A COMPARATIVE STUDY ON COMPRESSION AND DURABILITY OF CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH CERAMIC AND HYPO SLUDGE

[1]Shaik.Subhan Alisha, [2]M.Lakshmi Kumar, [3]P.Raju

[1]Department of Civil Engineering, DNR College of Engineering, JNTUK, (India)

[2]Department of Civil Engineering, DNR College of Engineering, JNTUK, (India)

[3]Department of Civil Engineering, SRKR Engineering College, AU, (India)

ABSTRACT

The advancement of concrete technology can reduce the consumption of natural resources and energy sources and reduces the burden of pollutants on environment. Presently Ceramic waste and paper sludge are the most active research areas that encompasses a number of disciplines including civil engineering and construction materials. Industry inevitably generates wastes, irrespective of the improvements introduced in manufacturing processes. In both the industries, about 15%-30% production goes as waste. These wastes pose a problem in present-day society. So, it is most essential to develop eco-friendly concrete from these wastes.

This project reports the results of an experimental study on replacement of (OPC) cement by ceramic waste powder and paper sludge accordingly in the range of 0%, 5%, 10%, 15%, 20%, by weight of cement. Concrete mixtures were produced, tested and compared in terms of compressive strength to the conventional concrete. These tests were carried out to evaluate the properties for 7, 14, 28 & 90 days. The results of this work have been presented in this dissertation. These tests were carried out to evaluate the properties for the test results of 7, 14, 28 and 90 days for compressive strengths in normal water and in MgSO4 solution of 1%, 2% and 3%. Also the durability aspect for ceramic and hypo sludge waste in cement concrete for sulphate attack was tested.

Keywords: sulphate effect, Ceramic waste powder, hypo waste powder, Durability of ceramic and hypo waste and ceramic and hypo waste compressive and split tensile test

I. INTRODUCTION

In the present scenario there is a critical shortage of natural resources, Production and utilization of concrete has rapidly increased, which results in increased consumption of natural aggregates. Generally in design of concrete mix, cement, fine aggregates and coarse aggregates are being used as traditional materials, which plays a crucial role in designing of a particular grade of concrete.

Pozzolanic concretes are used extensively throughout the world where oil, gas, nuclear and power industries are among the major users. The applications of such concretes are increasing day by day due to their superior structural performance, environmental friendliness, and energy conserving implications. The search for alternative binders, or cement replacement materials, has been carried out for decades. They have forced to focus on recovery, reuse of natural resources and find other alternatives. The use of the replacement materials offer cost reduction, energy savings, and arguable superior product.

Ceramic powder is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials. In ceramic industry, about 15% - 30% waste material generated from the total production. This waste is not recycled in any form at present.

Thus the concrete industry offers an ideal method to integrate and utilize a number of waste materials, which are socially acceptable, easily available, and economically within the buying powers of an ordinary man. Presence of such materials in cement concrete not only reduces the carbon dioxide emission, but also imparts significant improvement in workability and durability. In the present investigation, a feasibility study is made to use ceramic powder and hypo sludge as an admixture in cement concrete and compressive strengths are found for different percentages of partial replacements. . These tests were carried out to evaluate the properties for the test results of 7, 14, 28 and 90 days for compressive strengths in normal water and in $MgSO_4$ solution of 1%, 2% and 3%. Also the durability aspect for ceramic and hypo sludge waste in cement concrete for sulphate attack was tested.

1.1 Objective of The Work

The objective of this study was to use the ceramic waste and Hypo sludge which is generated during production and also to reduce the production costs of concrete in terms of natural resources, energy and also to provide an over view of the effects of elevated temperatures on the conventional and partially replaced cubes.

- To carry out mix design for M40 grade mix for both conventional and partially replaced concrete cubes made with 0%, 5%, 10%, 15% and 20%.
- To identify the compressive strength at normal for cubes for 7, 14 and 28, 90 days and 300X150 mm cylinders for each concrete mix.

II. METHODS AND MATERIALS

The evaluation of ceramic waste and hypo sludge for replacement of cement material begins with the concrete testing. Concrete contains cement, water, fine aggregate, coarse aggregate and grit With the control concrete, i.e. 0%, 5%, 10%, 15% ,20% of the cement is replaced with ceramic waste & hypo sludge the data compared with data from a standard concrete without ceramic waste and HYPO SLUDGE individually. Three cube samples were cast on the mould of size 150 X 150 X 150 mm and 300 X 150 mm cylinders for each concrete mix. After about 24h the specimens were de-moulded and water curing was continued till the respective specimens were tested after 7, 14, 28 & 90 days for compressive strength test Along with the split tensile strengths for 7,14,28 & 90 days on Universal Testing Machine (UTM).

