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EXPERIMENTAL INVESTIGATION ON PARTIAL REPLACEMENT OF CEMENT BY RED MUD AND FINE AGGREGATES BY COPPER SLAG

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ABSTRACT

Red mud is a waste material generated by the Bayer Process widely used to produce alumina from bauxite throughout the world. Enormous quantity of red mud is generated worldwide every year posing a very serious and alarming environmental problem of disposal of large quantities of red mud. A solid-waste generated at the Aluminum plants all over the world possess an increasing problem of storage, land cost & availability and pollution. Because of the complex physico-chemical properties of red mud it is very challenging task for the designers to find out the economical utilization and safe disposal of red mud and also In India, there is great demand of aggregates mainly from civil engineering industry for road and concrete constructions. Butnowadays it is very difficult problem for available of fine aggregates.Copper slag is one of the materials that are considered as a waste material which could have a promising future in construction industry as partial or full substitute of either cement or aggregates. It is a byproduct Obtained during the matte smelting and refining of copper. To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material.

The aim of the present work is to investigate the possibility of replacing the Portland cement by red mud and fine aggregates by copper slag. Anattempt is made to check the effectiveness of neutralized red mud (washed) as a partial replacement of Portland cement. Because of storing issues, the waste negatively affects the environment. To solve this problem, Portland cement was replaced up to 30 % RM weight of cement And fine aggregates was replaced up to 50% copper slag and evaluating its compressive and splitting tensile strength of red mud concrete andperformance of copper slag on strength properties as partial replace of fine aggregate in concrete mix design.

INTRODUCTION

Red mud is a solid waste product of the Bayer process, the principal industrial means of refining bauxite in order to provide alumina as raw material for the electrolysis of aluminum by the Hall–Heroult process. A typical plant produces one to two times as much red mud as alumina. This ratio is dependent on the type of bauxite used in the refining process. Red mud is composed of a mixture of solid and metallic oxide-bearing impurities, and presents one of the aluminum industry's most important disposal problems. The red color is caused by the oxidized iron present, which can make up to 60% of the mass of the red mud. In addition to iron, the other dominant particles include silica, unbleached residual aluminum, and titanium oxide etc.Red mud cannot be disposed of easily. In most countries where red mud is produced, it is pumped into holding ponds. Red mud presents a problem as it takes up land area and can neither be built on nor farmed, even when dry. Due to the Bayer process the mud is highly basic with a pH ranging from 10 to 13. Several methods are used to lower the alkaline pH to an acceptable level to decrease the impact on the environment. Research is done to find a suitable way to utilize the mud for other applications, but drying the mud requires much energy (latent heat for water evaporation) and can represent high costs if fossil fuels have to be used in the drying process.

What is red mud?

Red mud is the iron rich residue from the digestion of bauxite. It is one of major solid waste coming from Bayer process of alumina production. In general, about 2-4 tons of bauxite is required for production of each tone of alumina (Al2o3) and about one tone red mud is generated. Since the red mud is generated in bulk it

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has to be stored in large confined and impervious ponds, therefore the bauxite refining is gradually encircled by the storage ponds. At present about 60 million tons of red mud is generated annually worldwide which is not being disposed or recycled satisfactorily.

Effect of red mud on environment

In the last decade, the production of aluminum in spite of some stagnancy and set back periods has shown a steady rise of about 1%. The ecological consequences of aluminum production are well known; land devastation by bauxite exploitation usurpation of big land areas by erection of disposal

Production of Construction Materials from Red Mud Cement

Dicalcium silicate in red mud is also one of the main phases in cement clinker, and red mud canplay the role of crystallization in the production of cement clinker. Fly ash is mainly composed of SiO_2 and Al_2O_3, thus can be used to absorb the water contained in the red mud and improve the reactive silica content of the cement. Scientists conducted a series of studies into the production of cement using red mud, fly ash, lime and gypsum as raw materials. Use of red mud cement not only reduces the energy consumption of cement production, but also improves the early strength of cement and resistance to sulfate attack. Ekrem Kalkan studied using red mud as a cement stabilizer. In 1980, Barsherike studied the possibility and rationality of producing cement with red mud as the raw material component of Portland cement, and successfully prepared cement complying with the relevant standards.

BRICK

As an alternative to traditional raw materials used in brick production, red mud utilization can not only reduce the cost of raw materials, but also have great environmental significance. Dong-Yan Liu and Chuan-Sheng Wu.et.al separately reported the production of non-steam-cured and non-fired brick, fly ash brick, black pellet decorative brick and ceramic glazed tile. For instance, non-steam-cured and non-fired brick is developed by using industrial residues as raw materials, by adding cement and lime as binder and by pressing and natural curing technology

Glass

Yang et al. [12] conducted an experiment for red mud-fly ash glass, in which the maximum content of red mud and fly ash is collectively more than 90%. They acquired the optimum heat treatment process through investigation of crystallization and the factors influencing the crystal nucleation and growth. With red mud and chromium slag as the main materials, and quartz sand, fluorite, toner, manganese slag and other substances as the auxiliary materials.

