International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 8
August 2017

Feasibility Study of Replacement of Cement and Sand in Concrete and Mortar by ECOSPHERE

S P Khedekar, Shilpi Bhuinyan, K N Kulkarni
AISSMS College of Engineering, Pune

ABSTRACT :

Concrete is one of the oldest manufactured construction material used in the construction of various structures globally as well as the infrastructural development until today. However, continuous research in the areas of concrete material has resulted in the production of the various types of concrete known in various names each having unique characteristics to fulfill the current construction industry demand. Building construction places a huge burden on the environment for manufacturing concrete constitutes. These constitutes requires incorporate large quantity of natural resources, which is tune with current need of the sustainability. Judicious use of resources as well as utilization of waste and byproducts along with energy efficient methods is necessary to ensure sustainable construction. In our work we are introducing the new material which is byproduct in the chemical industry, which can be used as replacement of the cement and sand in the concrete and mortar. We have conducted the experimental work or testing which were done previously by the researchers by using the different material in the concrete with their different proportions.

Keywords: Cement ,Sand ,Ecosphere, sustainability

INTRODUCTION :

Cement and aggregates are major constituents in the manufacturing of concrete. The contribution of the aggregate is 75% in concrete; and provides volume to concrete; these aggregates are having the natural resources. For manufacturing of these constitutes requires huge quantity of the natural resources are used. Due to this huge quantity loss of the natural resources the adverse effect on the environments. For manufacturing of cement a major sources are lime-stone which evolved the CO2 a significant contribution of the greenhouse gases. Each tone of the cement produced release about 0.9 tone of CO2 into the environment which is dangerous to living hood and human being. The concrete have some of drawbacks which are stated above like heavy in weight, poor resistance to sulphate or chemical attack, detoriation in the marine structure, to improve these drawbacks use of the materials other than concrete constituents and have same chemical and physical properties. In the current industry there are many admixtures, polymers, mineral, and by-products used for improve above concrete drawbacks as well as physical and chemical properties. So there is a need of the replacement of these natural resources by a material which is manufactured from the wastes or by-products and which is echo friendly, there should no adverse effect on the environment and living hood

INTRODUCTION OF ECOSPHERE MATERIAL:

Ecosphere material is the product of the mechanical combustion of the siliceous material and Coal .The raw materials for manufacturing of Ecosphere are easily available near the vicinity of the process plant. The major constituent in the ecosphere material is the Silica (SiO_2 55-65%), Alumina (Al_2O_3 25-35%) and Calcium Oxide (CaO 1.5-4%) which are similar properties of cement and sand, but as in cement the major chemical constituent are Calcium Oxide (CaO 60-67%), Silica (SiO_2-17-25%) and Alumina (Al_2O_3 3.0-8%) and in Sand the major constituents are Silica (SiO2 89.67%), Alumina (Al2O3 0.90%) and Calcium Oxide (CaO 5.96%). The ECOSPHERE material is current used as filler material in the polymer industry; also it is used in the rubber industry. The maximum size of the ECOSPHERE material is in between 50µ to 350µ. The shape of ECOSPHERE material is Spherical form characterizes good viscosity as well as provides good flow ability.

The ecosphere material is a light weight, inert, spherical shape and non-metallic micro sphere composed largely content of Silica and Alumina. These properties are somewhat similar to the fine aggregate, hence the ECOSPHERE Material can be used as the replacement of fine aggregate in concrete and mortar. The Calcium Oxide is one of the chemical content of the ECOSPHERE material (CaO 3-5%) which is similar chemical composition of cement. But in the cement the percentage content of the Calcium Oxide (Cao 60-67%) is much higher than the ECOSPHERE material. The Calcium Oxide is form from chemical reaction of water and calcareous compound in the manufacturing process of cement. The Calcium Oxide is popular by its binding property, which obtained from the lime Stone. Due to this unique property of Calcium Oxide, this provides cement as a good bonding agent. But in the ECOSPHERE material the content of calcium Oxide is very low (CaO 3-5%), due to this less percentage of CaO the ECOSPHERE material cannot be replaced 100% cement in concrete and mortar, bet due to other similar chemical composition of ingredient and the CaO contents, it can be replace to certain extent of cement up to 40% - 50%, and sand can be replaced 100%.The other properties like light weight and less bulk density, the ECOSPHERE material can be used in the manufacturing of light weight blocks, which main intention is that to reduce the dead weight of masonry in the high rise buildings.

