An Experimental Investigation on Concrete With Partial Replacement of Cement With Bentonite Clay And Rice Husk Ash

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Abstract- *Concrete is the major building material which is being used in construction industry throughout the world. It is an extremely versatile material and can be used for all type of structures. Concrete is a combination of cement, fine aggregates, coarse aggregates and water, which are mixed in a particular proportion to get required strength. Cement is the most important constituent material, since it binds the aggregates and the process of manufacturing of cement is an energy intensive process besides polluting the atmosphere releasing of greenhouse gases like carbon-dioxide threatens to global warming also. To overcome this drawback there is a search of many mineral admixtures which can replace optimum content of cement in concrete. In view of the above drawback, this study is to reduce the effects caused using cement in concrete. Therefore, two materials like "Bentonite and Rice husk ash'' which are easily available are considered for partial replacement of cement in concrete. Bentonite is an eco-friendly material, didn't cause any damage to the environment. It can be used as a binding material which obeys pozzolanic properties. In India rice milling produces a by-product which is known as Husk. This husk is used as fuel in rice mills to produced steam for boiling process. This husk contains near about 75 % organic matter and the remaining 25% of this husk is modified into Ash during the firing process which known as rice husk ash (RHA). The rice husk ash (RHA) contains nearly about 85 % to 90 % amorphous silica. In this study an optimum content of up to 20% is considered as partial replacement of cement by bentonite and rice husk ash about maximum of 5% is considered. The individual material mixes and combined material mixes are designed. Such that for those mixes cubes and cylinders are casted to determine the properties. Three types of tests were conducted on concrete namely physical, mechanical and durability. The physical tests on cement are initial setting time, final setting time, consistency, specific gravity and soundness test and on aggregates are sieve analysis, fineness modulus and specific gravity. The mechanical properties like compressive strength on cubes at 7, 28, 56 and 90 days, split tensile strength test on cylinders. The durability tests like acid attack test and sulphate test are conducted. The above tests were going to conduct on the concrete with partial replacement of cement by rice husk ash and bentonite.*

I. INTRODUCTION

There have been tremendous developments happened during the 20th century compared to the technological advancements and innovations in the field information technology, communications, transportation and medicine, also in the materials usage compared previous years. Also, the technological advancement has been seen in the field of building and construction of major on shore, off shore structures, dams, monuments etc.

This technological advancement in engineering, scientific and industrial fields has led to the social impact which led to creation of wealth, leisure and living standards for those who are living in the industrialized nations. These technological advancements have happened during last four to five decades due to un-compromised social attitudes, improvement in the world economy.

However these changes have caused harmful effects on the human life such as environmental pollution which has led to the global warming. These advancements can be categorized in terms of urbanization population growth, technological growth, national security and also un-controlled pollution. In the overall by looking at the whole world there has been so many changes that had occurred which can be classified into advancement in the technology, increase in the population and urbanization throughout the world, and abnormal global warming and generation of garbage or waste.

The main reason for these changes is globalization - not only in economic terms, technological, human and community lives - but also regarding the changes in the climate and also changes in conditions of the weather throughout the world. This has grater negative impact on the environment compared to the positive economic growth and globalization.

GLOBAL WARMING DUE TO CEMENT INDUSTRIES:

Cement production is one of the main causes of the global warming. The main ingredients of the used in the Ordinary Portland cement (OPC) are 5% of gypsum and 95% of clinker. The process of obtaining the clinker involves crushing of the lime stone and other materials which are to be heated (900 to 1,450^{0}C). For producing 1 kg of cement, to reduce this emission of CO_2 the alternative ingredients are added in production of cement such as PPC, in this Portland cement replacing the clinker with pozzalonic material.

In the process of production of pozzalona cement the CO_2 emission will be reduced and causes to reduce the global warming. The effect of reducing the ratio of clinker percentage reduces the emission of the CO_2 by a greater amount. The clinker factor is the important parameter to be checked and kept in mind while producing the cement, by decreasing this factor the pollution of the environment can be decreased. One of the methods introduced by the researchers to decrease the clinker percentage by using the Pozzolana or the slag during the finishing of the clinker.