Hypo sludge is a recent arrival among cementitious materials. It was originally introduced as artificial pozzolona while producing paper the various wastes are comes out from the various processes in paper industries. From the preliminary waste named as hypo sludge due to its low calcium is taken out for our project to replace the cement utilization in concrete.

Under normal conditions, most concrete structures are subjected to a range of temperature no more severe than that imposed by ambient environmental conditions. Concrete's thermal properties are more complex than for most materials because not only is the concrete a composite material whose constituents have different properties, but its properties also depend on moisture and porosity. Elements could distort and displace, and, under certain conditions, the concrete surfaces could spall due to the build-up of steam pressure.

2.1 Materials:

CEMENT (IS: 12269-1987): Ordinary Portland cement is by far the most important type of cement. The OPC was classified into three Grades viz., 33 Grade, 43 Grade and 53 Grade depending upon the strength of the cement at 28 days when tested as per IS 4031-1988.

AGGREGATE: Aggregate properties greatly influence the behaviour of concrete, since they occupy about 80% of the total volume of concrete. The aggregate are classified as Fine aggregate and Coarse aggregate

Fine aggregate (IS: 383 – 1970): Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. Fine aggregate form the filler matrix between the coarse aggregate. The most important function of the fine aggregate is to provide workability and uniformity in the mixture. The fine aggregate also helps the cement paste to hold the coarse aggregate particle in suspension.

Coarse aggregate (IS: 383 – 1970): The coarse aggregate are granular materials obtained from rocks and crushed stones. Coarse aggregate form the main matrix of the concrete, in case of coarse aggregate maximum 20 mm coarse aggregate is suitable for concrete work. Crushed granite aggregate conforming to IS: 383-1970 was used for the preparation of concrete

CERAMIC WASTE: Ceramic material is hard, rigid. It is estimated that 15 to 30% waste are produced of total raw material used, and although a portion of this waste may be utilized on-site, such as for excavation refill. Reuse of this kind of waste has advantages economic and environmental, reduction in the number of natural spaces employed as refuse dumps.

Fig.1 Ceramic powder

Physical properties of Ceramic waste

S. No.	Property	Test Result
1.	Specific Gravity	1.89
2.	Bulk density (g/cm^3)	1.26
3.	Impact Test	23.69 %
4.	Water Absorption	6.56 %

Chemical composition (%) of waste ceramic

Composition	Ceramic powder
SiO_2	63.29
Al_2O_3	18.29
Fe_2O_3	4.32
CaO	4.46
MgO	0.72
P_2O_5	0.16
K_2O	2.18
Na_2O	0.75
SO_3	0.10
CL	0.005
TiO_2	0.61
SrO_2	0.02
Mn_2O_3	0.05
Loss of ignition	1.61

HYPO SLUDGE: The production of Hypo sludge is estimated about 35% of the daily production in the paper industries. These wastes are used as an ingredient of cement manufacturing in wet process. The paper industries dump these waste in any nearby pit or waste land and this causes environmental issues.

Fig.2 Hypo sludge

Physical properties of Hypo sludge

S. No.	Property	Test Result
1.	Specific Gravity	2.2
2.	Bulk density (g/cm^3)	1.48
3.	Impact Test	19.69 %
4.	Water Absorption	6.56 %

Chemical composition (%) of waste Hypo sludge

Chemical Properties	Ordinary Portland Cement (OPC)
Silicon Dioxide (SiO_2)	21.77%
Calcium Oxide (CaO)	57.02%
Magnesium Oxide(MgO)	2.71%
Sulphur Trioxide (SO_3)	2.41%
Aluminium Oxide (Al_2O_3)	2.59%
Ferric Oxide (Fe_2O_3)	0.65%
Loss on Ignition	2.82%

WATER: Clean potable water was used for mixing concrete. Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete and steel.

2.2 Workability Tests On Concrete

SLUMP CONE TEST: To conduct the Slump test first the mould is thoroughly cleaned and should be greased around the inner surface of slump cone. Now it is filled in four layers, each approximately ¼ of the height of the mould. Each layer is tamped 25 times by the tamping. After that the mould is removed from the concrete immediately by raising it slowly and carefully in vertical direction. This allows the concrete to subside. This subsidence is referred as SLUMP of concrete. This difference in height in mm is taken as slump of concrete. Hence the slump obtained is 75mm.

COMPACTION FACTOR TEST: Compaction factor measures the workability in an indirect manner by determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height.

Fig.3 Compaction factor test

2.3 Testing of Specimens

A time schedule for testing of specimens is maintained to ensure their proper testing on the due date and time. The specimens were taken out and allow drying under shade Specimens stored in water shall be tested immediately on removal from the water and while they are still in the wet condition. Surface water and grit shall be wiped off the specimens and any projecting fins removed. The cast specimens are tested as per standard procedures, immediately after curing the specimens in water for a period of 7, 14, 28 and 90days.

