A Study On Durability Of Concrete By Partial Replacement Of Cement With Steel Slag Powder Using Robo Sand

[1]SHAIK YASEEN, [2]Mohd Yousuf Ahmed
[1]M.Tech Student (Structural Engineering), [2]Assistant Professor
Nawab Shah Alam Khan College Of Engineering & Technology

Abstract - **Durability can be explained as the concrete ability to counteract the abrasion, chemical attack, weathering action or any other process of degradation. Durability also includes the effects of serviceability and quality of concrete when exposed to acid and sulphate attacks. Steel Slag powder as partial substitute for cement and ROBO sand as complete alternative for natural sand are combined mostly on basis of the criteria of durability properties and costing qualities. Not only these properties, pollution in environment can also be lowered upto some extent due to the fact that emission of unsafe gases like CO(carbon monoxide) & CO2(carbon dioxide) are limited. In this research paper our study is mostly limited to the evaluation and observation of changes in both weight reduction & compressive strength in 6 different mixes of concrete grade M30 namely CAC(Conventional Aggregate Concrete), concrete mix manufactured by altering 0%, 10%, 20%, 30%and 40% of cement with Steel Slag powder proportions and by using the substitute ROBO sand as fine aggregate in 100% proportions in all 5 subsituted samples. After the 28days curing done for specimen the adverse effect of 5% of HCL(Hydrochloric acid) and MgSO4(Magnesium Sulphate) with water content on these concrete cubes are observed and determined by immersing completely. These specimens(cubes) for 56 days & 90 days in these acidic solutions, the changes in properties in weight reduction & compressive strength was observed and upto a great extent. Finally, we can conclude that concretes made up of that ROBO sand and Steel Slag powder really got durable properties and good strength when compared with regular aggregate in extreme harm environment.**

keywords **- Concrete, Steel Slag Powder, Durability of Concrete, Robo Sand, Compressive Strength, Durability Tests.**

I. INTRODUCTION

1.1 General: In these days, concrete is commonly used material for construction because the ingredients used in making concrete like cement, aggregates etc, are of availability of raw materials, low cost, abundantly, huge durability and good strength. Nowadays the construction technology has enhanced, thus resulting in the rise of construction materials costing. The deficiency of Construction materials from various environmental sources affected the rise of cost. So search for some other or new materials through which environmental issues are not caused is important. This search leads to this research in which the study of durability and strength of partially replaced concrete.

1.2 Durability: The property of the concrete to prevent it from getting damage for great duration is called Durability. It can be explained as the capability of concrete property to withstand abrasion actions, chemical attack, & weathering action, at the same time keeping its desirable and acceptable characteristics simultaneously. It normally referred as the life span or duration of very low trouble performance. Different concretes has distinct durability degree properties depending upon exposure of environment and desirable properties. For ex, concrete exposure to tides in seawater will be having different durability requirements than the indoor concrete.

1.2.1 Factors Affecting Concrete Durability

Cement content: Concrete mix should be designed in such a way that it ensures cohesive property and avoids segregation & bleeding of concrete. If cement content is decreased, at the fixed water-cement ratio the workability might be affected and gets reduced leading to insufficient compaction. However, to improve workability the water is added and thereby the water-cement ratio increases & causing in increase in permeability of the material.

Compaction: The concrete mix as a whole has voids could be formed cause of insufficient compaction. Commonly it is being because of the used compaction equipment, steelwork density and type of formworks in structure.

Curing: Its necessary to allow suitable strength increasing moisture holding aid & to make certain hydrating technique take place definitely.

Cover: It is the thickness of concrete provided beyond reinforcement to avoid reinforcement damage, cover should to be observed within the restrictions of codes.

Permeability: Its regarded as the vital thing for durability, it could be observed that greater permeability is commonly induced because of greater porosity .Hence, curing appropriately, ample cement, perfect compaction & appropriate clear cover ought to serve in less permeability.