In Europe people use the blended cements compared to the other countries such as USA, UK and Asia. The average emission of the CO_2 from the cement industries is very high. For producing the one tone of clinker there is 0.9 tone of CO_2 being produced, which is adding so much for the environment pollution. This percentage of emission can be decreased by an amount of 0.3 to 0.4 tones; however it is not possible to reduce 0.53 percentage tone of the CO_2, which is caused due to the process emission. As per the statistics of the evaluation of the industry personnel, it has been seen that in last 25 years there has been reduction of 30% in CO_2 emission.

It was possible by adopting the fuel-efficient and novel processes which are causing the kiln processes. Also the further reduction of the CO_2 has been obtained with the use of cements blended with the minerals substituting the clinker. Europe's low energy usage rate for the clinkers production is 74% global one and the CO_2 emitted for cement production in Europe is only 64% of total CO_2 emitted by all the other countries of the world. From this it is clear that the reduction of the clinkers production leads to the decrease in the CO_2 emissions.

II. OBECTIVES

The goals of the experimental project study are:

1. Development of mix design for normal concrete related to IS: 10262-2009.
2. To study the strength characteristics of normal concrete of grade M25
3. The effects of rice husk ash and bentonite on the partial replacement of cement by concrete were studied and compared with ordinary concrete.

III. MATERIALS USED IN THE PROJECT

The materials used in the project are as follows:

1. Cement
2. Bentonite
3. Rise Husk Ash (RHA)
4. Fine aggregate (FA)
5. Coarse aggregate (CA)
6. Water.

CEMENT (OPC)

OPC is graded according to strength, contains good characteristic properties.

The properties of cement are

- Cement gives good strength to the concrete.
- Cement is a good binding material.
- Workability of cement is good.
- Cement is good resistance to the moisture.

Cement possesses a good plasticity

Physical Properties of OPC

S.No	Characteristic of cement	Value	Code Specification (IS4031-1988)
1	Fineness of cement	94.76%	–
2	Normal consistency	33%	Not specified
3	Initial setting time	40 Min	>30
4	Final setting time	350 Min	<600
5	Specific Gravity	3.14	–

Chemical Composition Cement

S.No	Oxide Composition	Percent Content
1	CaO	63
2	SiO_2	20
3	Al_2O_3	6
4	Fe_2O_3	3
5	MgO	1.5
6	SO_3	2
7	K_2O	1
8	Na_2O	1
9	C_3S	54.1
10	C_2S	16.6
11	C_3A	10.8
12	C_4AF	9.1

FINE AGGREGATE

River sand must be clean, inert and free from organic matter, silt and clay. For experimental work sand should be dried before use. The foremost constituent of sand is oxide, sometimes within the variety of quartz, that is chemical inert and exhausting. The size of sand should pass through 4.75 mm and retain on 150 microns IS sieve.

Depending upon the zone of the sand the corrections are applied for the amount of sand in the total aggregates in the mix design of concrete. The mix design is done by assuming the sand is from zone II and the corrections are applied at last depending upon the actual zoning of sand.

COARSE AGGREGATE

The coarse aggregate should free from clayey materials, slit & organic impurities etc. coarse aggregate is tested for specific gravity as per IS: 2386-1963. The CA maximum size will be 20mm. An aggregate with tough texture will provide a better aggregate-cement bond and hence it is preferred. The use of small coarse aggregate (20 mm) tends to increase in concrete strength compared to larger size aggregate.

Aggregates impart considerable influence on strength, durability and stability to concrete. Aggregate which is retained on 4.75 IS Sieve is called as CA. The aggregate were tested as per IS code 383-1970. An aggregate with tough texture will provide a better aggregate- cement bond and hence it is preferred.