COMPRESSIVE STRENGTH OF CONCRETE

Test for compressive strength was conducted according to IS: 516-1959. The specimens of 150mm cubes are exposed to a specific temperature and duration were released from the furnace and tested for compressive strength after cooling down the specimens to normal room temperature condition. The specimen cubes were placed in compression testing machine such that the load was applied on the opposite sides of the cube .The axis of the cube was aligned with the Centre of steel plate of the testing machine.

The load was gradually applied without any shock and increased continuously until the resistance of the specimen to the increasing load broke down and no greater load was sustained. Average of three test results of the specimen was considered as the compressive strength by ensuring the individual variation is not more than 15% of the average value. A total of 30 conventional cubes were casted for strength testing to account for different ages of curing 7 and 28 days and 150 cubes with partial replacement of ceramics at different proportions with exposed temperatures of 100^{o}C, 200^{o}C, 300^{o}C, 400^{o}C and 500^{o}C for time duration of 1 hour.

SPLIT TENSILE TEST ON CONCRETE SPECIMENS

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure. Due to the compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter as obtained from an elastic analysis. Specimens were removed from the moulds after 24 hours and cured .After curing, Cylinder specimens of different percentages of ceramic waste were tested under compression testing machine in accordance with IS:516 after a curing period of 7days & 28 days.

Fig.4 Specimen subjected to Split tensile strength

2.4 Durability

Durability can be defined as the ability of structure to give required performance during intended service period under the influence of degradation factors. A durable waste material like ceramic waste aggregate can help the environment by conserving natural resources. The quantity of waste generation can be reduced by recycling and environmental impact of repair and replacement. According to the ACI committee, durability is an ability of the concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties. Durability of concrete depends on the mixed design proportions, workmanship of the work, placing, compaction of concrete and mechanical properties of concrete. Chemical resistance of concrete depends on the selection of materials, weathering action and it can be improved further by introducing air bubbles into the concrete. The quality of concrete directly depends on the quantity of cement and water, which decides the strength and durability of hardened concrete.

Effect of sulphate on hardened concrete

The behaviour of acids on hardened concrete is conversion of $mgso_4$ compounds of attacking acids. Sulphate attack completely changes the hardened cement paste on surface and destroys pore system of the hardened concrete. Therefore in the case of acid attack, the permeability of sound concrete is less important as compared to the reaction that takes place. The severity of deterioration of concrete depends on the sulphates and temperature. The effect of acid is mainly during the transformation of concrete from fresh state to hardened state. In fact, no ordinary Portland cement concrete is acid resistant. In general practice, degree of attack increases as the concentration of acid increases. When pH value is < 6.5 attack of acids will observe, if its reading is < 4.5, severe attack will be observed.

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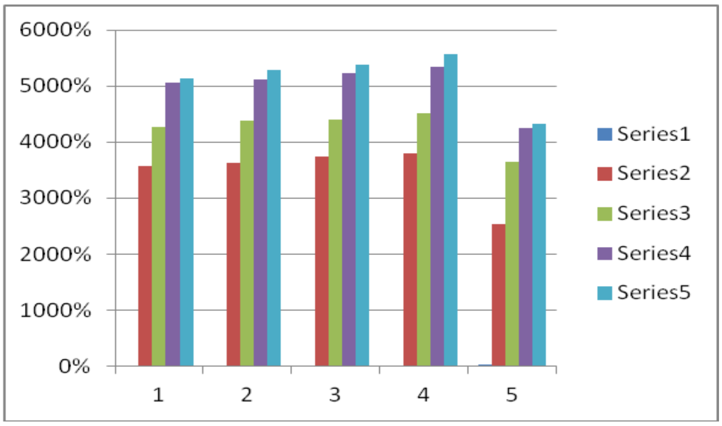
III. RESULTS AND DISCUSSION

3.1 COMPRESSIVE STRENGTH: In accordance with IS 516-1959 the compressive strengths of conventional and partially replaced cubes for 7, 14, 28 & 90 days are determined in compression testing machine.

Table 3.1 Compressive strength values for replacement of cement by ceramic waste after 7, 14, 28 & 90 days curing

S.no	% replacement of ceramic waste	COMPRESSIVE STRENGTH OF CUBES AT 7 DAYS (N/mm^2)	COMPRESSIVE STRENGTH OF CUBES AT 14 DAYS (N/mm^2)	COMPRESSIVE STRENGTH OF CUBES AT 28 DAYS (N/mm^2)	COMPRESSIVE STRENGTH OF CUBES AT 90 DAYS (N/mm^2)
1	0%	35.80	42.61	50.67	51.37
2	5%	36.21	43.83	51.23	52.93
3	10%	37.43	44.04	52.36	53.83
4	15%	38.02	45.23	53.39	55.63
5	20%	25.40	36.42	42.43	43.34

