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A STUDY ON COMPRESSIVE STRENGTH OF CONCRETE REPLACEMENT OF COARSE AND FINE AGGREGETE BY STEEL SLAG AND QUARRY DUST

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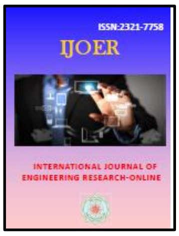

ABSTRACT

With the passage of time to meet the demand, there was a continual search in human being for the development of high strength and durable concrete. The history of high strength concrete (HSC) is about 35 years old, in late 1960s the invention of water reducing admixtures lead to the high strength precast products and structural elements in beam were cast in situ using high strength concrete (HSC). After the technology has come to age and concrete of the order of M60 to M120 are commonly used. Concrete of the order of M200 and above are a possibility in the laboratory conditions. The definition of high strength concretes (HSC) is continually developing. In the 1950s 34 N/mm^2 was considered high strength concrete, and in the 1960s compressive strengths of up to 52 N/mm^2 were being used commercially. More recently, compressive strengths approaching 138N/mm^2 have been used in cast-in-place buildings. The dawn of pre-stressed concrete technology has given incentive for making concrete of high strength. In India high strength concrete is used in pre-stressed concrete bridges of strength from 35N/mm^2 to 45N/mm^2. Presently Concrete strength of 75 N/mm^2 is being used for the first time in one of the flyover at Mumbai. Also in construction of containment dome at Kaiga power project used High Strength Concrete (HSC) of 60MPa with silica fume as one of the constituent.

High strength concrete (HSC) is used extensively throughout the world like in the gas, oil, nuclear and power industries are among the major uses. The application of such concrete is increasing day by day due to their greater structural performance, environmental friendliness and energy conserving implications. Apart from the usual risk of fire, these concretes are exposed to high temperatures and pressures for considerable period of time.

In the present study, the different admixtures were used to study their individual and combined effects on the resistance of concrete in addition to their effects on workability, durability and compressive strength by the replacement of admixtures by 10%, 15% of silica fume &10%, 20% and 30% of fly ash by the weight of cement with a constant amount of 0.5% steel hook fibers are added by volume of concrete, throughout the study.

Key Words: HSC, Workability, durability and Compressive Strength.

1. INTRODUCTION

Concrete is the most widely used man-made construction material all around the globe because of its superior specialty of being caste in any desirable shape. It is material synonymous with strength and longevity has emerged as the dominant construction material for the infrastructure needs of the present situation. Around five billion tones of concrete have been used around the world wide every year, in terms of cost it is equivalent to 25 to 30% of the nation budget.

1.1. IMPORTANCE OF CONCRETE

Concrete possess much importance because of its property of being moulded into any desired shape. It is strong, inexpensive, plentiful and easy to make. It possesses the property of versatility. Concrete is friendly to the environment. It is virtually all natural. It is recyclable. Famous concrete structures include the Burj Khalifa, Hoover dam, the Panama Canal and the Roman Pantheon.

1.2. PROPERIES OF CONCRETE

Concrete is an artificial conglomerate stone made essentially of Portland cement, water and aggregates. Concrete has relatively high compressive strength, but significantly lower tensile strength and are usually reinforced with the materials that are strong in tension. The elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develop. It has a very low coefficient of thermal expansion and as it matures concrete shrinks. Concrete subjected to long-duration forces is prone to creep.

1.3. SUBSTITUTION WITH CERAMIC AGGREGATE

The word "ceramic" was originated from the Greek word “keramos”, whose original meaning was “burnt earth Substitution of waste material in the preparation of concrete is a new concept for diminution of waste. Now a days wastage is increasing rapidly throughout the world. Among these, ceramic waste aggregate was generated in huge quantity because of its higher quantity usage. This ceramic waste was produced from ceramic industries, construction demolition waste. About 30% of waste is generated in ceramic industries during the manufacturing, transportation and usage. The amount of quantity of wastage is more due to its brittle nature. . In present study, ceramic insulator bushes are chosen because of its wastage and its thickness.

