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Strength and Durability Characteristics of Ternary Blended Cement Concrete using Partial Replacement of Laterite Sand as Fine Aggregate

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***Abstract*-Concrete is a widely used vital material in the construction world. The cost of cement and sand is steadily increasing and concrete is mixture of cement, fine aggregate, coarse aggregate and water, with or without admixtures. Nowadays, there is a large scarcity of natural sand. So it is very important to find alternate materials which can be used instead of the constituent materials of concrete, so that the concrete become economical. Laterite is one of the locally available materials, which is used from ancient time as a building material .It is very cheap and also abundantly available. The use of laterite to replace fine aggregate of concrete is becoming wide spread in building construction .Copper slag(CS) is a byproduct obtained during the smelting and refining of copper .In this paper, copper slag is replaced by cement .Silica fume(SF) is a byproduct of the smelting process in the silicon and ferrosilicon industry. Silica fume is used in concrete to improve is properties. In this study cement is replaced by silica fume and copper slag and fine aggregate is replaced by laterite sand. In this study six mixes of M25 grade are used. The replacement level by silica fume and copper slag are 0%SF 0%CS, 20%SF 0%CS, 15%SF 5%CS, 10%SF 10%CS, 5%SF 15%CS, 0%SF 20%CS for each mix respectively. Also fine aggregate is replaced by laterite sand for 25% for each concrete mix.**

I. INTRODUCTION

A cement is a binder, a substance that sets and hardens and can bind other materials together. The word "cement" traces to the Romans, who used the term opuscaementicium to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick additives that were added to the burnt lime to obtain a hydraulic binder were later referred to as cementum, cimentum, and cement. Cements used in construction can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to be used in the presence of water Non-hydraulic cement will not set in wet conditions or underwater, it sets as the cement dries and reacts with carbon dioxide in the air. It can be attacked by some aggressive chemicals after setting. Hydraulic cement is made by replacing some of the cement in a mix with activated aluminium silicates, pozzolanas, such as fly ash. This allows setting in wet condition or underwater and further protects the hardened material from chemical attack (e.g., Portland cement). The chemical process for hydraulic cement found by ancient Romans used volcanic ash (activated aluminium silicates). Presently cheaper than volcanic ash, fly ash from power stations, recovered as a pollution control measure, or other waste or by products are used as pozzolanas with plain cement to produce hydraulic cement. Pozzolanas can constitute up to 40% of Portland cement. Hydraulic cement can harden underwater or when constantly exposed to wet weather. The chemical reaction results in hydrates that are not very water-soluble and so are quite durable in water and safe from chemical attack. The most important uses of cement are as a component in the production of mortar in masonry, and of concrete, a combination of cement and an aggregate to form a strong building material.

Cement replacement reduces the overall carbon dioxide emission of the concrete. Improved surface finish of the completed structure. Reduces the permeability, shrinkage, creep. Give greater resistance to chloride ingress and sulphate attack. Improves long term strength, performance and durability.

The objectives of the present study are

- To study the workability
- To study the compressive strength
- To study the splitting tensile strength
- To study the flexural strength
- To study the durability characteristics

II. EXPERIMENTAL INVESTIGATION

The properties of the materials used for the preparation of concrete plays a vital role in fresh as well as hardened properties of concrete.Tests were conducted on each material for getting their properties. Experimental investigation were carried out to determine the strength characteristics of concrete with different percentages of silica fume and copper slag and a fixed percentage of laterite sand as replacement for cement and fine aggregate and thereby to arrive at the optimum replacement percentage of cement and also to study the durability of concrete.