Graph



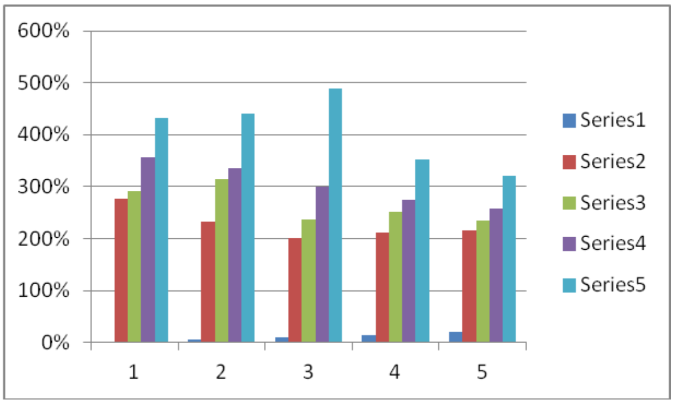
Graphical representation and Comparison of compressive strength results at 7, 14, 28 & 90 days

3.2 SPLIT TENSILE STRENGTH: In accordance with IS-516 the split tensile strength of conventional and partially replaced concrete cylinders for 7, 14, 28 and 90 days strength is determined by testing the cylinder specimens in compression testing machine.

Table 3.2 Split tensile strength values for replacement of cement by ceramic waste after 7, 14, 28 & 90 days curing

S.no	% replacement of ceramic waste	SPLIT TENSILE STRENGTH OF CYLINDERS AT 7 DAYS (N/mm^2)	SPLIT TENSILE STRENGTH OF CYLINDERS AT 14 DAYS (N/mm^2)	SPLIT TENSILE STRENGTH OF CYLINDERS AT 28 DAYS (N/mm^2)	SPLIT TENSILE STRENGTH OF CYLINDERS AT 90 DAYS (N/mm^2)
1	0%	2.77	2.91	3.56	4.32
2	5%	2.32	3.15	3.35	4.40
3	10%	2.01	2.36	3.00	4.89
4	15%	2.12	2.52	2.75	3.52
5	20%	2.16	2.35	2.58	3.21

Graph



Graphical representation and comparison of split tensile strength results at 7, 14, 28 & 90 days

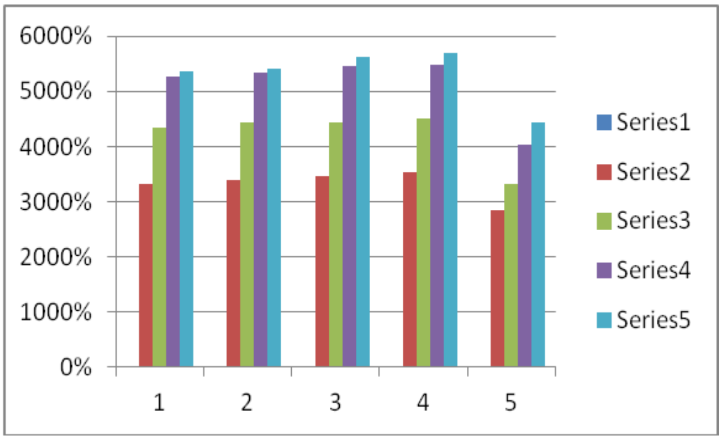
3.3 Replacement of Cement with Hypo Sludge

COMPRESISVE STRENGTH:

Table 3.3 Compressive strength values for replacement of cement by hypo sludge waste after 7, 14, 28 & 90 days curing

S.no	% replacement of Hypo sludge	COMPRESSIVE STRENGTH OF CUBES AT 7 DAYS (N/mm^2)	COMPRESSIVE STRENGTH OF CUBES AT 14 DAYS (N/mm^2)	COMPRESSIVE STRENGTH OF CUBES AT 28 DAYS (N/mm^2)	COMPRESSIVE STRENGTH OF CUBES AT 90 DAYS (N/mm^2)
1	0%	33.24	43.41	52.62	53.67
2	5%	33.92	44.26	53.41	54.12
3	10%	34.56	44.29	54.61	56.27
4	15%	35.23	45.00	54.83	56.83
5	20%	28.43	33.21	40.43	44.27