The 20 mm thick aggregate is used as the coarse aggregate in the concrete. For most building structures, coarse aggregates are made of gravel or crushed rock and have a size of 20 mm.

The following are the test to be done for coarse aggregate material

BENTONITE

Bentonite has fungal bleaching properties as a whole soil dirt, so it has a wide range of commercial significance, so it is also called bleaching clay. It contains more than 85% of the mineral clay, montmorillonite, which is considered a highly plastic clay.

The commercial importance of bentonite depends more on its physical and chemical properties rather than its chemical composition. In this study bentonite used was light yellow in colour and having a specific gravity of 2.42. The initial and final setting time is determined using vicat setup by replacing 0%, 5%, 10%, 15% and 20% of Cement by Calcium Bentonite powder. Normal consistency of 31% is kept same for each replacement and test was preceded. The test result gives higher initial and final setting time of 139 minutes and 373 minutes respectively.

Physical Properties of Bentonite

Sl.No	Property	Results
1	Swelling	5 sec in 24 Hours
2	Gel Index	11.00%
3	Water of Plasticity	86.95%
4	pH value	06.00%to 07.00%

Chemical Properties of Bentonite

Si.No	Property	Percentage(%)
1	Silica(SiO_2)	40 to 50
2	Alumina Oxide (Al_2O_3)	0.8 to 10
3	Ferric Oxide(fe2o3)	0.8 to 10
4	Calcium oxide (Cao)	0.8 to 10
5	Magnesium Oxide(MgO)	0.6 to 7
6	Titanium Oxide	01.50
7	Loss of ignition	20 to 22

(Source:- Astra chemicals Report)

RICE HUSK ASH

The Rice husk ash has a good response when used as a partial substitute for cement. These are prominent in countries that are rich in rice production. Appropriately, it has been found that rice husk ash is active in cement slurry. Therefore, the use and practicality of rice husk ash in the concrete industry are very important. In order to correctly understand the performance of rice husk in concrete, it is necessary to conduct a detailed study on its performance.

Approximately 100 million tons of by-products in the world come from rice processing. Their bulk density is very low, ranging from 90 to 150 kg/m3, which results in a larger dry volume value. The physical and chemical properties of rice husk ash depend on the components of the combustion process, such as the type of combustion, type of feed, temperature, residence time, and availability of oxygen (aerobic or anaerobic).

Physical properties of Rice husk ash

S.No	Property	Percentage (%)
1	Colour	Off white
2	Specific Gravity	2.25
3	Material passing through 100 Mesh	77.55%
4	Material passing through 300 Mesh	38.52%
5	Moisture	0.11%

Chemical Properties of Rice Husk Ash

S.No	Property	Percentage (%)
1	Silica-(SiO_2)	88.90
2	Alumina-(Al_2O_3)	2.50
3	Ferric Oxide-(fe2o3)	2.19
4	Calcium Oxide-(Cao)	0.22
5	Total Alkalis	0.69

(Source:-Astra chemicals report)

MIX DESIGN

Mix design is the method of selecting suitable ingredients of the concrete. (Cement, fine aggregate (FA), coarse aggregate (CA) and water) and determining their proportions.

The concrete mix design for M25 were carried out according to Indian standard Recommended on method as per IS: 10262-1982 and IS: 456-2000.

Details of mix proportions

Mix	Cement (%)	Rise Husk Ash(RHA) %	Calcium Bentonite(%)
C0	100	0	0
C1	90	5	5
C2	85	5	10
C3	80	5	15
C4	75	5	20

CONCRETE MIX DESIGN PROCEDURE AS PER IS: 10262 –2009

The Properties of plastic concrete are important for proper compaction The strength and durability for final structure

- DETERMINATION OF TARGET MEAN STRENGTH

Formula for calculating target means strength as follows

$F'_{ck} = F_{ck} + 1.65*S$

Where F'_{ck} = target mean strength

F_{ck}= characteristic compressive strength
S= standard deviation (The value of S is taken from IS 456-2000 table.)