1.2.2 Types of Durability of Concrete

Physical Durability: This kind of durability resists the below list

1. In Temperature stresses during hydration reaction

2. Permeability & Percolation of water
3. Thawing & Freezing action

Chemical Durability: This kind of durability resists the below list

1. Reinforcement corrosion
2. Delay Ettringite Formation(DEF)
3. Admission chloride
4. In Sulphate Attack
5. In Alkali Aggregate Reaction

1.2.3 Reasons for Lack of Concrete Durability

i) External Causes:

a. During Extreme Weathering Conditions
b. At Extreme Temperatures
c. In Extreme Humidity
d. Abrasion value
e. During Electrolytic Action
f. Gases attacks or Natural & industrial liquids.

ii) Internal Causes

a) Physical

- Variation in volume occurs because of changing thermal characteristics of cement paste & aggregates
- Cause of freezing.

b) Chemical

- Corrosion of Steel
- Alkali Aggregate Reactions

1.2.4 Determination of Concrete Durability

The various factors mentioned above cause losses in concrete structures. These can be summarized as follows-

- Loss of concrete strength
- Concrete is responsible to get affected by deterrents with ease.
- Reinforcement bars corrosion
- Loss of concrete serviceability
- Poor aesthetics and unpleasant appearance
- Folks and property danger
- Expensive maintenance costs
- Poor ability of materials
- Poor ability of involved agencies
- Decrease of service life
- Effects of external agencies like weathering, attack by Industrial or natural liquids, Gases, bacterial Growth etc
- Reaction between alkali & aggregates
- Ingression of moisture content/air facilitating the reinforcement corrosion and concrete cover cracking

Therefore determination and testing on concrete's durability are must for quality restraint and validity, safety assurance of the structure. Various tests and methods are used to ascertain the same. Few most regularly used methods according to IS456 are -

- Water Absorption test
- Acid test
- Sulphate attack test.
- Alkali test

II. LITERATURE REVIEW

- **"Studies On Strength And Durability Of Concrete Consisting Ggbfs And Foundry Sand" by Roshni K G , Vineeth P** presents a very comprehensive and concise analysis on the distinct views of durability of concrete when cement is substituted by fraction with GGBFS and normal sand is substituted with artificial sand. This paper has formed the groundwork for the present proposed lookup work. This work was once performed to initiate the outcomes of used foundry sand and GGBFS on strength and concrete durability.
- K. Nagamani, N. Mahendrana & R. Ilangovana of PSNA Engineering College, Dindigul, India published "**Strength And Durability Properties Of Concrete Containing Quarry Rock Dust As Fine Aggregate**" published in October 2008 in ARPN Journal of Engineering and Applied Sciences contains studies about the aspects of concrete durability with quarry rock combination as first class fine aggregate as an alternative to conventional river sand. 150 mm measured cubes of concrete & concrete beams having dimension in mm as 100x100x500 as L x B x D have been used as specimens for tests to know the respective flexural & compressive strength of specimens. Models were casted for concrete mix M20, M30 & M40 grades and for C.A(coarse aggregates) of measurement 20mm(millimeter) was made use. The main objective of this study of durability of concrete was to checkout & investigate the studies on drying and shrinkage properties, water

absorption and deterioration studies for both the Quarry Rock Dust concrete & Conventional Concrete according to the codal provisions. The durability studies conducted were able to draw the following conclusions –

- The quarry rock dust having chemical properties & physical properties satisfies all the requirements of provisions of IS codes.
- If 100% of conventional sand is substituted by Quarry Rock Dust obtained from the quarry. It sometimes shall give better, at least equal strength than the referred concrete mix of traditional Sand, in particularly of flexural strength studies & compressive investigations. The reported ƒ Studies here and everywhere has showed that the concrete strength with Quarry Rock Dust as F.A(fine aggregate) is observed 10%-12% more than identical traditional mix.
- The Durability of a mix consisting the F.A as Quarry Rock Dust under acidic & sulphate activity is much lesser compared with that of normal Concrete mix. Analysis of tests on permeability sincerely verifies, permeability property of concrete mix with Quarry Rock Dust was low when observed to that of concrete mix with conventional river sand.
- Therefore, it could be wind up that alternative of normal sand is the Quarry Rock Dust material as ingredient in concrete, as there is a possibility of complete replacement. However, greater research analysis are still carried out on Quarry Rock Dust material, which are quite vital for Quarry Rock Dust as F.A(Fine Aggregate) in practical application.