Graph



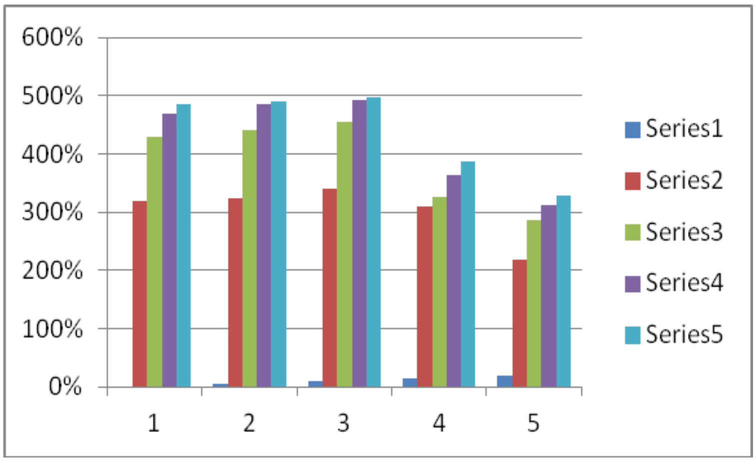
Graphical representation of comparison between 7, 14, 28 & 90 days compressive strength values for replacement of cement by hypo sludge

SPLIT TENSILE STRENGTH

Table 3.4 Split tensile strength values for replacement of cement by hypo sludge waste after 7, 14, 28 & 90 days curing

S.no	%replacement of Hypo sludge	SPLIT TENSILE STRENGTH OF CYLINDERS AT 7 DAYS (N/mm^2)	SPLIT TENSILE STRENGTH OF CYLINDERS AT 14 DAYS (N/mm^2)	SPLIT TENSILE STRENGTH OF CYLINDERS AT 28 DAYS (N/mm^2)	SPLIT TENSILE STRENGTH OF CYLINDERS AT 90 DAYS (N/mm^2)
1	0%	3.18	4.29	4.70	4.85
2	5%	3.24	4.40	4.86	4.90
3	10%	3.39	4.55	4.93	4.96
4	15%	3.10	3.25	3.64	3.87
5	20%	2.19	2.86	3.12	3.28

Graph



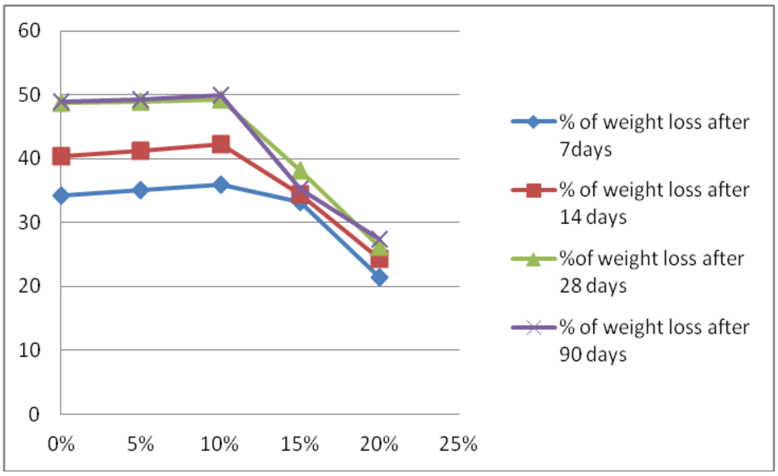
Graphical representation of comparison between 7, 14, 28 & 90 days split tensile strength values for replacement of cement by hypo sludge

DURABILITY:

Table 3.5 Percentage loss of weight after treating with 1% of $Mgso_4$ in ceramic waste after 7, 14, 28 & 90 days curing

S.no	% of replacement of ceramic waste	% of weight loss after 7days	% of weight loss after 14 days	%of weight loss after 28 days	% of weight loss after 90 days
1	0%	34.21	40.43	48.79	49
2	5%	35.1	41.28	48.9	49.27
3	10%	35.89	42.26	49.21	49.86
4	15%	33.23	34.45	38.21	35.28
5	20%	21.43	24.26	26.21	27.37

Graph

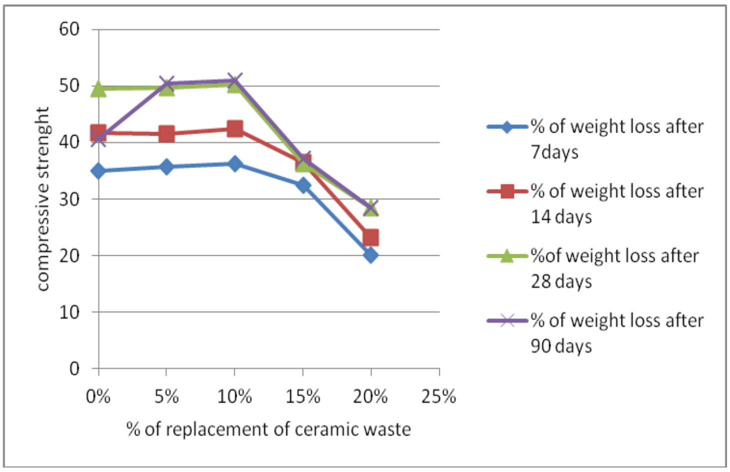


Graphical representation for percentage loss of weight after treating with 1% of $Mgso_4$ in ceramic waste after 7, 14, 28 & 90 days curing

