	20mm		Nil	Nil	2000	100
4	10mm		349	349	1651	82.55
5	4.75mm		1580	1939	61	3.05
6	Pan		71	2000	0	0
Blending of coarse aggregate						
Sl no	Sieve passing (10mm)	Sieve Passing (20mm)	10mm (50%)	20mm(50%)	Combined (100%)	Remark
1	100	100	50	50	100	100
2	100	79.24	50	39.62	89.62	95-100
3	82.55	14.26	41.27	7.13	48.4	25-55
4	3.05	0.48	1.525	0.24	1.765	0-10

Fig 2(a) The Pumicecrete concrete cubes

Fig 2(a) The Pumicecrete concrete cyclinders

Table 2. The mix design for quantity of water, cement and aggregates for a M25 grade concrete

Description	Water	Cement	Fine Aggregate	Coarse Aggt.
Quantities	191.58 ltr	383.1 kg	563 kg	1182 kg
Proportionby wt.	0.5	1	1.46	3.085

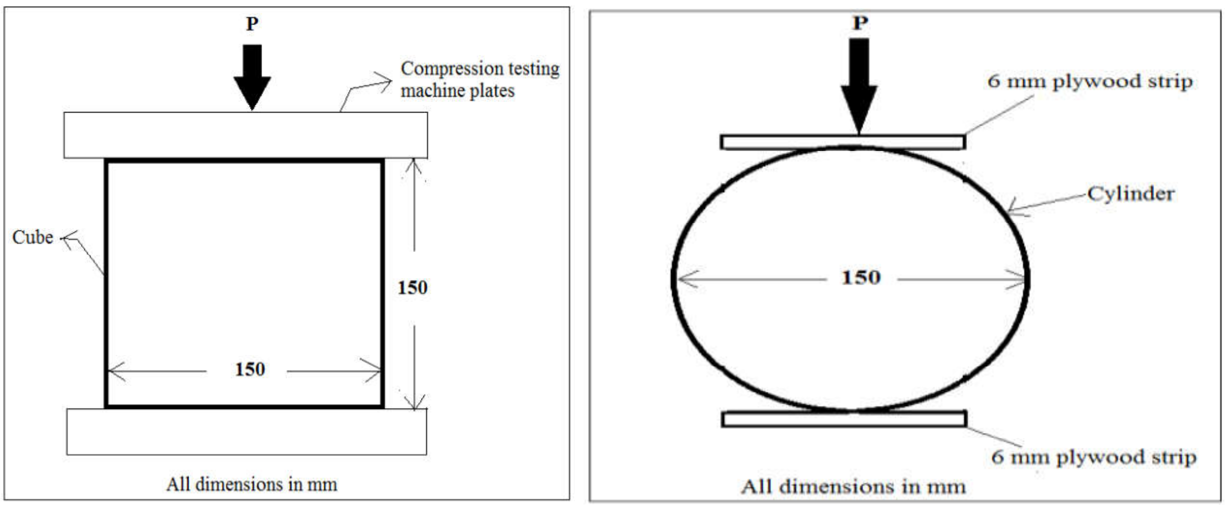

Fig. 3. Methodology for compressive strength and split tensile strength test for the concrete

Table 3. The compressive strengths of normal M-25 grade concrete after 7, 14 & 28days curing

Sl no	Comp. strength N/mm^2			Comp. strength N/mm^2 after 14days			Comp. strength N/mm^{2}after 28days			Remark
Sl no	days	Load (KN)	Comp. strength	days	Load (KN)	Comp. strength	days	Load (KN)	Comp. strength	After 28days the conc. satisfy M-25 grade
1	7	415	18.44	14	540	24	28	683	30.35	
2	7	425	18.94	14	555	24.66	28	700	31.11	
3	7	430	19.11	14	570	25.33	28	720	32	


Fig 4. The compressive test and split tensile strength of concrete with fly ash and pumice