- WATER-CEMENT (W/C) RATIO

The water-cement ratio is chosen from IS: 456-2000. It specify minimum cement content and minimum grade of concrete for the different exposure conditions with normal maximum size aggregate is 20mm. For the determination of w/c ratio for the target mean compressive strength at 28 days.

- CALCULATION OF REQURIED AMOUNT OF WATER

The water content is determined from Table 35 and 38of SP:23-1982, applied to normal concrete mix, which takes into account the type of aggregate (whether powdered or not crushed), the maximum size of aggregate and aggregate required as a measure of the level of workability.

- ESTIMATION OF AIR CONTENT

The entrapped air content is taken as (2%) from table No. 41 of SP 23-1982, based on nominal maximum size of the aggregate.

- ESTIMATIONOF CEMENT CONTENT

The cement content is calculated based on the selected water/water ratio and the estimated water content. According to the durability considerations specified in IS 456-2000, the calculated cement content is compared with the minimum cement content required. Use a larger value of above two.

- PROPORTIONS OF VOLUME OF FINE AND COARSE AGGREGATE

From IS:10262-2009 (Table-3) volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate is calculated. The percentage of sand in total aggregate depends upon the grading of sand to be incorporated in the mix.

Apart from the guidelines given in the figure 45 of the SP: 23-1982(35) for the calculation of the percentage of sand in total aggregate percentages of fine aggregates is also seen in relation to the ratio of total fine contents. Volume of Coarse aggregate is selected from table-3 from IS: 10262-2009

Volume of Fine aggregate=Total volume of aggregates - volume of coarse aggregate

- DATA FOR CONCRETE MIX DESIGN

(As per IS 10262-2009&IS456-2000)

- STIPULATIONS FOR PROPORTIONING

1. Grade of concrete = M_{25}
2. Cement Type = OPC 53 grade
3. Maximum size of nominal aggregate = 20 mm
4. Minimum cement content = 300 kg/m^3
5. Maximum W/C ratio = 0.44
6. Workability = 100 mm (slump)
7. Exposure condition = severe
8. Degree of supervision = Good
9. Type of aggregate crushed = Angular Aggregate
10. Maximum cement content = 450 kg/m^3
11. Chemical admixture = not used

- TEST VALUE FOR MATERIAL

1. Cement used OPC = 53 grade
2. Sp.gr of cement = 3.12
3. Sp.gr of water = 1
4. Specific gravity of coarse aggregate = 2.73
5. Specific gravity of fine aggregate = 2.61
6. Water absorption of coarse aggregate = 0.5%
7. Water absorption of fine aggregate = 1.0%
8. Free (surface) moisture of coarse and fine aggregate = Nil

M25 MIX DESIGN CALCULATION

- TARGET MEAN STRENGTH

Target mean strength (F'ck) = Fck +1.65s
Fck =25 N/mm^2
S = 4 N/mm^2 (as per IS 10262:2009, Table-1)
Target Mean strength= 25 + 1.65 X 4
=31.6 Mpa

- W/C Ratio

Taken from IS: 456-2000
For M25 grade of concrete, W/C =0.5

- MINIMUM CEMENT CONTENT

From the Table 5 of IS 456
Minimum cement content =320 kg/m^3

- CALCULATION OF WATER CONTENT

From Table2 of IS: 10262-2009,
Maximum water content for 20mm size of aggregate =186 liters (for 25to50mm slump)
For 100mm slump =186+6/100 *186= 197lit.