➢ In the publication **"COMPRESSIVE STRENGTH OF STEEL SLAG AGGREGATE AND ARTIFICIAL SAND IN CONCRETE"** in website IJCIET (on Feb 2015) by Professor Mrs. A. I. Tamboli and other professors, concrete cubes were put on experiment for compressive strength according to codal provisions of IS456, while cement is replaced by steel slag & natural sand with artificial sand.

Designing of concrete mix was done accordingly to the IS 456-2000 and IS 10262-1982 by assuming the mix has conditions like good tier of quality supervision and tolerant vulnerabilities. M20 mix was designed with 100% replaced natural sand by artificial sand and coarse aggregate is substituted with 0%, 10%, 20% and 30% of steel slag. They came to following conclusions as listed below -

- A 20% increase could be seen in the concrete's compressive strength because of replacement ratio i.e., with 100% natural sand substituted with the artificial sand.
- The improvement in concrete's compressive strength was seen to be 10% more to that of our regular concrete, cured for 28 days.
- Such kind of concrete mixes should be used in our regular construction works to have green engineering concept and good strength.

III. MATERIALS

The experimental program to determine the possibility of using the robo sand and waste steel slag powder & their outcomes on the concrete mechanical and physical characteristics with respect to its durability aspects, was based on following procedure as entailed in coming topics. After proper determination of various material properties involved, a design mix of M30 grade was prepared. Steel slag powder & robo sand were added to conventional concrete in various volume fractions and cubes were casted for each percentage. Robo sand should completely replace fine aggregate.

Tests on compression, for conventional concrete, and those on cubes after submerging them in the respective chemicals were conducted on 7, 28& 56 days respectively. A mean of 3 readings was taken as the final reading. Graphs been plotted b/w volume fraction and the different strengths to observe and mark the effects of the introduced materials on the different characteristics of concrete.

Cement: Locally available OPC of grade 53 was used. The cement brand named C.C.I was used during the entire course of this experiment.

Table 1 Physical Properties of OPC (Ordinary Portland cement)

S.no	Property	Test Method	Test Result
1	Specific Gravity	specific gravity bottle (IS 4031-part11)	3.14
2	initial setting time	Vicat apparatus (IS 4031-part 5)	35 min
3	normal consistency	vicat apparatus (IS 4031-part 4)	30%
4	Fineness	Sieve test on sieve no.9 (IS 4031 -part 11)	7%

Fine aggregate: Substances like crushed stone, gravel, sand together with OPC(Portland cement) & water are vital ingredients for concrete. To have a great mix, aggregates should be strong, clean, clean and should be free of clay, chemicals absorbed & few other tiny substances which can lead to degradation of cement. Aggregates which are 60-75% of total concrete quantity can be branched into 2 definite divisions i.e. coarse and fine. Commonly fine aggregates contains crushed sand or natural sand along elements mostly pass over a 3/8inch or 4.75mm sieve. Sand is generally mixed as fine aggregate & it's commonly dredged from a river, seabed & lake. After completion of digging, aggregate should be processed in following order: enough crushed, screened with sieves & washed with water to get proper gradation and cleanliness. If required, the benefaction process like separation of heavy media or jigging can be done for upgrading the quality of sand. Once it is processed, these are handled, stored to reduce segregation, degradation and to avoid contamination. Aggregates strongly affect the fresh concrete mix and its hardening

properties, proportions of concrete mix, and also economy. Consequently, the choosing of aggregates is a vital procedure and sure assessments are to be performed to verify these properties. Although few changes in aggregate properties are expected.
Fine aggregate is none other than normal sand available from nearby market. The properties like gradation, specific gravity, fineness modulus, bulk density were examined according to IS2386.