Table 3.6 Percentage loss of weight after treating with 2% of $Mgso_4$ in ceramic waste after 7, 14, 28 & 90 days curing

S.no	% of replacement of ceramic waste	% of weight loss after 7 days	% of weight loss after 14 days	%of weight loss after 28 days	% of weight loss after 90 days
1	0%	34.89	41.65	49.43	40.65
2	5%	35.64	41.49	49.65	50.43
3	10%	36.23	42.37	50.21	50.87
4	15%	32.45	36.45	36.24	37.21
5	20%	20.16	23.21	28.37	28.41

Graph

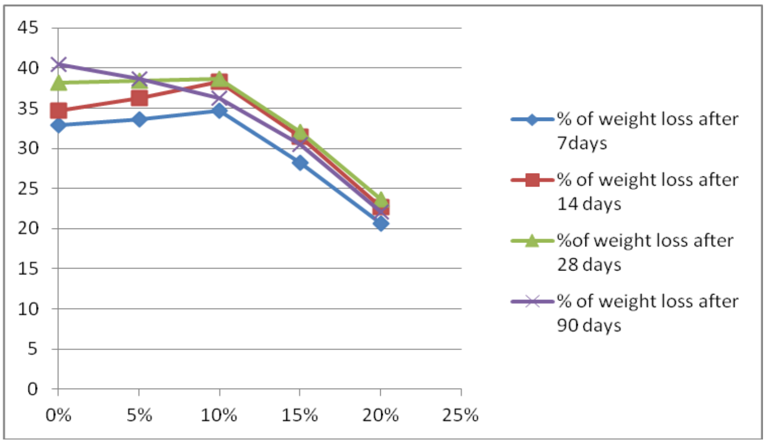


Graphical representation for percentage loss of weight after treating with 2% of $mgso_4$ in ceramic waste after 7, 14, 28 & 90 days

Table 3.7 Percentage loss of weight after treating with 3% of $Mgso_4$ in ceramic waste after 7, 14, 28 & 90 days curing

S.no	% of replacement of ceramic waste	% of weight loss after 7days	% of weight loss after 14 days	%of weight loss after 28 days	% of weight loss after 90 days
1	0%	32.87	34.64	38.21	40.42
2	5%	33.63	36.27	38.45	38.64
3	10%	34.67	38.23	38.66	36.21
4	15%	28.21	31.43	32.1	30.43
5	20%	20.69	22.64	23.61	22.05

Graph

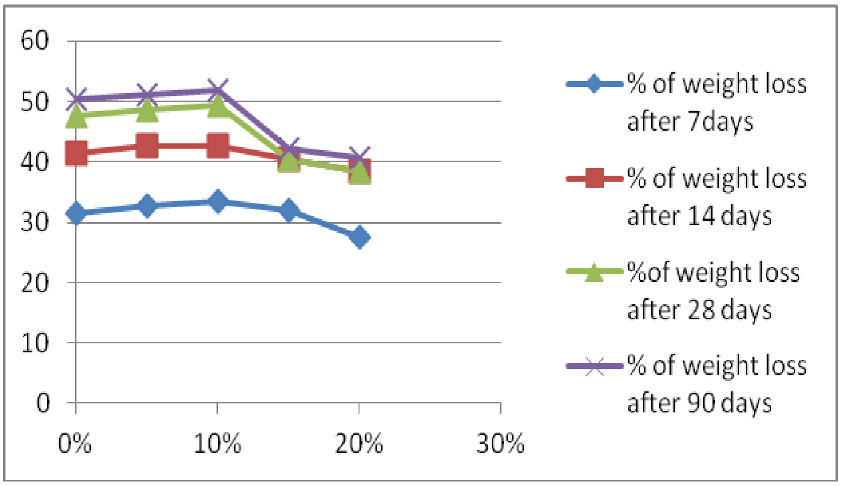


Graphical representation for percentage loss of weight after treating with 3% of $Mgso_4$ in ceramic waste after 7, 14, 28 & 90 days curing

Table 3.8 Percentage loss of weight after treating with 1% of $Mgso_4$ in hypo sludge after 7, 14, 28 & 90 days curing

S.no	% of replacement of hypo sludge	% of weight loss after 7days	% of weight loss after 14 days	%of weight loss after 28 days	% of weight loss after 90 days
1	0%	31.43	41.46	47.64	50.45
2	5%	32.64	42.58	48.69	51.21
3	10%	33.49	42.61	49.41	51.96
4	15%	32.1	40.43	40.43	42.24
5	20%	27.43	38.42	38.42	40.56