1.4. CERAMIC WASTE AGGREGATE COMPOSITION

Some ceramics are composed of only two elements. For example, alumina is aluminum oxide, Al_2O_3; zirconia is zirconium oxide, ZrO_2 and quartz Ceramics are good insulators and can withstand high temperatures. A popular use of ceramics is in art work silicon dioxide, SiO_2. Other ceramic materials, including many minerals, have complex and even variable compositions. For example, the ceramic mineral feldspar, one of the components of granite, has the formula $KAlSi_3O_8$. The chemical bonds in ceramics can be covalent, ionic, or polar covalent, depending on the chemical composition of the ceramic. When the components of the ceramic are a metal and a nonmetal, the bonding is primarily ionic; examples are magnesium oxide (magnesia) MgO, and barium titanate ($BaTiO_3$).

The materials used are normal coarse aggregate ,normal fine aggregate ,steel slag, quarry dust and opc of 53 grade cement after tested their properties according to tocodal provisions IS 2386:1963

The steel slag used here is an air cooled slag and is collected from NELCAST PVT LIMITED AT GUDUR OF S.P.S.R NELLORE District.

Steel slag is a waste product formed during steel making process. It is a non-metallic ceramic material formed from the reaction of flux such as calcium oxide with the inorganic non-metallic components present in the steel scrap.

We practice environmental responsibility in all our constructional works. To converse natural material and look for a more sustainable solution, we adopt the use of steel slag as a coarse aggregate to replace the natural aggregates.

Steel slag is our first choice for a number of construction projects owing to its technical properties, and also because lifetime maintenance and high strengths are obtained. In addition, there are significant advantages in using steel slag aggregates such as high skid resistance, better durability and resistance to rutting. The longer life of the construction will also obtained by the use of steel slag.

Fig -1: Sample of Steel SLAG

Quarry Dust can be defined as residue, tailing or other non-voluble waste material after the extraction and processing of rocks to form fine particles less than 4.75 mm. This product can be used for asphalt, substitute for sand, and filling around pipes. Quarry dust can be an economic alternative to the river sand.

Common river sand is expensive due to excessive cost of transportation from natural sources ,also large scale depletion of the sources creates environmental problems.

Fig -2: Sample of Quary dust.

2.1. PROBLEM IDENTIFICATION

Based on the experimented results conducted by research scholars, it was concluded that the compressive strength of concrete gradually decreased with increase in percentage of steel slag and quarry dust addition. The decrease in compressive strength of concrete is due to strength loss and weight loss of concrete. The compressive strength is optimum occurred at a percentages of 40-60% of quarry dust and 30-60% of steel slag. Beyond this limit the the compressive strength will be reduced.

3. TEST ON MATERIALS

3.1.CEMENT

Ordinary Portland cement 53 grade BHARATI conforming to IS:12269 has been procured and following tests have been carried out according IS: 8112 – 1989. Specific gravity, fineness of cement, normal consistency of cement, initial and final setting time of cement are determined in concrete technology laboratory. Experimental results are tabulated in Table.1 and compared the results with IS specification.

Table -1: Experimental Results on Cement

S.No	Tests	Experimented Values	Values as per IS specification
1	Fineness of cement	4%	<10%
2	Normal Consistency	30%	---
3	Specific gravity	3.05	<3.15
4	Initial setting time	75 min	Min of 30 min
5	Final setting time	265 min	Max of 10 hrs

3.2. NATURAL CRUSHED AGGREGATE

Crushed granite aggregate available from local sources has been used .The maximum size of coarse aggregate is 20mm. For the usage of this aggregate into concrete, it is necessary to determine the specific gravity, water absorption, and bulk density. Accordingly, tests have been carried out as per the procedure given in IS: 2386 (part-III)-1963.