A. Materials Used

- Port land cement(53 grade)
- Potable water
- Copper slag

Copper is one of the basic chemical elements which is a soft and ductile metal, known for its high thermal and electrical conductivity and has a reddish-orange surface in its pure state. It is commonly used in electrical, construction and transportation industries. Pure copper is rarely found in nature, but is usually combined with other chemicals in the form of copper ores. The process of extracting copper from copper ore varies according to the type of ore and the desired purity of the final product. Each process consists of several steps in which unwanted materials are physically or chemically removed, and the concentration of copper is progressively increase

- Silica fume

Silica fume is a by- product in the production of silicon alloys such as ferro-chromium, ferro-manganese, calcium silicon etc.It consists primarily of amorphous (non-crystalline)silicon dioxide

- Laterite sand

Laterites are soil types rich in iron and aluminium, formed in hot and wet tropical areas. Nearly all laterites are rusty-red because of iron oxides. They develop by intensive and long-lasting weathering of the underlying parent rock. Tropical weathering (laterization) is a prolonged process of chemical weathering which produces a wide variety in the thickness, grade, chemistry and ore mineralogy of the resulting soils. The majority of the land area containing laterites is between the tropics of Cancer and Capricorn. Historically, laterite was cut into brick-like shapes and used in monument-buildings

- M sand

- Coarse aggregate

B. Test on constituent materials

Cement: Ordinary Portland Cement of 53 grade, conforming to IS: 12269-1987 was used. Different laboratory tests were conducted on cement to determine standard consistency, initial and final setting time and compressive strength as per IS: 4031-1988

TABLE 1 CHEMICAL COMPOSITION OF CEMENT (OPC 53 GRADE)

Ingredient	Percentage
Lime(CaO)	62
Silica(SiO2)	22
Alumina(Al2O3)	5
Calcium sulphate (CaSO4)	4
Iron oxide(Fe2O3)	3
Magnesia(MgO)	2
Sulphur(S)	1

TABLE 2 PHYSICAL PROPERTIES OF CEMENT (OPC 53 GRADE)

Sl.No.	Properties	Test results	Requirement as per IS: 12269-1987 (Reaffirmed 2004)
1	Specific Gravity	3.15	-
2	Standard Consistency (%)	35	26 -38
3	Initial Setting Time (minutes)	60	Not less than 30 minutes
4	Final Setting Time (minutes)	420	Not more than 600 minutes

Silica fume: Silica Fume (Amorphous SiO2) named Micro silica from Sree Muruga Industries Pvt Ltd.,Kerala was used for the experiments. The specific gravity of silica fume was 2.4.

TABLE 3 CHEMICAL COMPOSITION OF SILICA FUME

Chemical components	% Weight
Silica (SiO_2)	90-96
Lime (CaO)	0.1-0.5
Iron oxide (Fe_2O_3)	0.2-0.8
Alumina (Al_2O_3)	0.5-0.8
Magnesia (MgO)	0.5-1.5

Fig.1. Silica Fume

Fine aggregate: Commercially available M sand passing through 4.75mm IS sieve and conforming to grading zone II of IS: 383-1970 was used for experiment. Sieve analysis was done to determine the fineness modulus and grain size distribution of M sand.

TABLE 4 PROPERTIES OF FINE AGGREGATE

Sl No	Properties	Test Results
1	Specific gravity	2.392
2	Bulk density (g/cc)	1.81
3	Porosity(%)	24
4	Void ratio	0.26
5	Fineness modulus	3.11

TABLE 5 PARTICLE SIZE DISTRIBUTION OF FINE AGGREGATE

Sieve size(mm)	Weight retained in each sieve(g)	% Weight retained in each sieve	Cumulative % weight retained	% Weight passing
4.75	0	0	0	0
2.36	184.2	18.42	18.608	81.392
1.18	256.2	25.62	44.228	55.772
0.60	214.79	21.479	65.707	34.293
0.30	178.9	17.89	83.597	16.403
0.15	152.43	15.243	98.84	1.16
Pan	11.6	1.16	100	0
Fineness modulus of fine aggregate = 3.11				

Copper slag: Copper is one of the basic chemical elements which is a soft and ductile metal, known for its high thermal and electrical conductivity and has a reddish-orange surface in its pure state. It is commonly used in electrical, construction and transportation industries. Pure copper is rarely found in nature, but is usually combined with other chemicals in the form of copper ores.