Aerated Concrete Block

Aerated concrete is a new light porous building material that has great performances such asthermal insulation, fire resistance and seismic resistance, and is made from calcareous and siliceous materials. Red mud aerated concrete, developed by using cement (15%), lime (12%–15%), red mud (35%–40%) and silica sand (33%–35%), has the compressive strength and bulk density, complying with the lowest intensity level (

Road base Material

High-grade road base material using red mud from the sintering process is promising, that may lead to large-scale consumption of red mud. Suggest using red mud as road material. Based on the work of a 15 m wide and 4 km long highway, using red mud as a base material, was constructed in Zibo, Shandong Province. A relevant department had tested the subgrade stability and the strength of road, and concluded that the red mud base road meets the level I standards of lime industrial waste stabilized soil and meets the strength requirements of the highway.

Copper slag

Granulated copper slag (or) copper slag which is a byproductfrom smelting of copper. For every tone of metal production, about 2.2 ton of waste slag isgenerated. Dumping or disposal of such huge quantities of slag cause environmental and space problems. During the past two decades, attempts have been made by several investigators and copper producing units all over the world to explore the possible utilization of copper slag. The Physical and mechanical properties of granulated copper slag shows that it can be used to make products like coarse and fine aggregates, cement, fill, ballast, roofing granules, glass, tiles etc.

Uses of copper slag

1. Copper slag has also gained popularity in the building industry for use as a fill material.
2. Contractors may also use copper slag in place of sand during concrete construction.
3. Copper slag can also be used as a building material, formed into blocks.
4. Copper slag is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools.
5. Copper slag is widely used as an abrasive media to remove rust, old coating and other impurities in dry

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abrasive blasting due to its high hardness (6-7 Mohs), high density (2.8- 3.8 g/cm^3) and low free silica content.

6. replacement of fine aggregate on the strength properties. Copper slag is the waste material of matte smelting and refining of copper such that each ton of copper generates approximately 2.5 tons of copper slag..

Following are the Objectives of this Project work

1. To Investigate the Utilization of Red mud as Supplementary Cementitious Material (SCM) and influence of this Red mud on the Strength Parameters of mortar.
2. To Study the Effect ofRed mud & Copper Slag (Replacement to Fine Aggregate) on compressive Strength of mortar.

CHAPTER-3
MEDTHOLOGY DETAILS

Brief Description

The purpose of the work presented in this report is to investigate the effects of using Red mud as An additive in mortar & study the hardened properties of mortar and also the effect of Red mud & Copper Slag (Replacement to Fine Aggregate) on strength parameters of mortar.The investigation work includes the following

- Part I: Basic Materials tests are doing for collected material
- Part II: Investigating the effect of replacing a part of the cement binder with red mud in Mortar.
- Part III: To study the effect of Red mud & Copper Slag (Replacement to Fine Aggregate) on strength parameters of mortar.

PART I

Table 1: Basic Materials Tests

Sl. No	Tests on Cement	Tests on Fine Aggregate	Tests on Coarse Aggregate	Tests on Red Mud	Tests on Copper Slag
1	Specific gravity of Cement	Specific gravity	Specific gravity	Specific gravity	Specific gravity
2	Fineness	Fineness Modulus	Fineness Modulus	Fineness	Fineness Modulus
3	Initial&Final setting time	Bulk Density	Bulk Density	---	---
4	Standard consistency of cement	Water Absorption	Water Absorption	---	Water Absorption

Materials

Cement

In this experimental work, Ordinary Portland Cement (OPC) 43 grade conforming to IS: 8112 -1989was used. The cement used was Ultra tech cement from the local distributors.The properties of cement are as shown in Table

Table 3.1: Properties of Cement (OPC 43)

Sl. No.	Material Property	Results obtained	Requirement as per IS:8112-1989

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2	Fineness	5.10%	Not more than 10%
3	Normal consistency	33%	Not more than 35%
4	Initial setting time	55 minutes	Not less than 30 min
5	Final setting time	355minutes	Not more than 600 min
6	Compressive strength at 3-days(MPa) 7- days(MPa) 28-days(MPa)	20.50 31.50 43.20	23 33 43

OBJECTIVES OF THE PRESENT WORK

Fine Aggregate

Locally available river sand belonging to zone II of IS 383-1970 was used for the projectwork. The sieve analysis data and physical properties of fine aggregate used are shown in Table 3.

Sieve Analysis and Physical Properties of Fine Aggregate

Sl.no	**Sieve**	**Mass retained i**	**% mass reta**	**% passing**	**Cumulative % ret 'F'**	**Specifications Zone II as per IS:383-197**
	4.75m	20	2.0	2.0	98	90-100
	2.36m	50	5.0	7.0	93	75-100
	1.18m	170	17.0	24.	76	55-90
	0.6m	270	27.0	51.	49	35-59
	0.3m	330	33.0	84.	16	8-30
	0.15m	130	13.0	97.	3	0-10
	Pan	30	3.0	100.	0	-
	Specific Gravity = **2.58**					
	Bulk Density = **1290 Kg/m³**					
	Water absorption = **1.0%**					
	Fineness Modulus=**3.35**					

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Result: The collected fine aggregate was belonging to zone II of IS 383-1970

Coarse aggregates

Locally available Crushed aggregates confirming to IS 383-1970 are used in this dissertation. The sieve analysis data and physical properties of coarse aggregates in Table 4.