3.3. STEEL SLAG AGGREGATE

Steel slag aggregate is procured from waste dump at Nelcast pvt limited Gudur-in Nellore district . The properties of steel slag aggregate such as specific gravity, water absorption, impact value, crushing value, abrasion value are determined and the results are tabulated in Table .2.

Table -2: Physical properties of ceramic aggregate

SI.NO	Property	Value
1	Specific Gravity	3.6
2	Water absorption in %	0.18
3	Impact Value in %	22
4	Crushing Value in %	20
5	Abrasion value in %	19

3.4. WATER

Locally available bore well water is used for the experimentation and curing purpose. The water is free from any contamination, substance and other organic matter. Following tests are conducted and tabulated along with permissible limits in Table .3.

Table -3: Physical properties of Water

S.No	Parameter	Experimental values in mg/l	Permissible limits
1	PH	7.5	6-8
2	Taste	Agreeable	Normal
3	Acidity	10	50
4	Alkalinity	88	250
5	Chlorides	300	2000 for PCC 3000for RCC
6	Total Hardness	230	300
7	Sulphates	90	150
8	Fluorides	0.60	1.5
9	Dissolved oxygen	6	5-7
10	Total solids	120	500
11	Total dissolved solids	150	500
12	Total suspended solids	100	300

3.4. Closure

Based on the experimental results of available concrete ingredients surrounded by Gudur town, design mix has been prepared as 1:1.5:3 and cubes were casted for evaluating the compressive strength of concrete. From the above results of concrete materials, those are safe and allowable to use in concrete composition because of its properties.

4. WORKABILITY OF CONCRETE

Workability of a concrete is a term which consists of the following four partial properties of concrete namely mix ability, transportability, mould ability, and compact ability. Cohesiveness and consistency both are concurrent properties of fresh concrete. Cohesiveness is a measure of the compact ability and finish ability of concrete. Consistency is requirement of water to mix the concrete properly.

I. Mixability: It is the ability of the mix to produce a homogeneous green concrete from the constituent materials of the batch, under the action of the mixing forces. A less mixable concrete mix requires more time of mixing to produce a homogeneous and uniform mix.

II. Transportability: Transportability is the capacity of the concrete mix to keep the homogeneous concrete mix to keep the homogeneous concrete mix from segregating during a limited time period of transportation of concrete, when forces due to handling operations of limited nature act.

III. Mouldability: It is the ability of the fresh concrete mix to fill completely the forms ormoulds without losing continuity or homogeneity under the available techniques of placing the concrete at a particular job/ this property is complex, since the behavior of concrete is to be considered under dynamic conditions.

IV. Compactibility: Compactibility is the ability of concrete mix to be compacted into adense, compact concrete, with minimum voids, under the existing means of compaction at the site. The best mix from the point of view of compatibility should close the voids to an extent of 99% of the original voids present, when the concrete was placed in the moulds.

4.1. GRADING OF AGGREGATE

This is one of the factors which will have maximum influence on workability. A well graded aggregate is the one which has least amount of voids in a given volume. Other factors being constant, when the total voids are less, excess paste is available to give better lubricating effect. With excess amount of paste, the mixture becomes cohesive and fatty which prevents segregation of particles. Aggregate particles will slide past each other with the least amount of compacting efforts. The better the grading, the less is the void content and higher the workability. The above is true for the given amount of paste volume.. In steel slag concrete composition two different sizes of aggregates 20 mm and 12.5 mm are used into the concrete.

4.2. MIX PROPORTIONS

Aggregate/ cement ratio is an important factor influencing workability. The higher the aggregate/cement ratio, the leaner is the concrete. In lean concrete, less quantity of paste is available for providing lubrication, per unit surface area of aggregate and hence the mobility of aggregate is restrained. On the other hand, in case of rich concrete with lower aggregate/cement ratio, more paste is available to make the mix cohesive and fatty to give better workability.