- CALCULATION OF CEMENT CONTENT

W/C = 0.5
C = W/0.5
Cement (C) =197/0.5 = 394 kg/m^3

PROPORTION OF VOLUME OF FINE AND COARSE AGGREGATE

For 20 mm size of coarse aggregate
Concrete volume = 1 m^3
Cement volume = 394/3.15 *1/1000 =0.1250 m^3
Water volume = 197/1* 1/1000 =0.197 m^3
For Zone -1
Volume of all Aggregates: C.A =0.6
Fine aggregate=0.4
Mass of coarse aggregate = 0.678 x2.73 x0.60 x1000 =1110.57 kg/m^3
Mass of fine aggregate =0.678 x2.61 x0.40 x1000
= 707.83 kg/m^3

MIX PROPORTION: The following is the mix proportion which is used to obtain the concrete mixture

1. Mass of water = 197 kg/m^3
2. Mass of cement = 394 kg/m^3
3. Mass of fine aggregate = 707.83 kg/m^3
4. Mass of coarse aggregate = 1110.57 kg/m^3
5. Water cement ratio = 0.5

Cement: Fine Aggregate: Coarse aggregate=394:707.83:1110.57
Cement: Fine Aggregate: Coarse aggregate = **1: 1.8: 2.82**
W/C = 0.5

PREPARATION OF CONCRETE

Producing high-quality concrete requires careful attention at every stage of concrete manufacturing. Interestingly, the composition of good concrete and bad concrete is the same. If similar measures are not taken and good regulations are not followed, the quality of the resulting concrete will be poor. we must carefully control the use at each stage, please use the same substance. This will result in good visibility. Therefore, we must understand the good rules followed to produce high-quality concrete at each stage of concrete production.

Different stages of concrete manufacturing are:

a) Batching
b) Mixing
c) Placing
d) Compacting
e) Curing

BATCHING

The measurement of materials to prepare concrete is called as batching. The following are the methods to do batching

1. Volume batching (based on volume)
2. Weigh batching (based on weight)

MIXING

Through mixing of the materials is needed to produce the uniform concrete. The mixing should be homogeneous, uniform in color and consistency. The following are methods to carryout mixing of concrete.

1) Hand mixing.(Man Power will be used)
2) Machine mixing(Machinery will be used)

PLACING

Properly designing, assembling, mixing and transporting the concrete mixture is sufficient, which is very important for placing the concrete in a regular manner to obtain the best results. The following precautions are to be taken,

1. Placing of concrete with earth mould.
2. Placing of concrete with in large earth mould or timber plank formwork.
3. placing of concrete in layers with in timbers or steel shutters.
4. Placing of concrete with in usual formwork and Placing of concrete under water.

COMPACTING

Compaction concrete is a recognized method of expelling residual air from concrete. During the mixing process, the air in the concrete is likely to be suspended, transported and put into the concrete. The lower the workability, the greater the amount of trapped air. In other words, hard concrete mixtures have a high entrapped air content and therefore require higher compacting forces than high-process mixtures.

WATER CURING

Submerging all the specimen in water, where already curing tanks were constructed with the cement concrete bed with smooth finishing at bottom and brick work walls with required height and plastered for do not absorb water by brick masonry, it will fulfill required aspects in curing system for elimination of shrinkage and also for heat of hydration process.

COMPRESSIVE STRENGTH TEST:

Testing of hardened concrete plays a vital role in concrete. Tests area unit created by casting cubes or cylinder from representative concrete. Which is based on the **IS: 516-1959.** For the hardened properties of concrete to conduct the most common test is compressive strength. The size of the specimens for cube 150mm x 150mm x 150mm cubes was casted with various concrete mixtures.

After casting are stored in water tank for curing for different ages like 7 days, 28 days, 56 days and 90 days. After curing specimens were removed from water and they are dried

for about one hour. The cubes are placed in the testing machine and before placing the bearing surface of the machine is cleaned. The load will be applied on the cube without shock at the rate of 140kg/cm2/minute until the specimen fails.

The load was applied at a constant rate by increase in stress as failure approached. When test cube fails, maximum load applied shall be noted. Similarly the remaining samples were tested for each sample, average 3specimens should be tested for accuracy results. When concrete is stressed beyond the elastic range, micro cracks develop at the interface and continuously grow up to failure mode.