Table 1 Sieve Analysis chart of natural sand - (fine aggregate)

s.no	Sieve tube	Weight retained in gms	cumulative weight retained	cumulative % weight retained
1	10	0	0	0
2	4.75	5	5	0.5
3	2.36	9	14	1.4
4	1.18	91	105	10.5
5	600	397	502	50.2
6	300	387	889	88.9
7	150	102	991	99.1
8	pan	9	1000	Nil

Table 2 Sieve Analysis chart of robo sand - (fine aggregate)

s.no	Sieve tube	Weight retained in gms	cumulative weight retained	cumulative % weight retained
1	10	0	0	0
2	4.75	4	4	0.4
3	2.36	8	12	1.2
4	1.18	95	107	10.7
5	600	385	492	49.2
6	300	387	879	87.9
7	150	107	986	98.6
8	pan	14	1000	Nil

Robo Sand, its a fine aggregate which is manufactured from crushing slag, gravel, stone. Commonly, used for aggregate material not more to 4.75 mm size which is prepared from gravel, crushed rock & other material intended for construction purpose. Robo sand is a high-quality material, in comparision to non-refined surplus from coarse aggregate production.

Manufactured sand is a substitute for river sand. The demand for sand has increased tremendously due to fast growing construction industry leading to insufficiency of suitable river sand in most part of the world. Due to reduction of quality river sand to use in construction industry, the use of manufactured sand has escalated. Another reason for use of M-Sand is its availability and transportation cost. Seeing that this sand can be grounded from hard granite rocks, it can be obtained from the surrounding places, which reduces the cost of transportation from river sand bed which is far-off.

Table 3 Comparison of river sand and robo sand

	RIVER SAND	ROBOSAND
Specific Gravity	2.68	2.72
Water absorption % by wt.	0.20	2.5%
Material finer than 75 micron (% by weight)	0.04	0.08

Table 4 Chemical comparison of river sand and robo sand

	RIVER SAND	ROBOSAND
Marine Products	2- 4%	Nil
Over Sized Material	6- 8%	Nil
Clay & Silt	5-8%	Nil
Moisture	4-5%	Nil
Total	17- 25%	Nil

Coarse Aggregate: Particles larger than 4.75mm or commonly ranges b/w 4.75 and 20mm in diameter are coarse aggregates. Majority of coarse aggregates consists of gravels which is used in mix along crushed stone taking utmost proportion. Coarse aggregate is prepared by process of crushing, large size gravel or boulders quarry rock, cobbles. The same properties and characteristics are desired in coarse aggregate as that of fine aggregate and hence appropriate experiments were done to evaluate these characteristics for concrete mix design.

Table 5 Coarse aggregate physical properties(20mm)

S.No	Property	Test Method	Value
1	Fineness Modulus	Sieve Analysis (IS 2386-1963 Part 2)	7.07
2	Specific gravity	Pycnometer (IS 2386 -1963 Part 3)	2.74

Water: The conditions specified in IS456:2000 state that "the type of water used as cement ingredient and for curing shall be clean and shall be restricted from any harmful quantities of sugar, alkalis, salts, acids, oils, organic substances and any other elements that may degrade the steel or concrete."
Generally portable water is treated adequate for concrete mixing. Therefore, the locally available portable water is used for all purposes. The pH shouldn't be under value 6 as mentioned in code.

IV. METHODOLOGY

Mixing

Ingredients are blend in a rotating drum or hand mixing using trowels. The cementitious materials were wholly mixed with hand and after that the aggregates were added followed by slow addition of water and blending. In fiber reinforced concrete, fibers were sprinkled evenly during mixing of the matrix. Wet mixing was done till a mixture of uniform color, consistency were achieved which was then considered ready for casting. Compaction factor tests were done before casting for each batch.
Workability: Every batch of concrete, soon after mixing, was tested for consistency by any procedure explained in IS1199-1959, given that care was taken to assure that no water or any other material was lost. The concrete was remixed after compaction

test with the remaining batch prior to casting. The period of remixing was kept to a minimal to avoid drying yet enough to make a homogenous mass.