Following are the advantages of the ECOSPHERE material;

- High Strength in Compression
- High Durability
- Good Flow-ability
- Good Sound insulation as well as Thermal insulation
- Low bulk density
- Water repellent agent
- It is utilized as high performance multifunctional additive in mechanical as well as electrical industry.

Table No 1: Physical Properties of ECOSPHERE Material

Size	50 – 350 µ
Shape and appearance	Spherical and free flow ability
Colour	Gray- light gray- off white
Particle density	0.5- 0.8 gm/cc
Bulk density	0.35 – 0.45 gm/cc
Hardness	5 – 6 moth's scale
Compressive strength	14 – 35 N/mm^2
Softening point	Above 1450° C
PH value	6.0 - 8.0
Coefficient of thermal expansion	$8 X 10^{-6} K$
Surface moisture	Less than 0.5%
Solubility	Negligible in water
Oil absorption	16^{-18} gm oil/ 100gm
Specific resistance	$10^{11} – 10^{13}$ Ω/cm²
Water absorption	Less than 5%

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 8
August 2017

Table No.2: Physical Properties of ECOSPHERE, Cement and Sand

Particulars	ECOSPHERE	Cement	Sand
Size	50 – 350 µ	15 – 20 µ	Less than 4.75mm
Shape and appearance	Spherical and free flow ability		Rounded
Color	Gray- light gray- off white	Gray, white	
Particle density	0.5- 0.8 gm/cc	1.44 gm/cc	1.57 gm/cc
Bulk density	0.35 – 0.45 gm/cc		-
Hardness	5 – 6 Mohr's scale		
Compressive strength	14 – 35 N/mm^2	45- 67 N/mm^2	-
Softening point	Above 1450° C		
PH value	6.0 - 8.0	13	
Coefficient of thermal expansion	8 X 10^{-6} K		9.9 X 10^{-6} per ^oC
Surface moisture	< 0.5%		1.25 %
Solubility	Negligible in water		Negligible in water
Oil absorption	16 $^{-18}$ gm oil/ 100gm	-	-
Specific resistance	$10^{11} – 10^{13}$ Ω/cm²	-	-
Water absorption	Less than 5%	23%	15-24% (oven dry)

CHEMICAL PROPERTIES

Table No 3: Chemical Composition of ECOPHERE Material

Silica	55 – 65%
Alumina	25 – 35%
Calcium oxide	1.5 – 4.0%
Iron oxide	1 -5%
Titanic	0.5 – 1.5%

APPLICATIONS

- The ecosphere material is used widely in the plastic industry as a polyethylene, polypropylene, organic silicon resin, nylon, PVC, sole material.
- It is also used in glass fiber reinforced plastic, sealant, putty and weight reducing additive.
- They are used in the rubber industry light, wear resistance and high compressive set rubber shoe sole, gasket and ' O ' ring.
- They are used in the auto industry as engine sound arrester cover, automobile brake lining, foot mat, steering wheels.
- Construction industry: - in various admixtures and filler material.

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 8
August 2017

- Electrical industry: - Light-weight insulation products, electrical encapsulation.
- Frictional material; - most suitable as functional additive for disc brake pads, clutch facing.
- It is compatible with non-asbestos organic products used in phenol and epoxy based application. It offers benefits like better friction stability, thermal stability, improved flow characteristics and weight reduction.

Table No 4: Chemical Composition of Cement and cement Replacement Materials

Sr. No.	Chemical Constitutes	Cement %	Fly Ash %	GGBFS %	Metakaolin %	ECOSPHERE %
1	Silica (SiO_2)	17-25	51.7	30-38	55	55-65
2	Alumina (Al_2o_3)	3.0-8.0	26.8	15-20	29	25-35
3	Ferric oxide (Fe_2O_3)	0.5-0.8	4.39	0.2-5.0	2.5	1.4-5
4	Calcium Oxide (CaO)	60-67	3.4	30-45	-	3-5
5	Magnesium Oxide (MgO)	0.1-4.0	0.95	4.0-17	0.5	-
6	Sodium Oxide (Na_2O)	0.4-1.3	1.28	1.0-5.	0.03	-
7	Potassium Oxide (K_2O)	0.4-1.3	0.65	-	3.1	-
8	Sulphur Oxide (SO_3)	1.3-3.0	0.31	-	-	-