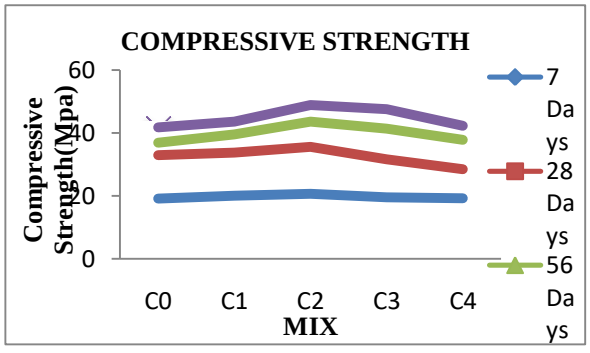
To calculate the strength of the specimen below formula is used. It is expressed in N/mm^2

Compressive strength= (Maximum load /Cross sectional area)

After conducting the compressive strength test the following properties are observed from the concrete using the alternative materials. Below table gives the compressive strength for 7, 28, 56 and 90 days respectively.

Compressive Strength Test Results

Mix	Compressive Strength in Mpa			
	7 Days	28 Days	56 Days	90 Days
C0	19.11	32.89	36.89	41.78
C1	20	33.78	39.56	43.56
C2	20.66	35.56	43.56	48.89
C3	19.56	31.56	41.33	47.56
C4	19.22	28.44	37.78	42.33



Compressive strength graphical representatio

SPLIT TENSILE STRENGTH TEST:

Determining the tensile strength of concrete is essential to determine the load at which concrete members may crack. Fracturing is a form of tension failure. Choose two numbers and perform tensile tests on each cylinder with a diameter of 150 mm x 300 mm, a cylinder with a diameter of 150 mm and a cylinder with a length of 300 mm (using CTM) to test the following characteristics Each cement cured the material for 28 days.

The split test is a well-known indirect test used to determine the tensile strength of concrete, sometimes also called the split tensile strength of concrete. The measured tensile strength of the sample should be calculated to the nearest 0.05 N/mm2.

Any reliable CTM should have sufficient testing capability and be able to withstand the load. Then record the maximum applied load. Attention should also be paid to the appearance of the concrete and any abnormal features in the type of failure.

$$F_{ct}= 2P/\pi DL$$

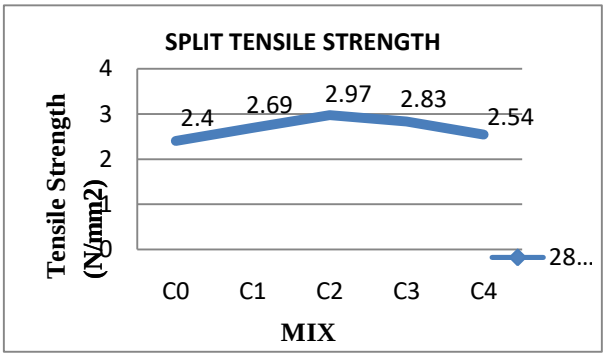
Where

P= maximum load applied
L= length of the cylinder in mm
D= Diameter of the specimen in mm

After conducting the split tensile strength test the following properties are observed from the concrete using the alternative materials. Below Table shows the details of the percentages of the bentonite and rice husk ash, and the split tensile strength for 28 days.

Split tensile strength results

MIX	% of Rise Husk Ash	% of Bentonite	28 Days Strength (M Pa)
C0	0	0	2.4
C1	5	5	2.69
C2	5	10	2.97
C3	5	15	2.83
C4	5	20	2.54