Table 4: Compressive strength of M-25 conc. when substituted by 25% and 33% pumice as coarse aggregate& 10, 20 and 30% fly ash replacing cement

Sl no	Comp. strength N /mm^2(7curing days)			Comp. strength N/mm^2 after 14days			Comp. strength N/mm^2 after 28days			Remark
	days	Load (KN)	Comp. strength	days	Load (KN)	Comp. strength	days	Load (KN)	Comp. strength	After 28days curing, non of the trial by blending conc. does satisfy M-25 grade as per IS 456/2000
M-25 conc. when replaced with 25% pumice &10% fly ash										
1	7	333	14.66	14	417	18.53	28	520	23.11	
2	7	345	15.33	14	491	21.82	28	555	24.66	
3	7	366	16.26	14	525	23.33	28	593	26.35	
M-25 conc. when Replaced with 25% pumice & 20% fly ash										
1	*7*	*343*	*15.22*	*14*	*495*	*22*	*28*	*570*	*25.33*	
2	*7*	*365*	*16.22*	*14*	*525*	*23.33*	*28*	*587*	*26.08*	
3	*7*	*395*	*17.55*	*14*	*540*	*24*	*28*	*615*	*27.33*	
M-25 conc. when Replaced with 25% pumice &30% fly ash										
1	7	315	14	14	400	17.77	28	480	21.33	
2	7	321	14.26	14	425	18.88	28	527	23.43	
3	7	335	14.88	14	450	20	28	560	24.88	
M-25 conc. when Replaced with 33% pumice & 10% fly ash										After 28days curing, non of the trial replacement (blending) conc. satisfy M-25 grade as per IS 456/2000
1	7	320	14.22	14	420	18.66	28	510	22.66	
2	7	348	15.46	14	435	19.33	28	519	23.06	
3	7	355	15.77	14	438	19.46	28	530	23.55	
M-25 conc. when Replaced with 33% pumice & 20% fly ash										
1	7	295	13.11	14	390	17.33	28	435	19.33	
2	7	310	13.77	14	405	18	28	438	19.48	
3	7	313	13.91	14	411	18.26	28	444	19.73	
M-25 conc. when Replaced with 33% pumice & 30% fly ash										
1	7	290	12.88	14	375	16.66	28	401	17.82	
2	7	305	13.55	14	388	17.24	28	413	18.35	
3	7	310	13.77	14	393	17.46	28	420	18.66	

At later ages when liberated lime resulting from hydration of cement, reacts with fly ash and contributes considerable strength to the concrete. This method of fly ash use is adopted for mass concrete works where initial strength of concrete has less importance compared to the reduction of temperature rise.

Cement

Locally available Konark Ordinary Portland Cement (OPC) of 53 grade of Cement Brand conforming to ISI standards has been procured and various tests have been carried out