It was procured from Laxmi Industries Pvt. Ltd., Tamilnadu. Its specific gravity was found to be 3.4.

Fig.2. Copper Slag

TABLE 6 CHEMICAL COMPOSITION OF COPPER SLAG

Property	(% wt)
Iron Oxide – Fe_2O_3	42 – 48
Silica – SiO_2	26- 30
Aluminium Oxide – Al_2O_3	1 – 3
Calcium Oxide – CaO	1.0– 2.0
Magnesium Oxide – MgO	0.8– 1.5

Laterite :Laterite is a highly weathered material, rich in secondary oxides of iron, aluminium or both. It is being extensively used as building block from the early civilization. Laterite obtained from natural source was used for replacing fine aggregate.

The specific gravity and fineness modulus of laterite used were 2.31 and 2.96 respectively.

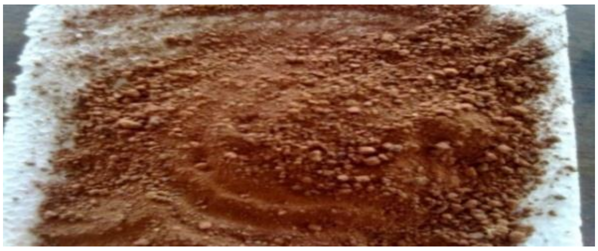

Fig.3. Laterite

Coarse aggregate: Coarse aggregate used in this study were 20mm nominl size. The physical properties were tested and it conformed to the IS 383:1970.The coarse aggregate used was found to belong to belong to standard zone. Specific gravity and fineness modulus of coarse aggregate used were 278 and 6.51 respectively.

Water: Potable water was used for the experimental investigation. Water available in the college water supply system was used for casting as well as curing of the test specimens.

C. Mix Design

As per IS:10262-2009 M25 mix was designed and the mix proportion was obtained as 1:1.4:2.81. Water cement ratio was 0.48. Six mixes were made namely TBC 0, TBC 1, TBC 2, TBC 3, TBC 4, TBC 5. TBC 0 was the control mix with 25 % Laterite sand and 0 % silica fume,0 % copper slag.

TABLE 7 MIX DESIGNATION FOR DIFFERENT MIXES

Sl No	Mix	Silica Fume(%)	Copper Slag(%)	Cement(%)	Laterite Sand(%)	Fine Aggregate(%)	Coarse Aggregate(%)
1	TBC0	0	0	100	25	75	100
2	TBC1	20	0	80	25	75	100
3	TBC2	15	5	80	25	75	100
4	TBC3	10	10	80	25	75	100
5	TBC4	5	15	80	25	75	100
6	TBC5	0	20	80	25	75	100

TABLE 8 QUANTITIES OF MATERIALS REQUIRED FOR M25 MIX FOR $1M^3$

Material	Mix designation	Mix designation	Mix designation	Mix designation	Mix designation	Mix designation
	TBC0	TBC1	TBC2	TBC3	TBC4	TBC5
Coarse Aggregate (kg/m^3)	853.32	853.32	853.32	853.32	853.32	853.32
Fine Aggregate (kg/m^3)	513.547	385.160	385.160	385.160	385.160	385.160
Laterite (kg/m^3)	0	128.386	128.386	128.386	128.386	128.386
Cement (kg/m^3)	323	258.4	258.4	258.4	258.4	258.4
Silica fume(kg/m^3)	0	64.6	48.45	32.3	16.15	0
Copper slag(kg/m^3)	0	0	16.15	32.3	48.45	64.6
water(kg/m^3)	186	186	186	186	186	186

D. Specimen details and casting of specimens

Standard cubes of size 150x150x150mm for compressive strength test,cylinders of 150mm diameter and 300mm height for compressive and splitting tensile strength test, beams of size 500x100x100mm for flexural strength test. For durability study small cubes of sizes 100x100x100mm and for RCPT study 150mm diameter and 50mm thick concrete specimens were used. The compressive strength test was carried out at 3, 7, 28, 56 and 90 days. The flexural and splitting tensile strength and the durability studies were carried out for all the six mixes.