4.3. SLUMP CONE TEST

Workability of fresh concrete shall be carried out by performance of slump test. Slump value can be carried out according to the IS: 1199-1959. To determine the consistency or workability of steel slag & quarry dust concrete, slump cone test has been performed in the laboratory. Before conducting the experiment, apply demould agent i.e.., oil/grease inside the cone for avoidance of further sticking of the fresh concrete. Unsupported fresh concrete flows to the sides and a sinking in height takes place. This vertical settlement is known as slump. In this test fresh concrete is filled into a mould of specified shape and dimensions, and the settlement or slump is measured when supporting mould is removed. Slump increases as *water-content* is increased.

Fig -3: Slump cone apparatus

Four mixes are to be prepared with water-cement ratio (by mass) of 0.50, 0.60, 0.70 and 0.80, respectively, and for each mix take 10 kg of coarse aggregates, 5kg of sand and 2.5kgof cement with each mix proceed as follows.

1. Mix the dry constituents thoroughly to get a uniform colour and then add water.
2. Place the mixed concrete in the cleaned slump cone mould in 4 layers, each approximately ¼ of the height of the mould. Tamp each layer 25 times with tamping rod distributing the strokes in a uniform manner over the cross-section of the mould. For the second and subsequent layers the tamping rod should penetrate in to the underlying layer.
3. Strike off the top with a trowel or tamping rod so that the mould is exactly filled.
4. Remove the cone immediately, raising it slowly and carefully in the vertical direction.
5. As soon as the concrete settlement comes to a stop, measure the subsidence of concrete in mm which will give the slump.

5. CONCRETE TESTING

Based on the detailed review of literature it is concluded that there is need to substitute coarse aggregate by Steel slag coarse aggregate in the concrete production to avail the natural aggregate for future generation, so that the cost of production of concrete can be reduced considerably where the steel slag aggregate is available in plenty of quantity.

5.1. MIX PROPORTION

Mix proportion of 0.48: 1: 1.53: 2.88 is chosen according to its ingredients i.e, water, cement, fine aggregate and coarse aggregate.

1.Water: Locally available bore well water was used for mixing and curing.

2.Cement: OPC 53 grade of BHARATHI cement was used.

3.Fine aggregate: Locally available sand passing through 4.75 mm IS sieve and retaining on 2.36 mm IS sieve was used.

4.Coarse aggregate: Locally available coarse aggregate and ceramic aggregate of size 12 mm and 20 mm are used.

Table -4: Quantity of materials used

Materials	Replacement of C.A by Ceramic aggregate					
	0%	20%	40%	60%	80%	100 %
Cement	10	10	10	10	10	10
Fine aggregate	15.3	15.3	15.3	15.3	15.3	15.3
Natural crushed aggregate	28.8	23.04	17.28	11.52	5.76	0
0Ceramic aggregate	0	5.76	11.52	17.58	23.04	28.8

5.2. CASTING OF CUBES

Mix proportion of 0.48: 1: 1.53: 2.88 is chosen according to its ingredients i.e, water, cement, fine aggregate, coarse aggregate. For every mix, 6 cubes are prepared to test, each 3 cubes for 7 days and 28 days after curing. Mix the cement and sand with trowel on non-porous plate until uniform colour is achieved. Place the coarse aggregate in the flat surface and place the cement sand mix upon the aggregates and mix the entire materials thoroughly. Then add water to the mixture. The water/cement ratio used in this mix is 0.48.Water is replaced by Hydrochloric acid accordingly in proportions of 5% and 10% respectively. The time of mixing shall be in any case not less than 3 to 5 minutes. Mixing time is the time elapsed between the water is added to the mix and casting of cubes.

Fig -4: Cube moulds ready to use

Fig -5:Casting of cube moulds

Fig -6:Cube moulds on vibratory machine

5.3. CURING OF CONCRETE SPECIMENS

Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration. Since the hydration of cement does take time days and even weeks rather than hours-curing must be undertaken for a reasonable period of time if the the concrete is to achieve its potential strength and durability. Curing may also encompasses the control of temperature since this effects the rate at which cement hydrates.