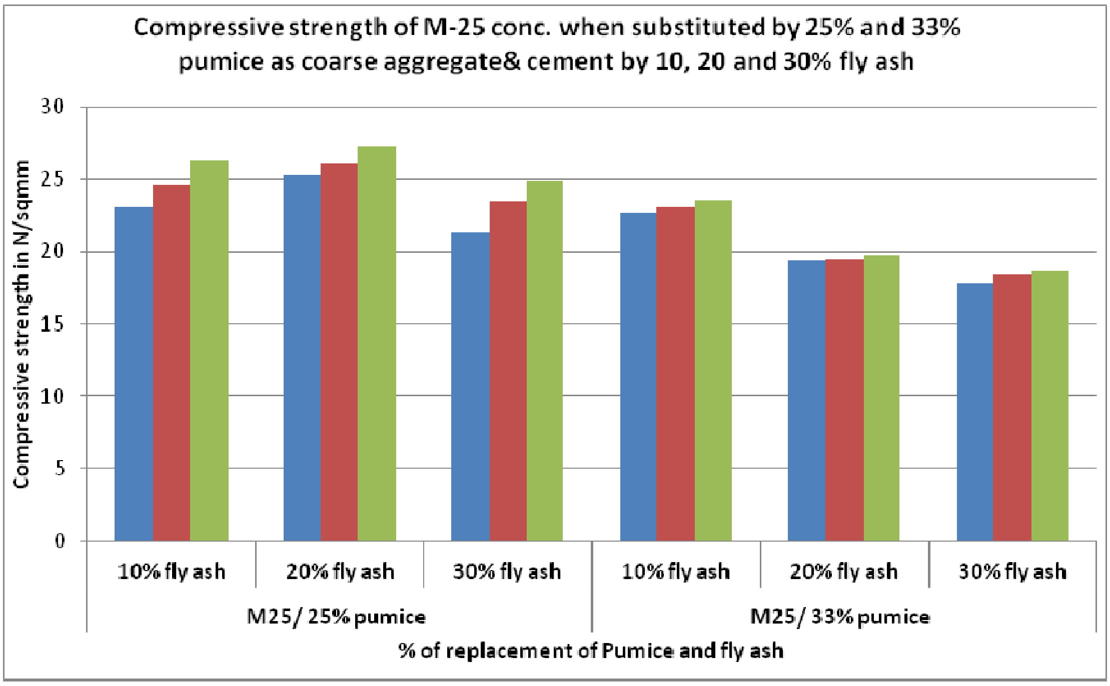

Table 4: Split tensile strength of M-25 conc. when replaced with 25% and 33% pumice as coarse aggregate& 10, 20 and 30% fly ash replacing cement

Sl no	Comp. strength N /mm^2(7curing days)			Comp. strength N/mm^2 after 14days			Comp. strength N/mm^{2}after 28days			Remark
	days	Load (KN)	Comp. strength	days	Load (KN)	Comp. strength	days	Load (KN)	Comp. strength	
M-25 traditional concrete as per IS code 456/2000.										After 28days curing the concrete .blended with 25% with Pumice as coarse aggt. and 20% fine aggt. replaced by fly ash closely satisfy M-25 grade traditional concrete
1	7	125	1.76	14	145	2.05	28	145	2.05	
2	7	130	1.83	14	150	2.12	28	150	2.12	
3	7	140	1.9	14	160	2.21	28	160	2.21	
M-25 conc. when replaced with 25% pumice &10% fly ash										
1	7	110	1.55	14	125	1.76	28	135	1.90	
2	7	115	1.62	14	130	1.83	28	145	2.05	
3	7	120	1.69	14	140	1.9	28	155	2.19	
M-25 conc. when Replaced with 25% pumice & 20% fly ash										
1	*7*	*115*	*1.62*	*14*	*125*	*1.76*	*28*	*150*	*2.12*	
2	*7*	*125*	*1.76*	*14*	*140*	*1.98*	*28*	*155*	*2.19*	
3	*7*	*130*	*1.83*	*14*	*145*	*2.05*	*28*	*160*	*2.21*	
M-25 conc. when Replaced with 25% pumice &30% fly ash										
1	7	105	1.48	14	110	1.55	28	135	1.90	
2	7	110	1.55	14	120	1.69	28	140	1.91	
3	7	115	1.62	14	130	1.83	28	145	2.05	
M-25 conc. when Replaced with 33% pumice & 10% fly ash										After 28days curing the concrete .blended with 33% with Pumice as coarse aggt. and 10% fine aggt. replaced by fly ash closely satisfy M-25 grade traditional concrete
1	7	110	1.55	14	120	1.69	28	155	2.19	
2	7	125	1.76	14	140	1.9	28	160	2.26	
3	7	130	1.83	14	145	2.05	28	165	2.3	
M-25 conc. when Replaced with 33% pumice & 20% fly ash										
1	7	106	1.49	14	128	1.81	28	143	2.02	
2	7	120	1.69	14	135	190	28	145	2.05	
3	7	125	1.76	14	140	1.98	28	155	2.19	
M-25 conc. when Replaced with 33% pumice & 30% fly ash										
1	7	100	1.41	14	120	1.69	28	125	1.76	
2	7	115	1.62	14	130	1.88	28	140	1.98	
3	7	125	1.76	14	135	1.90	28	145	2.05	