TABLE 9 SPECIMEN DETAILS

Sl no	Specimen	Properties	Size(mm)	No.
1	Cube	Compressive strength	150×150×150	90
2	Cylinder	Split tensile strength	150 Diameter×300 Height	36
		Compressive strength		
3	Beam	Flexure tensile strength	500 × 100×100	18
4	Small cube	Durability study	100 × 100 ×100	108
5	Disc	RCPT	50 Diameter × 150 Height	18

Requried numbers of concrete cubes,cylinders,beams were casted .Also for durability studyrequired numbers of small cubes were casted and for RCPT study concrete specimens were casted. Specimens were demoulded after 24 hours of casting and were kept in a curing tank for water curing.

E. Tests on specimens

The specimens after casting and curing were subjected to testing.Testing the specimens determines the strength and also the quality of concrete.Tests were performed on the concrete both in fresh states and hardened states for getting workability ,strength and durabilityof concrete with silica fume ,copper slag and fine aggregate with constant percentage of laterite.The test performed were

1. Tests on workability of concrete
   - Slump Test
   - Compacting Factor Test
2. Tests on strength of concrete
   - Compressive Strength Test
   - Splitting Tensile Strength Test
   - Flexural Strength Test
3. Test on Durability Of Concete

III. RESULTS AND DISCUSSION

A. Properties of fresh concrete

Fresh concrete properties were studied for all the mixes and it is determined by slump test and compaction factor test.The test results are shown in Table 10andTable 11. From the result obtained ,it is found that workability increases form TBC 0 to TBC 5.

TABLE 10 VARIATION OF SLUMP VALUE WITH DIFFERENT MIXES

Sl No	Mix Designation	Slump(mm)
1	TBC 0	30
2	TBC 1	32
3	TBC 2	33
4	TBC 3	35
5	TBC 4	38
6	TBC 5	41

TABLE11 VARIATION OF COMPACTING FACTOR WITH DIFFERENT MIXES

Sl No	Mix Designation	Compacting factor
1	TBC 0	0.80
2	TBC 1	0.82
3	TBC 2	0.84
4	TBC 3	0.86
5	TBC 4	0.88
6	TBC 5	0.90

B. Properties of hardened concrete

1) Cube Compressive Strength

Cube Compressive test was carried out for cube of size 150mmx150mmx150mm in compression testing machine for all the six mixes at the age of 3,7,28,56 and 90days.From test results TBC 2 showed maximum compressive strength compared to all other mixes.From the compression test ,TBC 2 was obtained as the optimum mix.percentage increase 7 day compressive strength is 26% and 28 day compressive strength is 34%.

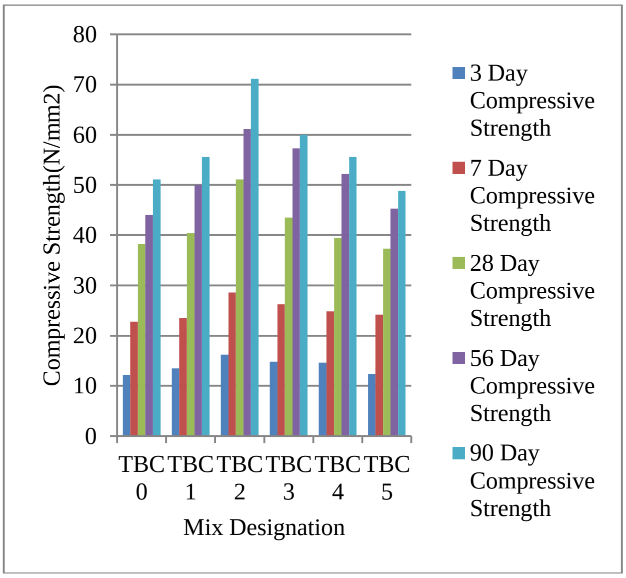

Fig.4. Variation of compressive strength of cube

2) Compressive Strength of Cylinder

The cylinder compressive strength test of concrete was carried out for six mixes. From these results ,it can be seen that the compressive strength of cylinder of TBC 2 was higher than other mixes.