Fig -7:Curing of Cocrete specimens in water

5.4. TESTING OF CONCRETE SPECIMENS

The concrete specimens after curing in water are tested for 7 days and 28 days strength by using Compressive testing machine of 2000 KN capacity. Compression test is the most common test conducted on hardened concrete, partly because it is easy test to perform and most of desirable characteristic properties of concrete are qualitatively related to its compressive strength. Compression test is carried out on specimens of cubical shape. The size of specimen is 15 x 15 x 15 cm. The cube specimens after curing were placed at the center of the testing machine and the load is to be applied at a rate of 20 KN per minute until the concrete specimen fails under compression.

Fig -8:Testing of concrete specimen.

6. RESULTS AND DISCUSSIONS

6.1. WORKABILITY OF CONCRETE

Workability of a concrete is a term which consists of the following four partial properties of concrete namely mix ability, transportability, mould ability, and compact ability. Cohesiveness and consistency both are concurrent properties of fresh concrete. Cohesiveness is a measure of the compact ability and finish ability of concrete. Consistency is requirement of water to mix the concrete properly. Workability of concrete depend not only the properties of concrete but also the nature of application. A very dry concrete seems to be have low workability and too wet condition seems to have high workability, both of these are not enough to improve the good characteristics of concrete.

Table -5: Test results of slump with different replacements for 5% HCl

S.No	Nomenclature	% of Hcl	% Replacement of natural coarse aggregate with ceramic waste aggregate	Slump value in mm
1	R	5	0	150
2	CWAC20	5	20	140
3	CWAC40	5	40	130
4	CWAC60	5	60	125
5	CWAC80	5	80	122
6	CWAC100	5	100	120

Table -6: Test results of compaction factor with different replacements for 5% Hcl.

S.No	Nomenclature	% of HCl	% Replacement of natural coarse aggregate with ceramic waste aggregate	Compaction factor
1	R	5	0	0.93
2	CWAC20	5	20	0.93
3	CWAC40	5	40	0.92
4	CWAC60	5	60	0.86
5	CWAC80	5	80	0.85
6	CWAC100	5	100	0.85

Table -7: Test results of compaction factor with different replacements for 10% Hcl.

S.No	Nomenclature	% of Hcl	% Replacement of natural coarse aggregate with ceramic waste aggregate	Compaction factor
1	R	10	0	0.89
2	CWAC20	10	20	0.86
3	CWAC40	10	40	0.85
4	CWAC60	10	60	0.84
5	CWAC80	10	80	0.83
6	CWAC100	10	100	0.81