Graph

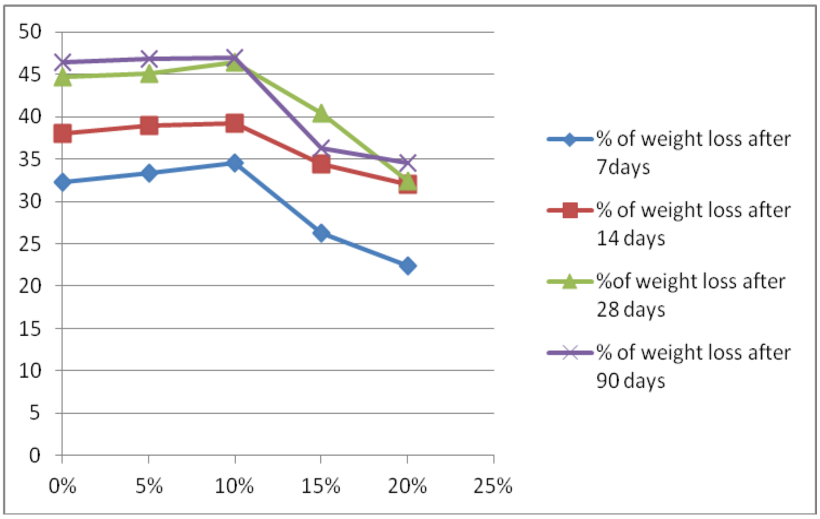


Graphical representation for percentage loss of weight after treating with 1% of $mgso_4$ in hypo sludge after 7, 14, 28 & 90 days curing

Table 3.9 Percentage loss of weight after treating with 2% of Mgso$_4$ in hypo sludge after 7, 14, 28 & 90 days curing

S.no	% of replacement of hypo sludge	% of weight loss after 7days	% of weight loss after 14 days	%of weight loss after 28 days	% of weight loss after 90 days
1	0%	32.21	38.07	44.67	46.42
2	5%	33.27	38.93	45.1	46.81
3	10%	34.49	39.27	46.41	47
4	15%	26.28	34.4	40.4	36.21
5	20%	22.42	32.01	32.4	34.48

Graph

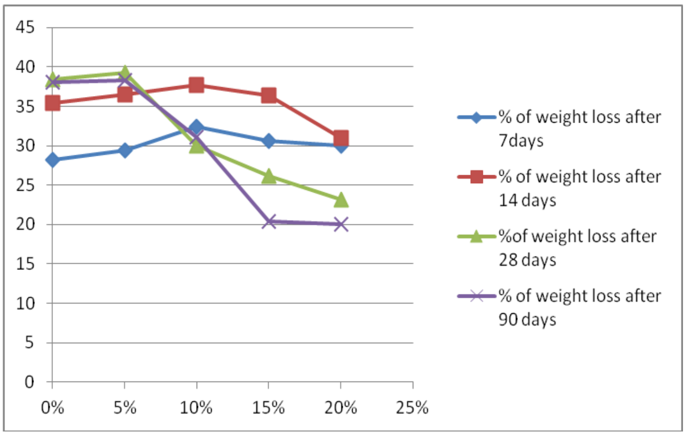


Graphical representation for percentage loss of weight after treating with 2% of mgso$_4$ in hypo sludge after 7, 14, 28 & 90 days curing

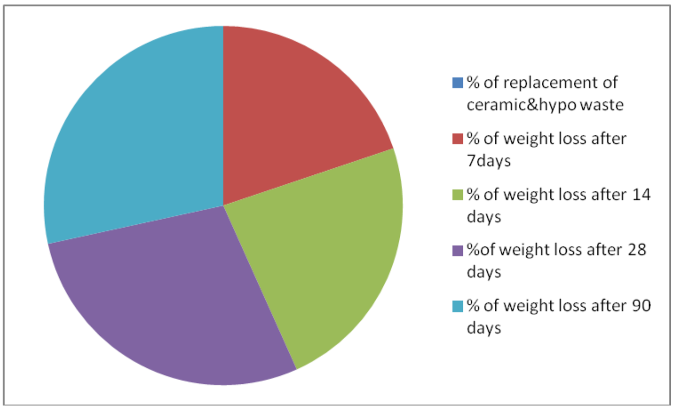
Table 3.10 Percentage loss of weight after treating with 3% of Mgso$_4$ in hypo sludge after 7, 14, 28 & 90 days curing

S.no	% of replacement of hypo sludge	% of weight loss after 7days	% of weight loss after 14 days	%of weight loss after 28 days	% of weight loss after 90 days
1	0%	28.26	35.43	38.42	38
2	5%	29.42	36.5	39.21	38.26
3	10%	32.44	37.64	30	31.04
4	15%	30.64	36.42	26.21	20.42
5	20%	30	30.96	23.21	20