Split tensile strength graphical representation

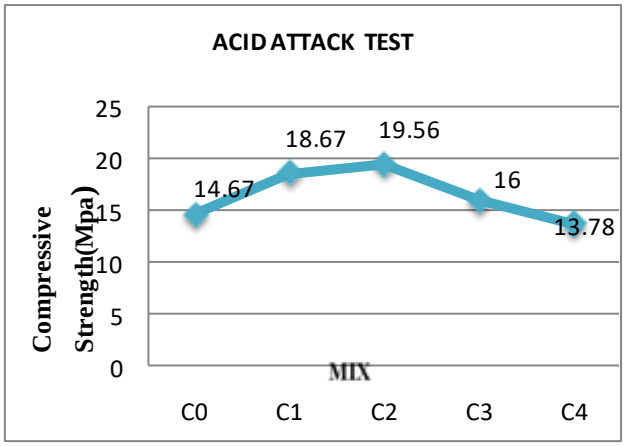
ACID ATTACK TEST

Acid Attack test is one of the tests to find out the acid attack on the concrete cube specimens .for this study the specimen of size 150X150X150 mm were casted and cured. After 28 days of curing i.e. from the period of casting are removed and again the cubes are placed in water which contains diluted solution of sulphuric acid (5%) for 28 days.

After completion of 28 days acid water curing, the cubes were taken from the solution and were surface dried and then weights of the specimens were found. The behavior of acids on solid concrete is likely to convert calcium compounds to calcium salts of attack acids. Hydrochloric acid with concrete, calcium chloride, which precipitates as gypsum and nitric acid with concrete, resulting in calcium nitrate, the result of this reaction, and the structure of the concrete is damaged.

Acid attack test results

Mix	Compressive Strength(N/mm²)
C0	14.67
C1	18.67
C2	19.56
C3	16
C4	13.78



Graphical representation of compressive strength for acid attack test after 28 days.

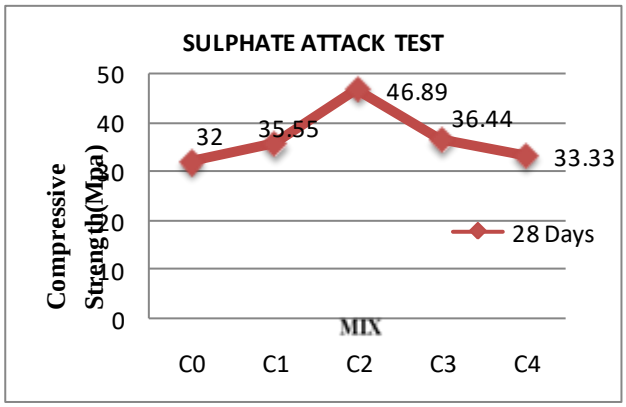
SULPHATE ATTACK TEST

For conducting this test specimen of size 150X150X150 mm were casted and curing for 28 days. After 28 days curing the cubes are removed and are placed in water which contains sodium chloride (NaCl) about 3.5% of water for a period of 28 days.

After of 28 days chloride water curing the cubes were taken out and cut in to two equal parts, after that the chemical called silver nitrate (AgNO3) of 0.1M is sprayed on those cubes. Due to chemical reaction between sodium chloride and silver nitrate, a white precipitate is formed on the specimens and the depth up to which it indicates white precipitate will provide the penetration of chlorine ions in the cube

Sulphate attack test results

Mix	Compressive Strength(N/mm²)
C0	32
C1	35.55
C2	46.89
C3	36.44
C4	33.33



Graphical representation of compressive strength for sulphate attack test after 28 days.

IV. CONCLUSION OF THE STUDY

Rice husk ash(RHA) and Calcium bentonoite(CB) is used in production of cubes of concrete and cylinders replacement cement by 5% of RHA as constant and with different percentages of CB' as 5%, 10%, 15%, 20%. These cubes of concrete and cylinders of concrete are cured and tested for compressive strength and split tensile strength for 7days, 28days, 56days, 90days and results were noted. Based on experimental investigation conducted following conclusions are made. Various mechanical and physical and chemical tests were conducted on the cured concrete specimens developed by replacing the cement with Bentonite and RHA.

The results emphasis that after curing for 28 days , specimen prepared with 5 % of RHA and 10% of Bentonite gave increased strength of about 24% than the conventional concrete. From this is concluded that the optimum percentage of the Bentonite, RHA in the concrete are 10% and 5% and is

also a very useful technique for decreasing the pollution at the same time improving the strength of the concrete.

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