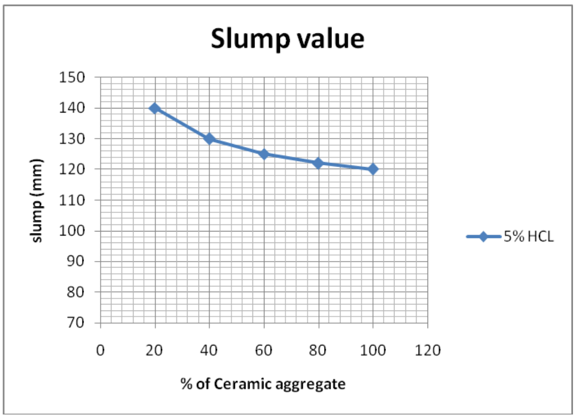

Fig -9:Slump for 5% Hcl

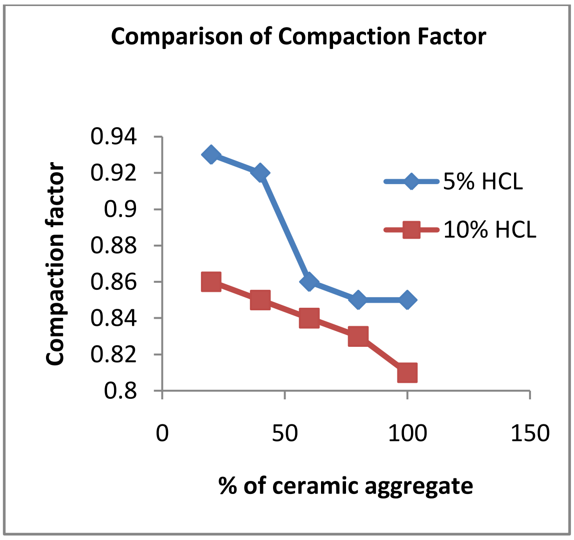

Fig -10:Comparison of Compaction factor 5% and 10% HCl

Workability of concrete is determined by its shape, size, surface texture and water absorption. Ceramic waste aggregate possess angular shape and has smooth surface which in turn possess rough surface on crushing. The maximum size of aggregates used is 20 mm. Ceramic aggregate exhibits higher water absorption capacity. Ceramic waste aggregate exhibited 0.18% of water absorption and natural crushed granite aggregate exhibited 0.10% of water absorption. Ceramic concrete exhibited higher moisture content and by which gel pores and cavities could not be filled with sufficient cement paste as compared with reference concrete. The cohesiveness of ceramic aggregate in concrete composition is dipping when the replacement has been increased. Due to the higher angularity, water absorption and surface area of ceramic waste aggregate the slump values decreased. Due to these factors the workability factors such as Slump value and Compaction factor decreased gradually with increase in replacement of natural coarse aggregate with ceramic waste aggregate as well as Hydrochloric acid.

6.2. Weight Loss

Test results of weight loss of ceramic concrete with 5% acid & 10% acid are shown in Table.8,9,10 & 11.

Table -8: Weight Loss of ceramic concrete with 5% acid for 7days

S.No	% of Ceramic	% of Acid	Weight (gm)
1	0	5	8154
2	20	5	8013
3	40	5	7940
4	60	5	7879
5	80	5	7798
6	100	5	7705

Table -9:Weight Loss of ceramic concrete with 5% acid for 28days

S.No	% of Ceramic	% of Acid	Weight (gm)
1	0	5	8415
2	20	5	8295
3	40	5	8212
4	60	5	8138
5	80	5	8004
6	100	5	7889

Table -10:Weight Loss of ceramic concrete with 10% acid for 7 days

S.No	% of Ceramic	% of Acid	Weight (gm)
1	0	10	8062
2	20	10	7958
3	40	10	7925
4	60	10	7853
5	80	10	7812
6	100	10	7796

Table .11:Weight Loss of ceramic concrete with 10% acid for 28 days

S.No	% of Ceramic	% of Acid	Weight (gm)
1	0	10	8423
2	20	10	8206
3	40	10	8198
4	60	10	8135
5	80	10	8018
6	100	10	7959