according IS 8112-1989 in the present study. The following physical properties of cement conducted in laboratory and the results were Fineness (5%), Specific Gravity (3.12), Standard Consistency (34%), Initial Setting Time (30 min) and Final Setting Time (24 hrs)

Fine Aggregate

The locally available natural clean and free from dirts river sand was procured conforming to grade zone-II of Table of IS 383-1970.

The fine aggregates were larger than 3/16 inch (4.75mm) in diameter. Results of various tests were Specific gravity (2.156), Water absorption (1 %), Loose bulk density (1500 Kg/m^3), Compacted bulk density (1670 Kg/m^3).

Coarse Aggregate

Machine crushed confirming to IS 383- 1970 consisting 20 mm maximum size hard granite chips of 67% passing through 20mm sieve and retained on 12 mm sieve and 33% passing through 12 mm and retained on 10 mm sieve was used as coarse aggregate throughout the work. Results of various tests were Specific gravity (2.77), Water absorption (0.781%), Loose bulk density= 1466 Kg/m3 and Compacted bulk density = 1690 Kg/m3. The calculations are given in Table 1.

WATER

Water fit for drinking as used in the laboratory is used for mixing and preparation of concrete and was also used for curing.

METHODOLOGY

Cement or cement +fly ash and fine aggregate was blended thoroughly on a none-absorbent platform (water tight). Then desired coarse aggregates were mixed uniformly. Water was added (IS code 456/2000) and mixed in electric power mixure till the concrete was homogeneous and satisfy workability and consistency. The fresh concrete was filled in the cleaned and oiled cubes and cylindrical molds of size are 150mm x 150mm x 150mm, and 300mm x 150mm (dia) and vibrated on the table vibrator for compaction. After 24 hours of setting the specimen concrete blocks are removed from the molds are submerged in water tank having temperature 27 ± 2^0 C. Three specimens for each test were removed after 7, 14 and 28 days from the curing tank and dried at room temperature. The dried M25 grade specimen were thoroughly cleaned and tested for its strength in the machine. The mix design for a M25 grade concrete and the concrete specimen prepared for testing is in Table 2 and Fig 2(a) and fig 2(b).

Compressive stress was calculated as Compressive strength = (P / A) × 1000, Where, P = Load in KN and A = Area of cube surface = 150 x 150 mm^2. For normal concrete and each percentage of pumice and fly ash, 9 cube specimens were casted and the cube compressive strength of concrete at different replacements of 10%, 20%,30% fly ash with the cement and with 25% and 33% light weight aggregate replaced in coarse aggregate were found.(Fig 3). Lines were drawn so that they are in the same axial plane. The diameter of specimen was determined to the nearest 0.2 mm by averaging the diameters of the specimen lying in the plane of pre-marked lines measured near the ends and the middle of the specimen. The length of specimen also shall be taken be nearest 0.2 mm by averaging the two lengths measured in the plane containing pre marked lines. The size of the cylinder specimen was of 150 mm diameter and 300 mm in length. specimens were prepared on the plywood strip and align it so that the lines marked on the end of the specimen are vertical and centered over the plywood strip. The second plywood strip is placed length wise on the cylinder centered on the lines marked on the ends of the cylinder. The load was applied without shock and was increased continuously at the rate to produce a split tensile stress of was approximately 1.4 to 2.1 N/mm2/min, until no greater load can be sustained. Split tensile strength was calculated as $2P/\pi dL$ where P = Load in kN, d = Diameter of cylinder (150 mm) and L = Length of cylinder 300 mm)

Compressive strength for normal concrete

The compressive strengths of M-25 grade conventional concrete has been prepared as per design mix. The casted cubes after 7, 14 & 28days curing exhibited the results as in Table 3 and Fig 4.