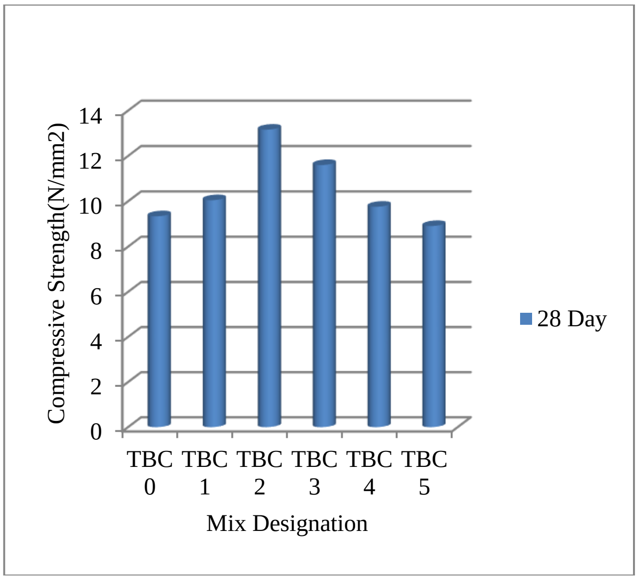

Fig.5. Variation of compressive strength of cylinder

3) Splitting tensile strength of cylinder

Splitting tensile strength test was done for six mixes at the age of 28 days of water curing From these results,it can be seen that the splitting tensile strength of cylinder of TBC2(15%SF,5%CS,25% Laterite sand) was higher than all other mixes.percentage increase in splitting tensile strength at 28 day is 44%.

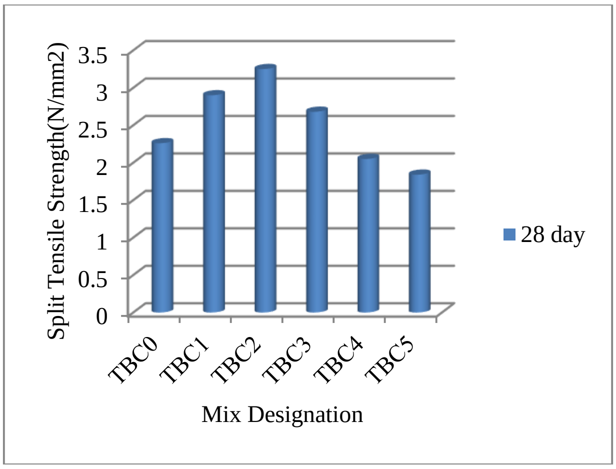

Fig.6. Variation of splitting tensile strength

4) Flexural strength of Beam

Flexural strength test was done for six mixes at the age of 28 days of water curing From these results,it can be seen that the Flexural strength of beam of TBC2(15%SF,5%CS,25%Laterite sand) was higher than all other mixes.percentage increase in Flexural strength at 28 day is 41%.

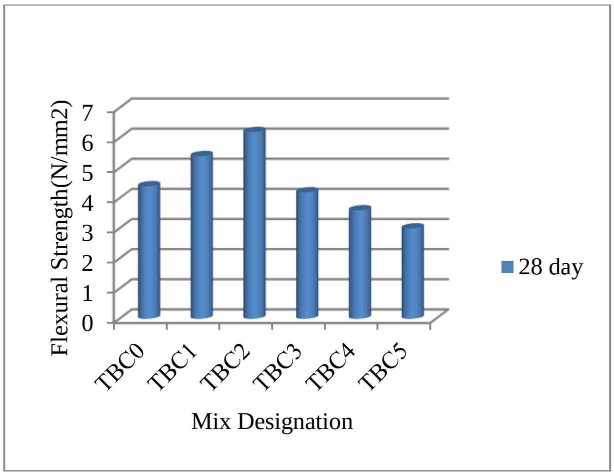

Fig.7. Variation of Flexural strength

C. Durability study of concrete

Durability of concrete is the ability to resist weathering action,chemical attack,abrasion or any process of deterioration or it is the ability to last a long time without significant deterioration. Concrete ingredients their proportioning interactions between them, placing and curing practices determine the ultimate durability and life of the concrete. Durability studies were carried out for six mixes at the ages of 56 and 90 days.