Compaction: The compaction was done by hand, with the help of standard tamping rod conforming to IS10086-1982 was used and the strokes of the bar were applied evenly all over the mould cross s/n for both the cubical and beam specimens, a total of 35 strokes per layer. The strokes were applied in a way such that they go deep into the bottom layer & the bottom layer was rodded completely at depth.

Curing of specimens: After casting, samples made are left undisturbed in the moulds for 24hrs at room temperature. The samples are then taken out from the mould and immediately moved into the curing pond having fresh and clean water.

Casting of Specimens: The cast iron moulds are made free from any mineral oil & dust particles is applied inside the mould before concrete is taken into it. The moulds are of size 150mm for cubes and 15x150x700mm for the beam specimens were used conforming to IS procedures. The moulds were kept on a level surface. Excess concrete left was removed using a trowel and the finished level was smoothed over using the same.

Compressive strength: It depends on various factors like quality control during production of concrete, cement strength, water-cement ratio, quality of concrete material etc and is taken as the primary and indicative property of concrete. Most quality control aspects of concrete are based upon its characteristic strength, which can be explained as strength of specimen, which was cured for 28 days.

Test for compressive strength can be done either on cylinder or cube. Various IS codes suggests concrete cube or concrete cylinder as the std specimen for the test.

For cube test 2 types of specimens either cubes of 15X15X15cm or else 10X10X10cm which counts on aggregate size are recommended as per IS456. For the purpose of this research cubical moulds of size 10m x 10cm x 10m were used. This concrete was poured into the mould, tampered in a manner so that no voids are present. After completing 24hrs these moulds were taken out & specimens were kept for curing. The top surface of these specimen was leveled with a trowel and made smooth and even. These specimens were tested by compression testing machine or Universal Testing Machine (UTM) after 7 & 28 days curing. Load was applied slowly by the machine at 140kg/cm^2/min till the specimens. This load was taken as the failure load for the specimen at that age. An average of three readings was taken as the final reading for each variation.

Summary: All the aforementioned tests were conducted under laboratory conditions abiding by the regulations and limits set forth by the relevant codes of IS456 and IS516 after a mix was designed based on IS10262. An average of three readings for every test for every batch of concrete was taken to reduce chances of negligence and error. All calculations, readings and recordings were taken as per SI system, and relevant conversions were made wherever necessary. All the samples were hand mixed and tamped and therefore certain deviations in the characteristic strengths were observed and accounted for. The recordings and observations of the tests and are represented in their tabular and graphical forms in the subsequent chapter.



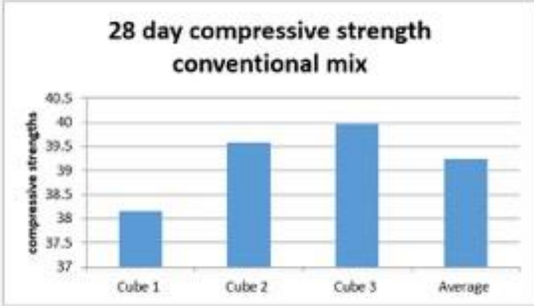
Acid Attack test: This test was done after the curing of specimens(cubes) for 28 days and the specimens were dried for 1 day then again were immersed in water with 5% dilution in Hydrochloric acid for 56 days and 90 days and there compressive tests and weight reduction tests were conducted.

Sulpahte Attack Test: This test was done after the curing of specimens(cubes) for 28 days & those were dried for 1 day then again were submerged in water with 5% dilution in Magnesium Sulphate for 56& 90 days and there compressive tests and weight reduction tests were conducted.