Table No 5: Chemical Composition of Aggregate and Aggregate Replacement Materials

Sr. No.	Chemical Constitutes	Sand %	Coarse aggregate	Granulated slag %	Crystalline slag %	ECOSPHERE %
1	Silica (SiO_2)	89.67	40.65	39.99	40.26	55-65
2	Alumina (Al_2o_3)	0.90	8.87	9.73	8.98	25-35
3	Ferric Oxide (Fe_2O_3)	0.91	3.25	3.56	2.98	1.4-5
4	Calcium Oxide (CaO)	5.96	40.56	41.13	40.89	3-5
5	Magnesium Oxide (MgO)	0.2	3.65	3.38	3.40	-
6	Sodium Oxide(Na_2O)	0.01	0.01	0.01	0.01	-
7	Potassium Oxide (K_2O)	0.3	0.65	0.58	0.6	-
8	Sulphur oxide (SO_3)	0.05	0.79	0.67	0.59	-

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 8
August 2017

EXPERIMENTAL WORK

The work includes following tests.

A. Tests on Concrete

B. Tests on Mortar (Plaster)

C. Comparison with Light weight blocks.

i. Comparison of Siporex blocks with Blocks prepared with ECOSPHERE.

ii. Comparison of Conventional brick with Bricks prepared with ECOSPHERE

A. Tests on concrete:

a) Replacement of cement by ECOSPHERE

i. Compressive and Split Tensile Strength tests:
Percentage of replacement: - 5%, 10%, 15%, 20% and 25%.

ii. Water Absorption and Workability tests:
Percentage of replacement: - 5%, 10%, 15%, 20% and 25%.

iii. Density test:
Percentage of replacement: - 5%, 10%, 15%, 20% and 25%.

b) Replacement of Sand by ECOSPHERE

i. Compressive and Split Tensile Strength tests:
Percentage of replacement: - 10%, 20%, 30%, 40%, 50%, 75% and 100%.

ii. Water Absorption and Workability tests:
Percentage of replacement: - 10%, 20%, 30%, 40%, 50%, 75% and 100%.

iii. Density test:
Percentage of replacement: - 10%, 20%, 30%, 40%, 50%, 75% and 100%.

B. Tests on Mortar:

a) Replacement of Sand by ECOSPHERE

i. Compressive Strength test of Mortar:
Proportion or Percentage of replacement: -

1. 1 : 4 (Cement : Sand) and (Cement : ECOSPHERE)
2. 1 : 5 (Cement : Sand) and (Cement : ECOSPHERE)
3. 1 : 6 (Cement : Sand) and (Cement : ECOSPHERE)

b) Water Absorption and Workability tests:
Proportion or Percentage of replacement: -

1. 1 : 4 (Cement : Sand) and (Cement : ECOSPHERE)
2. 1 : 5 (Cement : Sand) and (Cement : ECOSPHERE)
3. 1 : 6 (Cement : Sand) and (Cement : ECOSPHERE)

c) Density test:
Proportion or Percentage of replacement: -

1. 1 : 4 (Cement : Sand) and (Cement : ECOSPHERE)
2. 1 : 5 (Cement : Sand) and (Cement : ECOSPHERE)
3. 1 : 6 (Cement : Sand) and (Cement : ECOSPHERE)

C. Comparison with Light weight blocks

a) Comparison of Siporex blocks with blocks prepared with ECOSPHERE

i. Compressive Strength test:
Proportion: -

1. 1 : 1 : 2 (Cement : ECOSPHERE : Sand)
2. 1 : 2 : 1 (Cement : ECOSPHERE : Sand)
3. 1 : 3 (Cement : ECOSPHERE)

ii. Water Absorption test:

1. 1 : 1 : 2 (Cement : ECOSPHERE : Sand)
2. 1 : 2 : 1 (Cement : ECOSPHERE : Sand)
3. 1 : 3 (Cement : ECOSPHERE)

iii. Density test:

1. 1 : 1 : 2 (Cement : ECOSPHERE : Sand)
2. 1 : 2 : 1 (Cement : ECOSPHERE : Sand)
3. 1 : 3 (Cement : ECOSPHERE)

b) Comparison of conventional bricks with bricks prepared with ECOSPHERE

i. Compressive Strength test:

Proportion: -

1. 1 : 1 : 2 (Cement : ECOSPHERE : Sand)
2. 1 : 2 : 1 (Cement : ECOSPHERE : Sand)
3. 1 : 3 (Cement : ECOSPHERE)

ii. Water Absorption test:

1. 1 : 1 : 2 (Cement : ECOSPHERE : Sand)
2. 1 : 2 : 1 (Cement : ECOSPHERE : Sand)
3. 1 : 3 (Cement : ECOSPHERE)

iii. Density test:

1. 1 : 1 : 2 (Cement : ECOSPHERE : Sand)
2. 1 : 2 : 1 (Cement : ECOSPHERE : Sand)
3. 1 : 3 (Cement : ECOSPHERE)

Tests on Concrete with Replacement by ECOSPHERE Material: Following are the tests which are to be conducted.

a) Compressive strength test

b) Split tensile Strength

c) Water Absorption

d) Workability.

e) Density

Compression test is the most common test conducted on hardened concrete, because the most of the desirable characteristics properties of concrete are qualitatively related to its compressive strength. The compression test is carried out on specimens cubical or cylindrical in shape. Prism is also sometimes used, but it is not common test in our country.

Test Specimens

For compression test use Standard cube specimen of size 150 mm lengths, 150mm wide and 150mm deep. The mould is prepared in preferably steel or cast iron; the thickness of the mould is 7mm, this thickness enough to prevent distortion of the plate. They are made in such a manner as to facilitate the removal of the mould specimen without damage and are so machined that, when it is assembled ready to use, the dimension and internal faces are required to be accurate within the limits.

5.1.1.2 Test setup and Test procedure:

a) Design requirements:

1. Characteristic concrete strength at 28 days (f_{ck}) – 30 N/mm^2.
2. Maximum size of aggregate – 20mm
3. Degree of Workability – 0.85cf.
4. Type of exposure – Mild
5. Degree of quality control – good

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 8
August 2017

b) Data for Materials:-

1. Type of Cement – Ordinary Portland Cement (43 grade)
2. Specific Gravity of cement – 3.15
3. Specific Gravity of fine Aggregate – 2.6
4. Specific Gravity of Coarse Aggregate – 2.75
5. Water Absorption of Coarse aggregate – 1%
6. Water Absorption of Fine aggregate – 1.5%
7. Free Surface Moisture Coarse aggregate – Nil
8. Free Surface moisture Fine aggregate – 1.26%.

c) Test Setup:

In dissertation work we prepared the concrete cubes for compressive strength tests, there are 6 numbers of blocks prepared for 7days and 28days strength test for each mix. For preparation of these blocks the materials quantity required like cement, fine aggregate, coarse aggregate and water are to be calculated as per the specification and mix proportion, also calculate the required quantity of the ECOSPHERE as per mix proportion with different percentage.

d) Quantity of material:

Size of Concrete Block (L X B X D) = 150 X150 X 150mm

Characteristics strength of concrete (f_{ck}) = 30 N/mm^2

Unit weight of fine aggregate (ξ_{FA}) = 1570 kg/m^3

Unit weight of Coarse aggregate (ξ_{CA}) = 1680 kg/m^3

Unit weight of Cement (ξ_C) = 1440 kg/m^3

Unit weight of ECOSPHERE (ξ_{ECO}) = 400 kg/m^3

Water Cement Ration (W/C) = 0.5

No. of specimen = 06

Volume of concrete cubes = $(0.150)^3 = 3.375 \text{ X } 10^{-3}$ m^3

Total volume of material = $3.375 \text{ X } 10^{-3} \text{ X } 6 = 0.0203$ m^3

Dry Volume (Increase 54%) = $1.54 \text{ X } 0.0102 = 0.032$ m^3

For M30 Mix the proportion is 1:1.5:3 with 43 grade of cement.

(Cement: fine aggregate: coarse aggregate)

Addition of proportion =1+1.5+3= 5.5.

e) Quantity of materials:

Cement	Fine Aggregate	Coarse Aggregate	Water
8.4 Kg	13.7 Kg	29.4 Kg	4.2 Liters

Table No 6 : Mix Proportion with reduction of cement by ECOSPHERE

Mix	Reduction of cement	Cement Kg	ECOSPHERE Kg	Fine Aggregate Kg	Coarse Aggregate Kg
M1	0%	8.4	0.0	13.7	29.4
M2	5%	7.9	0.12	13.7	29.4
M3	10%	7.3	0.23	13.7	29.4
M4	15%	6.85	0.35	13.7	29.4
M5	20%	6.58	0.47	13.7	29.4
M6	25%	6.28	0.585	13.7	29.4

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 8
August 2017

Reduction of Sand by 10%

Table No 7: Mix Proportion with reduction of Sand by ECOSPHERE.