1) Alkali Attack Test

This test was performed on six mixes. TBC 0,TBC 1,TBC 2,TBC 3,TBC 4,TBC 5.Sodium Hydroxide was used for this study.This was done to find out the effect of alkali on the concrete mixes.From the results obtained ,it is found that the percentage strength loss was more for TBC 0 and less for TBC 2.This indicates that TBC 2 shows good resistance than control mix.

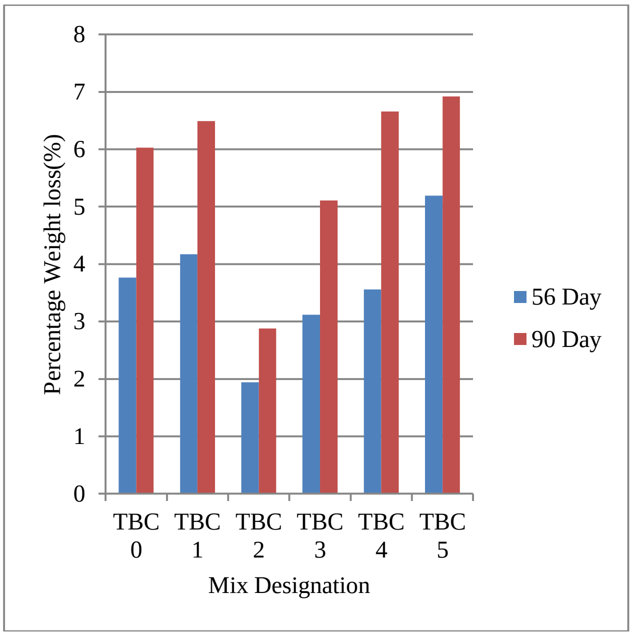

Fig.8. Percentage weight loss in alkaline solution

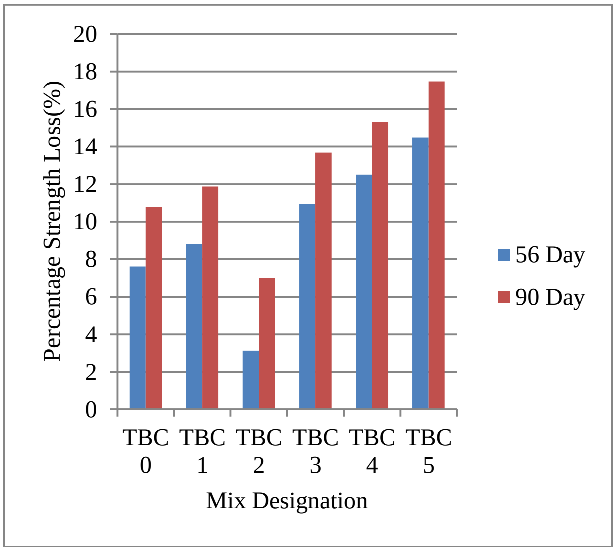

Fig.9. Percentage strength loss in alkaline solution

2) Acid Attack Test

This test was done for TBC 0,TBC 1,TBC 2,TBC 3,TBC 4,TBC 5 mixes at the ages of 56 and 90 days after the exposure to sulphuric acid solution.From the test results it is found that comparing the six mixes the percentage strength loss was less for optimum mix ie,TBC 2.