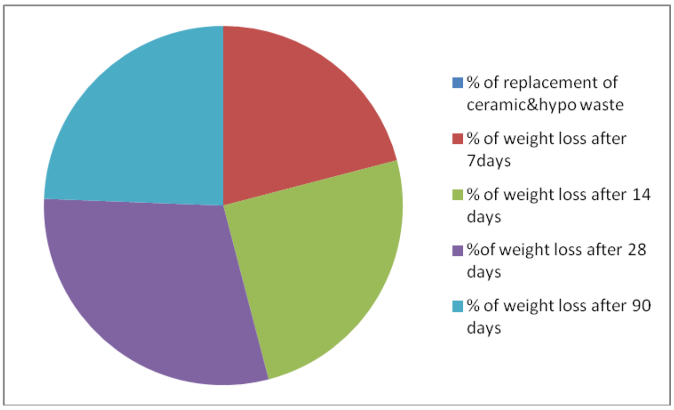
Graph



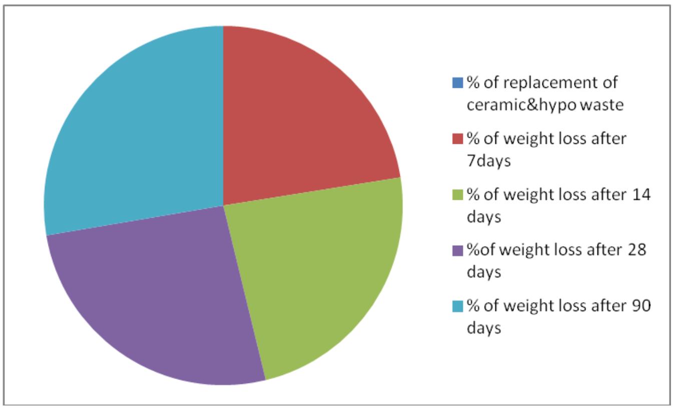
Graphical representation for percentage loss of weight after treating with 3% of mgso$_4$ in hypo sludge after 7, 14, 28 & 90 days curing



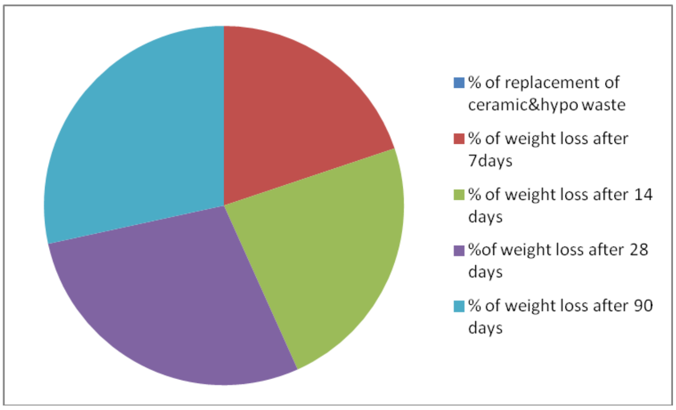
Comparison between 1% Mgso$_4$ treatment of ceramic waste & hypo sludge



Comparison between 2% Mgso$_4$ treatment of ceramic waste & hypo sludge



Comparison between 3% $Mgso_4$ treatment of ceramic waste & hypo sludge



Comparison between 1%,2%,3% Mgso4 strength values for replacement of cement by ceramic waste and hypo sludge for 7, 14, 28 & 90 days

IV. CONCLUSIONS

- The Compressive strength of concrete achieves the target strength up to 15% replacement of cement with ceramic powder. Further replacement of cement with ceramic powder there is a decrease in the compressive strength.
- The decrease in compressive strength with the increase in replacement percentage of ceramic waste is due to the higher content of silica present in its composition, which leads to the loss of binding property of cement.
- The split tensile strengths of partially replaced concrete is slightly decreased when the ceramic is mixed at 10%, when compared with the control mix.
- The compressive strength of 15% partially replaced cubes are slightly decreased
- The decrease in compressive strength with the increase in replacement percentage of hypo sludge is due to the presence of low silica content in the composition which tends to decrease in its strength.
- Hypo sludge also contains the other chemicals in which some reactions are carried out in concrete which results in decreasing strength
- The compressive strength of concrete at 15% is stable and when we increase the percentage replacement of hypo sludge it slightly decreases when compared to normal mix concrete.

- The split tensile strengths of partially replaced concrete is slightly decreased when the hypo sludge is mixed at 15%, when compared with the control mix.
- For ceramic partial replacement up to 10% partial replacement it is resistant against sulphates attack up to 1%,2% and decreasing for 3%
- For Hypo sludge partial replacement it is observed that up to 10% partial replacement, the partial replacement against sulphate attacks up to 1% and it is decreasing for 2%, 3%.
- Due to pozzolonic action in ceramic concrete achieved significant improvement in its mechanical properties later stages of curing in sulphates for 1% is optimum for both hypo and ceramic.

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