V. TESTS RESULTS AND DISCUSSION

Table 6 Compressive strength of concrete after 7 and 28 days curing in water

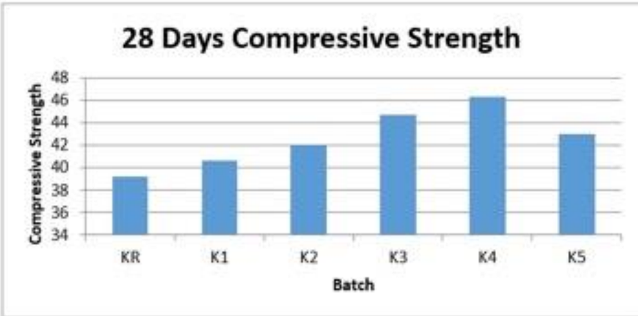
	7 Days	28 days
Cube 1	25.7	38.162
Cube 2	26.717	39.576
Cube 3	27.311	39.958
Average	26.576	39.232



Graph 1 28 day compressive strength conventional mix

Table 7 Compressive strengths with SS and Robo Sand

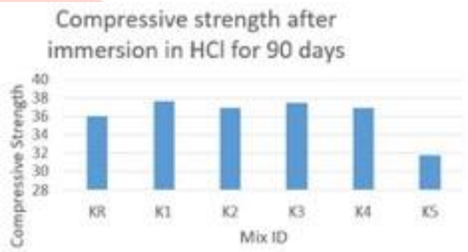
S.No.	% of slag	7 Days (Mpa)	28 Days (MPa)
1	M30(KR)	26.576	39.23
2	0%(K_1)	27.31	40.63
3	10%(K_2)	28.35	42
4	20%(K_3)	29.62	44.65
5	30%(K_4)	31	46.32
6	40%(K_5)	28.66	42.95



Graph 2 28 Days Compressive Strength

Table 8 Compressive strengths for 56 and 90 days after submerging in HCl

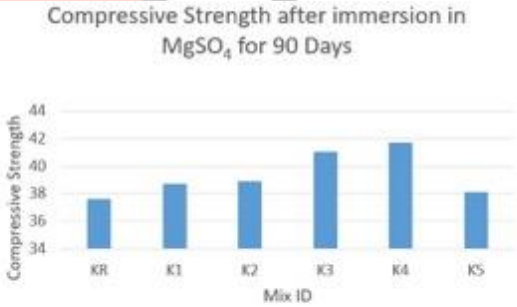
S.No	% of slag	56 Days	90 Days
1	M30 concrete	37.63	36.06
2	0%	39.26	37.64
3	10%	39.6	36.91
4	20%	41.36	36.51
5	30%	41.87	36.93
6	40%	37.69	31.83



Graph 3 Compressive strengths for 90 days after submerging in HCl

Table 9 Compressive strengths for 56 and 90 days after submerging in MgSo4

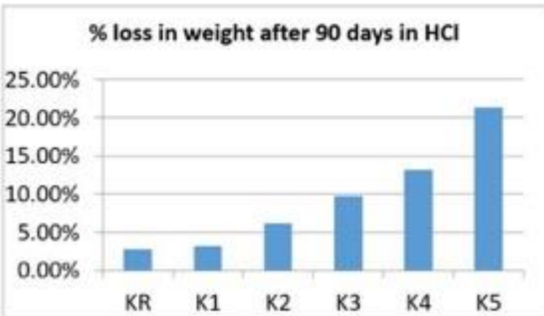
S.No.	% of slag	56 Days (MPa)	90 Days (MPa)
1	M30	38.43	37.65
2	0%	39.85	38.77
3	10%	40.68	38.91
4	20%	42.06	41.09
5	30%	44.21	41.71
6	40%	40.75	38.08