Mix	Reduction of cement	Cement (Kg)	Fine Aggregate (Kg)	ECOSPHERE (Kg)	Coarse Aggregate(Kg)
M1	0%	8.4	13.7	0.0	29.4
M2	10%	8.4	12.3	0.35	29.4
M3	20%	8.4	11.1	0.70	29.4
M4	30%	8.4	9.60	1.05	29.4
M5	40%	8.4	8.22	1.40	29.4
M6	50%	8.4	6.85	1.75	29.4
M7	75%	8.4	3.42	2.62	29.4
M8	100%	8.4	0.0	3.50	29.4

TEST RESULTS Following table gives the test results of compressive strength for M30 grade concrete mix with replacement of cement and sand with different percentage of. Also we are finding the density of the each mix with replacement of cement and sand in concrete.

Table No 8: Compressive Strength test Results with Replacement of cement with Different percentage by ECOSPHERE Material. (M30 mix)

Sr. No.	Reduction of cement (%)	Average Compressive Strength (N/mm^2)				Density (kg/m^3)	Ratio of strength
		7 days	Average	28days	Average		28days/7days
1	0	15.56	17.64	34.42	32.66	2780	1.85
		16.44		30.87			
		20.88		32.69			
2	5	15.67	16.64	28.09	28.14	2704	1.69
		14.28		27.43			
		19.96		29.01			
3	10	17.89	19.4	29.89	31.12	2610	1.604
		21.34		31.56			
		17.77		32.05			
4	15	24.82	22.65	38.44	**36.44**	2489	1.604
		19.55		34.59			
		20.2		36.29			
5	20	26.67	**23.46**	36.15	34.67	2335	1.477
		24.44		32.71			
		19.27		35.17			
6	25	22.14	20.42	33.42	30.11	2178	1.47
		17.65		28.76			
		21.47		28.15			

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 8
August 2017

Table No 8: Compressive Strength test Results with Replacement of sand with Different percentage by ECOSPHERE Material. M30 mix

Sr. No.	Reduction of cement (%)	Average Compressive Strength (N/MM^2)				Density (kg/m^3)	Ratio of strength
		7 days	Average	28days	Average		28days/7days
1	0	15.56	17.64	34.42	32.66	2780	1.85
		16.44		30.87			
		20.88		32.69			
2	10	22.15	20.07	32.66	30.18	2645	1.51
		18.1		28.87			
		19.96		29.01			
3	20	24.78	24.96	34.57	35.42	2465	1.42
		23.28		37.44			
		26.82		34.25			
4	30	29.41	**27.85**	38.44	**38.87**	2305	1.39
		26.31		41.18			
		27.83		36.99			
5	40	26.67	24.17	36.15	34.33	2185	1.42
		24.44		32.71			
		21.4		34.13			
6	50	22.14	21.42	33.42	31.42	2015	1.46
		20.65		28.76			
		21.47		32.1			
7	75	18.46	17.63	27.81	29.18	1985	1.65
		17.45		32.67			
		16.98		27.06			
8	100	17.13	16.6	30.88	26.67	1834	1.61
		16.89		24.83			
		15.85		24.3			