Fig.10. Specimens immersed in sulphuric acid solution

Fig.11. Formation of efflorescence

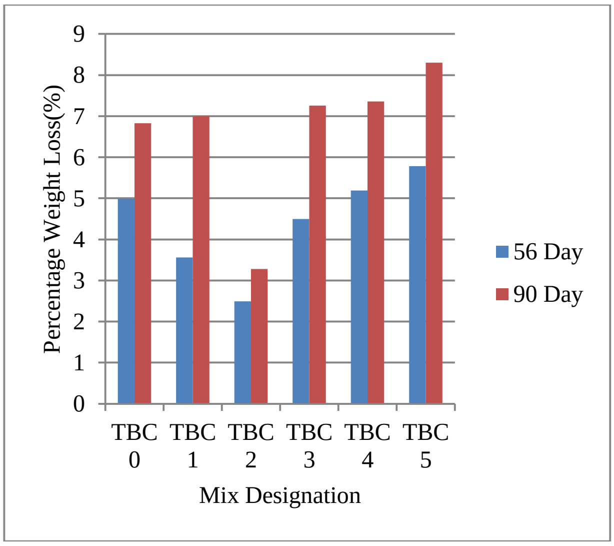

Fig.12. Percentage weight loss in acid solution

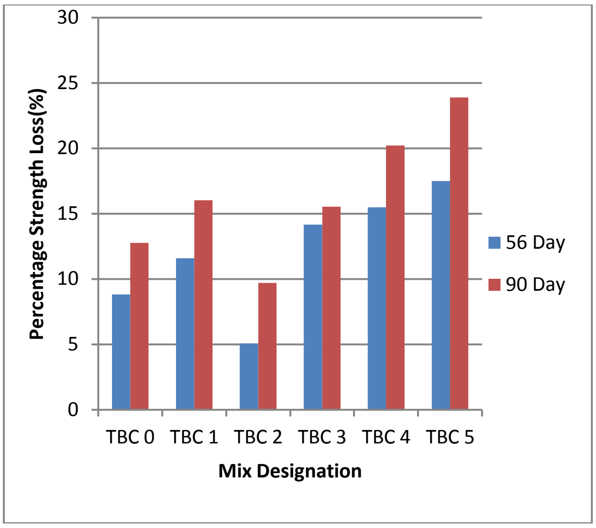

Fig.13. Percentage loss in compressive strength in acid solution

3) Sulphate Attack Test

The compressive strength and weight of the specimens were determined and compared with specimens subjected to water curing .This test was done for six mixes at the ages of 56 and 90 days after the immersion of sodium sulphate solution.From the result it is found that the strength loss and weight loss is more for TBC 5. When compared to TBC 0 and TBC 2 optimum mix show slight poor resistance to sulphate attack than control mix.