Graph 4 Compressive strengths for 90 days after submerging in MgSo4

Table 10 Weight loss in HCl

S.No.	ID	Wt.	Wt. after immersion in HCl			
			56 Days	% decrease	90 Days	% decrease
1	KR	2.48	2.44	1.61%	2.41	2.82%
2	K1	2.51	2.46	1.99%	2.43	3.19%
3	K2	2.54	2.45	3.54%	2.38	6.30%
4	K3	2.59	2.43	6.18%	2.34	9.65%
5	K4	2.63	2.43	7.6%	2.28	13.31%
6	K5	2.66	2.39	10.15%	2.09	21.43%

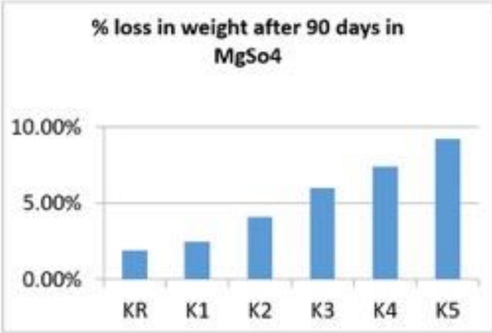


Graph 5 % weight loss after 90 days in HCl

The observations show that there is a drop in the weight with the rise in percentage of steel slag powder in cement after 56 & 90 days. These analysis represent that steel slag in cement is sensitive to the action of HCl as indicated by the increase in weight loss with rise in percentage of substitute of cement.

Table 11 Weight loss in MgSO4

S.No	ID	Wt.	Wt. after immersion in $MgSo_4$			
			56 Days	% decrease	90 Days	% decrease
1	KR	2.48	2.45	1.21%	2.43	2.02%
2	K1	2.51	2.47	1.59%	2.45	2.39%
3	K2	2.54	2.48	2.36%	2.44	3.94%
4	K3	2.59	2.51	3.09%	2.4	6.18%
5	K4	2.63	2.53	3.80%	2.43	7.60%
6	K5	2.66	2.54	4.51%	2.41	9.40%



Graph 6 % weight loss after 90 days in MgSo4

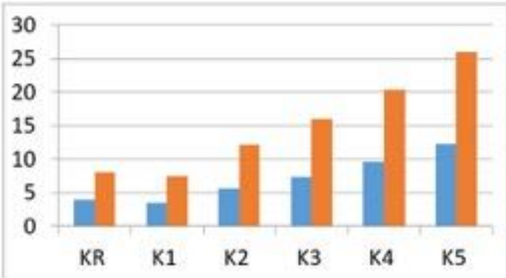
Submerging in $MgSO_4$ for 56 & 90 days shows the weight decreases with time because of sulphate attack. Maximum loss of strength occurs at 40% replacement level as indicated by the graph.

Graph 7 Comparison for 90 Days weight loss

The comparison of the rates of weight losses for HCl and MgSO4 reveal that the loss rate is higher for HCl when contrast with MgSO4.The trend is observed for both 56 & 90 days. It is also seen that loss increases with rise in content of steel slag powder.

Table 12 Strength loss in HCl

S.No	Mix ID	% loss in strength for 56 days (HCl)	% loss in strength for 90 days (HCl)
1	KR	4.1	8.1
2	K1	4.5	8.9
3	K2	5.7	12.1
4	K3	7.4	18.2
5	K4	9.6	20.3
6	K5	12.2	25.9

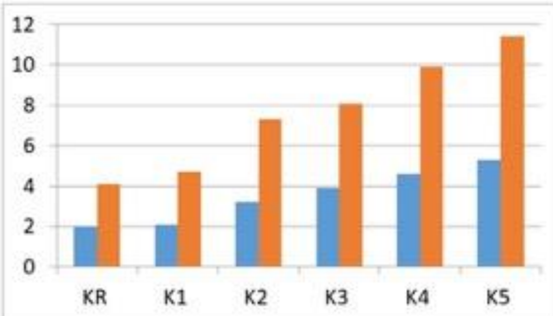


Graph 8 Strength loss in HCl

The strength loss pattern shows a similar trend to that of weight loss for both 56 and 90 days. The strength loss becomes significant after 20% of steel slag powder in cement by weight.