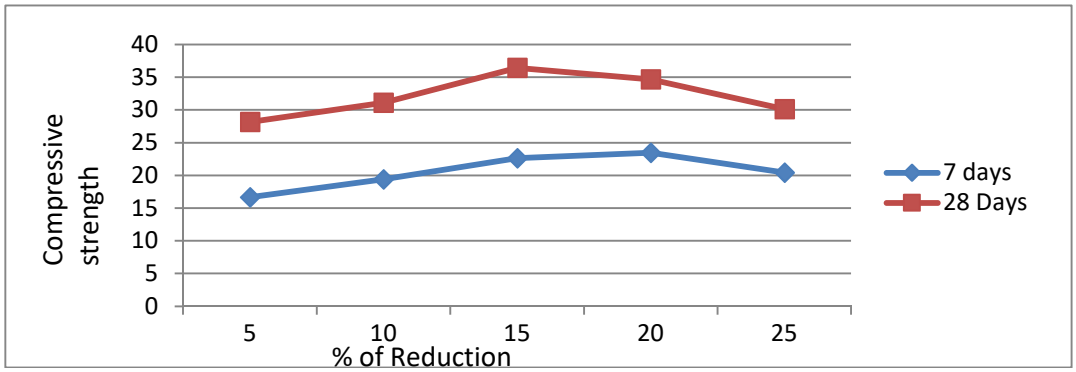

Figure 1: Compressive strength of concrete with replacement of cement by ECOSPHERE

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 8
August 2017

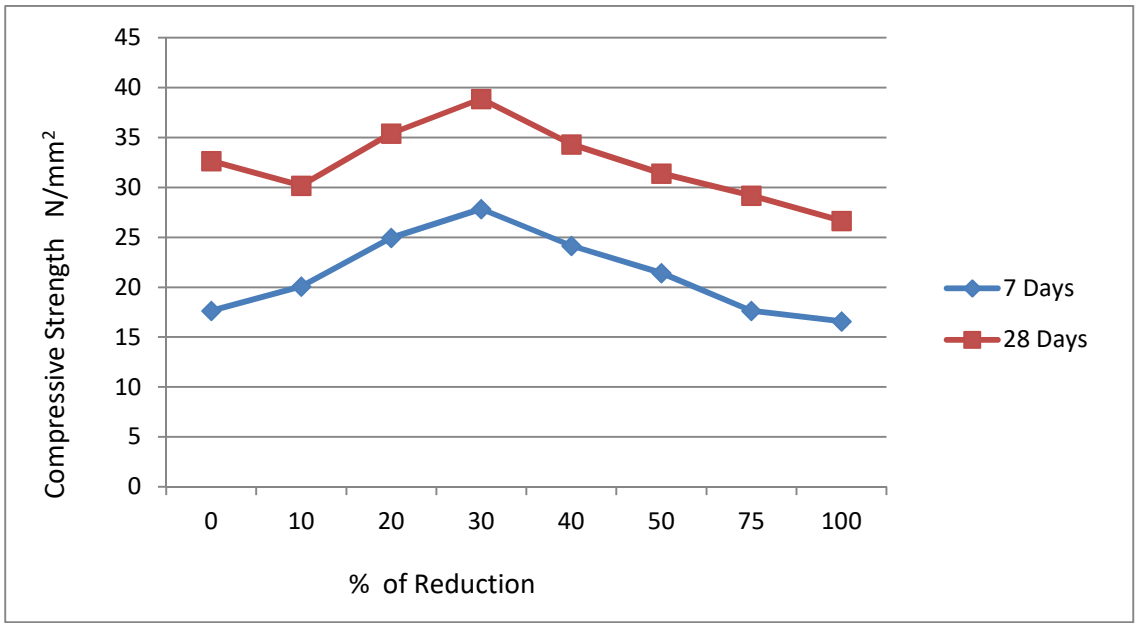

Figure 2 : Compressive strength of concrete with replacement of Sand by ECOSPHERE

DISCUSSIONS AND CONCLUSIONS

Test on concrete

A. Replacement of cement

1. There is sudden decrease in compressive strength and split tensile strength of concrete when 5% cement is replaced by ECOSPHERE.
2. But further, when percentage reduction of cement is increased, both the strengths are increased.
3. 28 days compressive and tensile strength are maximum with 15% replacement of cement. Hence the optimum percentage of replacement of cement in concrete by ECOSPHERE is 15% for 28days and 20% for 7days.
4. Ratio of 28days strength to 7days strength reduces with percentage increase in replacement of cement by ECOSPHERE. Hence ECOSPHERE can be used as accelerator.
5. Density of concrete reduces with percentage increase in reduction of cement by ECOSPHERE.
6. It has been concluded that the workability improves with replacement of cement by ECOSPHERE.
7. Water Absorption decreases with increase percentage ECOSPHERE.