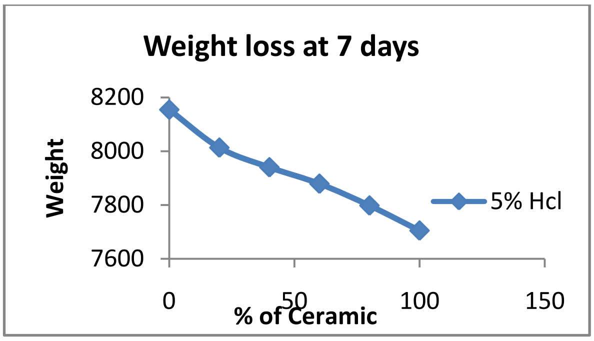

Fig -11: Weight loss of ceramic concrete with 5% of HCl at 7days

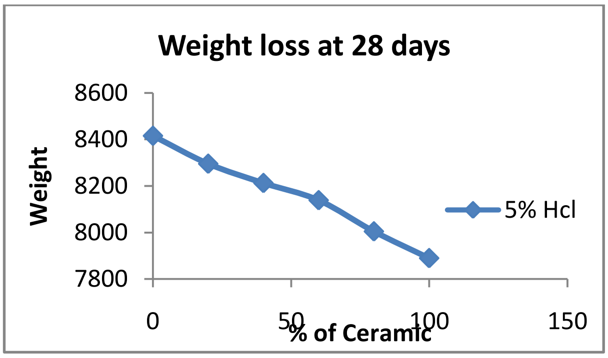

Fig -12: Weight loss of ceramic concrete with 5% of HCl at 28days

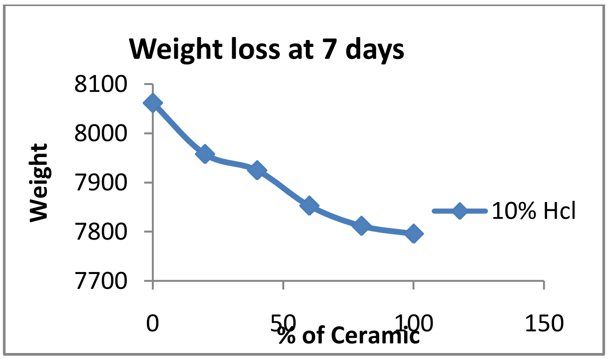

Fig -13: Weight loss of ceramic concrete with 10% of HCl at 7days

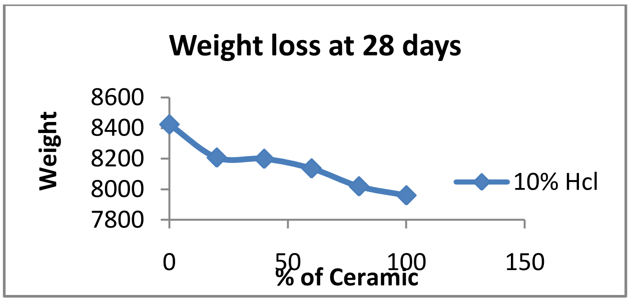

Fig -14: Weight loss of ceramic concrete with 10% of HCl at 28days

It was observed that the percentage of weight loss of ceramic concrete with 5% acid for 7 days & 28 days decreased by 0.96% & 6.02%. The percentage of -weight loss of ceramic concrete with 10% acid for 7 days & 28 days decreased by 4.62% & 2.76%.

7. CONCLUSIONS

Workability of ceramic aggregate concrete is decreased when the aggregate is replaced with ceramic waste and when the normal water is replaced with hydrochloric acid.

I. The slump value has been decreased from 150 mm to 120 mm at 5% addition of HCl. At 10% addition of HCl , the slump has been decreased from 130 mm to 90 mm.

II. Compaction factor has been decreased from 0.93 to 0.85 at 5% addition of HCl. At 10% addition of HCl the compaction factor has been decreased from 0.89 to 0.81.

III. The average 7 days compressive strength of reference mix at 5% HCl is 36.67 Mpa. The average 7 days compressive strength of reference mix at 10% HCl is 31.55 Mpa.

IV. When normal aggregate is replaced with ceramic aggregate at 20%, 40%, 60%, 80% and 100% , the compressive strength shows as 35.11, 32.89, 29.04, 25.78 and 23.41 Mpa. These values shows that compressive, strength is reduced to 32.32% at 100% replacement with ceramic waste.

V. When normal aggregate is replaced with ceramic aggregate at 20%, 40%, 60%, 80% and 100%,the compressive strength shows as 29.77, 28.14, 26.67, 24.74 23.11 Mpa. These values shows that compressive strength is reduced to 22.37% at 100% replacement with ceramic waste.

VI. At 5% HCl the weight loss of ceramic aggregate concrete at 7 Days and 28 days was found to be 0.96% and 6.02% respectively. At 10% HCl the weight loss of ceramic aggregate concrete at 7 days and 28 days was found to be 4.62% and 2.76% respectively.

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