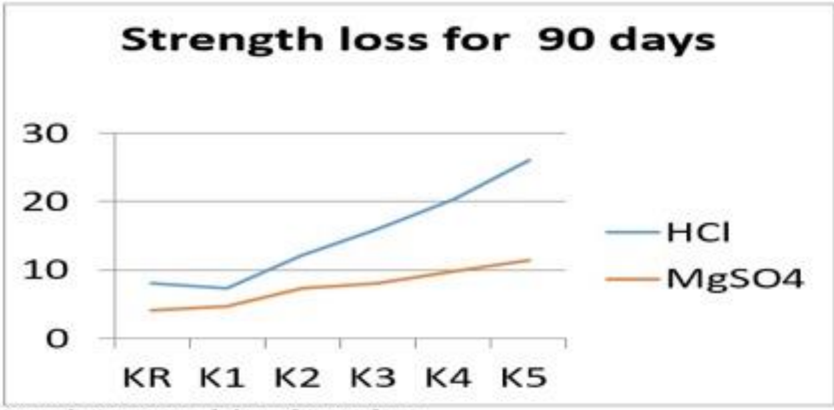
Table 13 Strength loss in MgSO4

S.No	Mix ID	% strength loss for 56 days (MgSO4)	% strength loss for 90 days (MgSO4)
1	KR	2.0	4.0
2	K1	1.9	4.6
3	K2	3.1	7.4
4	K3	4	8.0
5	K4	4.6	10.0
6	K5	5.1	11.3



Graph 9 Strength loss in MgSO4

Strength loss for 56 & 90 days submerged in MgSO4 follow an increasing pattern with rise in Steel Slag powder. Here too the maximum loss in strength occurs at 40% replacement.



Graph 10 Strength loss for 90 days

The graphs represent that strength loss for HCl is greater than MgSO4.
The maximum loss in strength occurs for the combination K5, that is 40% cement altered with steel slag powder.
These graphs give a clear indication that the combination of these materials gives concrete that is vulnerable to HCl but offers a good cover against to sulphate attack.

VI. CONCLUSION

General conclusion

- The maximum increase in compressive strength was achieved at 30% STEEL SLAG POWDER as partial substitute of 24% in comparision to normal concrete.
- The optimal percentage of Steel Slag powder as alternative of cement is 30%.
- The concrete mix K_4 (30% STEEL SLAG POWDER) showed better resistance to sulphate attack than acid attack. The decrease in the compressive strength was marginal for all mixes at 56 & 90 days of submerging for sulphate solution. The compressive strength decreases by 5% for 56 days and 10% for 90 days
- The decrease in the compressive strength was considerable for all mixes at 56 & 90 days of submerging in HCl. The compressive strength decreases by 10% for 56 & decreases by 20% for 90 days.
- The concrete workability increases with rise of STEEL SLAG POWDER content as cement alternative.

Scope for further Investigation

- The above experimental program can be further extended can by conducting various other tests such as water absorption, carbonation etc.
- By conducting experiments on concrete using partial replacements of sand by artificially prepared sand.

REFERENCES

[1] Prof. Mrs. A. I. Tamboli –"Compressive strength of steel slag aggregate and artificial sand in concrete" in IJCIET (Feb 2015)
[2] Lohani T.K. , Padhi M., Dash K.P., Jena S.- "Optimum utilization of Quarry dust as partial replacement of sand in concrete"
[3] R. Ilangovana , N. Mahendrana and K. Nagamanib- "Strength and durability properties of concrete containing quarry rock dust as fine aggregate"
[4] Huang Yi , Guoping Xu, Huigao Cheng, JuSteel Slag powderhi Wang, Yinfeng Wan, Hui Chen, -"An overview of utilization of steel slag"
[5] "Utilization of steel slag as coarse and fine aggregate" by Gozde Inan Sezeretal.
[6] "Experimental Investigation of Coarse aggregate with Steel Slag In Concrete" by T.Subramani, G.Ravi
[7] www.wikipedia.com
[8] www.slagcement.org