B. Replacement of Sand

1. There is sudden decrease in compressive strength and split tensile strength of concrete when 10% sand is replaced by ECOSPHERE.
2. But further, when percentage reduction of sand is increased, both the strengths are increased.
3. 28 days compressive and tensile strength are maximum with 30% replacement of sand. Hence the optimum percentage of replacement of sand in concrete by ECOSPHERE is 30% for 28days and 7days.
4. Ratio of 28days strength to 7days strength reduces with percentage increase in replacement of sand by ECOSPHERE. Hence ECOSPHERE can be used as accelerator.
5. Density of concrete reduces with percentage increase in reduction of sand by ECOSPHERE.
6. It has been concluded that the workability improves with replacement of sand by ECOSPHERE.
7. Water Absorption decreases with increase percentage ECOSPHERE.

REFERENCES

1. ACI Committee 211.4R-93. "Guide for Selecting Proportions for High Strength Concrete with Portland cement and Fly Ash." ACI Manual of Concrete Practice, pt 1, 2001.
2. A.H. Asbridge, G.A. Chadbourn and C.L.Page, "Effects Of Metakaolin And The Interfacial Transition Zone On The Diffusion Of Chloride Ions Through Cement Mortars", UK School of Engineering and applied science, Aston University, Birmingham Cement and concrete research, 31(2001)1567-1572.
3. Andrea Boddy, R. D. Hootun and K. A. Gruber, "Long Term Testing Of the Chloride-Penetration Resistance of Concrete Containing High-reactive Metakaolin", Department of civil Engineering, University of Toronto, Cement and concrete research, 31(2001), 759-765.
4. Awal, A.S.M and Hussein, M.W, "Some Aspects of Durability Performances of Concrete Incorporating Palm Oil Fuel Ash." Proceedings of Fifth International Conference on Structural Failure, Durability and Retrofitting. Singapore 210-217, (1997).
5. Awal, A.S.M, "A Study Of Strength And Durability Performances Of Concrete Containing Palm Oil Fuel Ash." University Teknologi Malaysia. PhD Thesis (1998).
6. Chiara F. Ferraris, Karthik H. Obla, and Russell Hill. "The Influence of Mineral Admixtures on the Rheology of Cement Paste and Concrete." Cement Concrete Research 31, 245-255, (2001).
7. D.M.Roy and P. Arjunan, "Effect of Silica Fume, Metakaolin, And Low-Calcium Fly Ash on Chemical Resistance of Concrete" , M.R. Silsbee Materials research laboratory, the Pennsylvania state university, University Park, Cement and concrete research 31(2001)1809-1813.
8. F. Curcio, BA. DeAngehs and S. Pagliolico, "Metakaolin as Pozzolonic Microfiller for High Performance Mortars", Cement and Concrete Research, Vol-28, No-6, pp, 803, 1998.
9. H.S. Wong [17], H. Abdul Razzak, "Efficiency of calcined kaolin and silica fume as cement replacement material for strength performance." civil engineering dept, faculty of engineering, university of Malaya, 50603 lambhpantai, kualalumpur, Malaysia. Cement and concrete research, 34 (2004) 935-940.
10. I.B.Topcu and B.Isikdag. "Effect of Expanded Perlite Aggregate on the Properties of Lightweight Concrete." Journal of Materials Processing Technology PROTEC-11355; No. of Pages 5. (2007).
11. Indian Standard Code of Practice, "IS 650-1991- Standard Sand for testing cement- Specification", BIS-1991, Second revision, New Delhi.
12. Indian Standard Code of Practice, "IS 1077-1981, Guide for manufacturing common brunt clay building brick-Specification", BIS-1991, third revision, New Delhi.
13. Indian Standard Code of Practice, "IS 2117-1982, common brunt clay building brick- Specification", BIS-1995, fifth revision, New Delhi.
14. Indian Standard Code of Practice, "IS 2185-1983 part-3, Specification for concrete masonry unit, hollow and solid light weight blocks", BIS-1996, third revision, New Delhi.
15. K. Abdullah, M. W. Hussein, F. Zakaria, R. Muhammad, Z. Abdul Hamid, "POFA: A Potential Partial Cement Replacement Material in Aerated Concrete", Faculty of Civil Engineering, University Technology Malaysia, 81300, APSEC conference Sept-2006.
16. Kamile Tosun, Burak Felekoğlu and Bülent Baradan, "Effect of Metakaolin And Silica Fume on Mortar and Concrete", Dokuz Eylul University, Civil Engineering Department, Izmir, mortars and concrete, ACI Journal Proceedings', 79(1982) 444-57.