Replacement of 25% pumice &10% fly ash

Replacement of 25% pumice &10% fly ash was made and the the results obtained after 7, 114 and 28 days curing are given Table 4. From the above study, the results obtained with 25% light weight aggregate replacement in normal aggregate were studied with fly ash replacement in cement by 10%, 20% and 30%. At 20% replacement of cement by fly ash the maximum compressive strength is observed i.e 26.24N/mm² at 28 days and at 33% light weight aggregate replacement in normal aggregate were studied with fly ash replacement in cement by 10%, 20% and 30%. At 10% replacement of cement by fly ash the maximum compressive strength is observed i.e 23.09 N/mm² at 28 days. (Table 4) and Fig 5.Thje results of various compressive strength of M-25 conc. when substituted by 25% and 33% pumice as coarse aggregate& 10, 20 and 30% fly ash replacing cement after 7days, 14 days and 28days curing (Table 4 and Fig 5).

The results obtained with 25% light weight aggregate replacement in normal aggregate were studied with fly ash replacement in cement by 10%, 20% and 30%. At 20% replacement of cement by fly ash the maximum compressive strength is observed i.e 26.24 N/mm² at 28 days and at 33% light weight aggregate replacement in normal aggregate were studied with fly ash replacement in cement by 10%, 20% and 30%. At 10% replacement of cement by fly ash the maximum compressive strength is observed i.e 23.09 N/mm² at 28 days.

Split tensile strength of concrete

The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The Flexural strength, a measure of tensile strength of concrete is essential and measured of the concrete beam/slab without reinforcement so that it should not fail in bending. So to find this property a test is conducted by the help of concrete cylinder known as the splitting tensile strength test which is basic and important From the study of split tensile strength of blended concrete by replacement of 25% Pumice as light weight aggregate and with fly ash replacement in cement by 10%, 20% and 30%, it is observed that the 20% replacement of cement by fly ash gave the maximum split tensile strength of 2.17 Mpa after 28 days curing. The 33% light weight aggregate replacement in normal aggregate when studied with fly ash replaced by cement at 10%, 20% and 30%, . it was observed that at 10% replacement of cement by fly ash the maximum split tensile strength was 2.25 Mpa at 28 days curing by water. Table 4: Split tensile strength of M-25 conc. when replaced with 25% and 33% pumice as coarse aggregate& 10, 20 and 30% fly ash replacing cement

Management of Pumicecrete

LWC and LWA are of important construction materials as they save cost, material, labour and time. They can be used without hesitation as screeds and fire resistance walls, roofs insulated from heat, anticorrosion, light weight partition or panel walls, domestic building constructions and in RCC structures. Apart from the above, LWC/LWA concrete is affected by sulphate, polluted air, frost shrinkage, temperature stress and moisture. This type of concrete is prone to mechanical assault like excessive loading, earthquake termers, and abrasion. Temperature stresses can develop crack in such concrete. So LWC/LWA is location and climate specific the use of this concrete as replacement to traditional concrete need rigorous laboratory trials and engineers expertise (http://theconstructor.org/concrete/all-about-light-weight-concrete/1670/). The use of the type of pumicecrete (M25) for green house building is to be thought before any construction in temperate, coastal and industrial areas.

Conclusion

The overall performance of different combinations M-25 concrete substituted by 25% and 33% pumice as coarse aggregate and 10, 20 and 30% fly ash replacing cement, it is observed that when coarse aggregates are replaced with 25% pumice and cement by 20% fly ash give optimum performance and the compressive strength matches with the M-25 traditional concrete saving cost and weight. However the use of the type of pumicecrete for green house building is to be thought of before any civil construction.

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