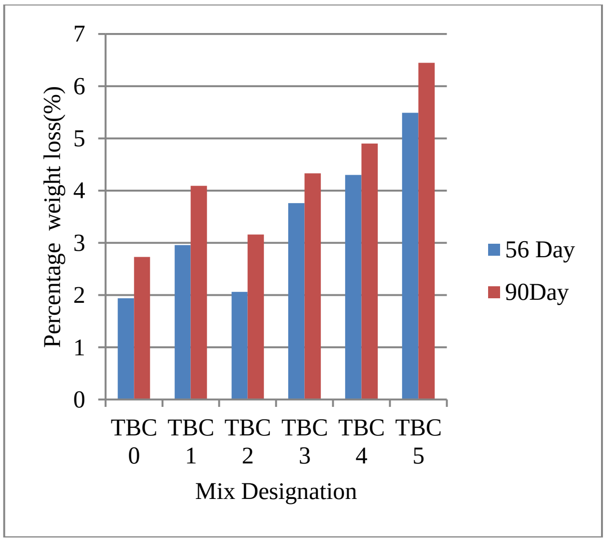

Fig.14. Percentage weight loss in sodium sulphate solution

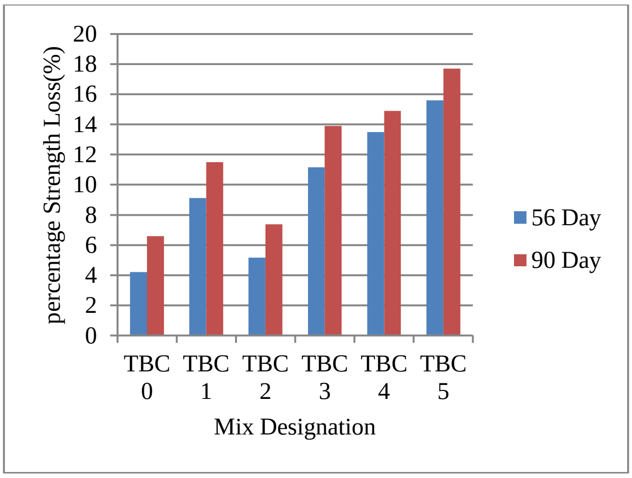

Fig.15. Percentage loss in compressive strength in sodium sulphate solution

4) Sea Water Attack Test

After exposing the specimens in sea water percentage strength loss and percentage weight loss was determined at 56 and 90 days.From the results it is clear that percentage strength loss is lesser for TBC 2.This indicates that TBC 2shows better durability property than the other five mixes.

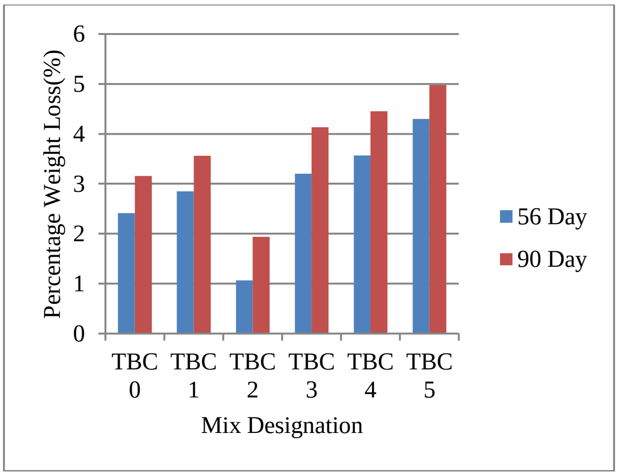

Fig.16. Percentage weight loss due to sea water attack

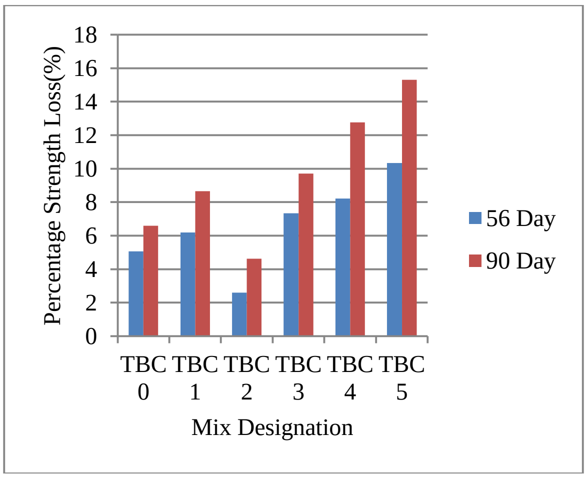

Fig.17. Percentage loss in compressive strength

V. CONLUSION

From the experimental study the conclusions arrived are:

- Workability of mix increases from TBC0 to TBC5
- The maximum compressive strength was found for TBC2
- The compressive strength of optimum mix is greater than of control mix
- The compressive strength increased by 34% in 28 days.
- The splitting and flexural strength was also found to be greater in TBC2 mix.
- The splitting tensile strength increased by 44% in 28 days.
- The flexural strength increased by 41% in 28 days.
- In alkaline solution curing TBC 2 showed good response than that of control mix.
- The strength loss and weight loss due to sea water attack is lower for TBC 2 than that of other mixes.
- In sulphate attack test control mix show slightly lower strength loss and weight loss than that of optimum mix TBC 2.
- From the observations TBC2(15% SF,5% CS,25% Laterite Sand) is most suitable to both strength and durability.
- The optimum mix TBC 2 show good acid resistant than control mix.

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