Sieve Analysis and Physical Properties of Coarse Aggregate

	IS Sieve Size	Percentage passin coarse aggregates		Percentage passing of diff fractions			Specifications per IS:3 1970		
		I (20 mm)	II (12.5 m	I 60%	II 40%	Combin e 100%	Graded	Single sized I	Single sized II
1	20 mm	100	100	60	40	100	95-100	85-100	--
2	12.5 mm	0	98.5	0	0	0	--	--	85-10
3	10 mm	0	35.2	0	29.5	29.5	25-55	0-20	0-45
4	4.75 mm	0	8.4	0	4.1	4.1	0-10	0-5	0-10
5	Specific Gravity = 2.60								
6	Bulk Density = 1382 Kg/m^3								
7	Water absorption = 0.6%								

Red Mud

Red mud is the iron rich residue from the digestion of bauxite. It isone of the major solid waste coming from Bayer process of aluminaproduction. We collected red mud from Hindalco Industries Limited, Belgaum, Karnataka (INDIA).

Properties of Red mud

Sl. No.	Material Property	Results obtained
1	Specific gravity	2.90
2	Fineness	4.10%

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Chemical Composition of Red mud

Chemical composition (Hindal Co,Belgum)	Bauxite residue (%)	Typical values Worldwide (%)
Fe_2O_3	45	30-60
Al_2O_3	15	10-20
CaO	4	2-8
SiO_2	8	3-50
Na_2O	5	2-10
TiO_2	10	Traces-25%
Traces of LOI	11	10-14

Copper Slag

Copper Slag is a byproduct material produced from the process of manufacturing Copper.It is totally inert material and its physical properties are similar to natural sand. The slag is a mixture of lime, silica, and alumina, the same proportion. We collected Copper slag from local distributors of Coimbatore (Tamilnadu).

Sieve Analysis and Physical Properties of Copper slag

Sl. no	Sieve no.	Mass retained in gms	% passing	Cumulative % retained 'F'	Specifications for Zone II as per IS:383-1970
1	4.75mm	3	3	97	90-100
2	2.36mm	8	14	89	75-100
3	1.18mm	28	39	61	55-90
4	0.6mm	36	75	25	35-59
5	0.3mm	17	92	8	8-30
6	0.15mm	7	99	1	0-10
7	Pan	1	100	0	0
8	Specific Gravity = 3.58				
9	Finness modulus=3.19				

Result: The collected Copper Slag was belonging to zone II of IS 383-1970.

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Chemical Composition of Copper Slag

Sl. No	Chemical Compounds	% of Compounds
1	Fe_2O_3	68.29
2	SiO_2	25.84
3	Al_2O_3	0.22
4	CaO	0.15
5	MgO	0.2
6	Na_2O	0.58
7	K_2O	0.23
8	Mn_2O_3	0.22
9	TiO_2	0.41
10	CuO	1.2
11	LOI	6.59
12	Insoluble residue	6.59

PART II

Investigating the effect of replacing a part of the cement binder with red mud in Mortar.

Casting of Mortar Mixes (1:3 proportion)

The normal mortar cubes are originally cast as per Indian Standard Specification. To find the compressive strength of cement mortar cubes, first we take cement and sand in 1:3 proportion and water content equal to [(P/4+3.0) % of combined weight of cement and sand]. Here, P is the normal consistency of cement paste. The cubes are cast and cured as usual and tested for compressive strength in the compression testing machine at different ages: 3, 7 and 28 days. [3] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e., velocity of AGV is controlled by the microprocessor controller.This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential part of the system although with changing demands on physical input as the degree of mechanization is increased.

The Compressive strength of cement indicates the compressive strength of cement mortar cubes (7.07cmx7.07cmx7.07cm) of 1:3 proportion, using standard sand as fine aggregate , tested under compression (Grade of cement indicates their compressive strength at the end of 28-days of curing). Many other properties of mortar / concrete are related to compressive strength of cement, because cement is used in structure in the form of mortar or concrete.

For each cube, take the quantities of materials as follows-

- Cement = 185gm

- Fine aggregate = 555gm
- Water = (P/4+3.0) percent of combined weight of cement and sand

Mix the cement and sand with trowel on non-porous plate for one minute. Then add water to the mixture of cement, sand and mix it until the mixture of uniform colour is obtained. The time of gauging shall in any case not be less than 3 minutes and not more than 5 minutes, gauging time is the time elapsed between the water added to the mix and casting of cubes.

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1. Apply thin layer of oil to the interior faces of the moved. Place it on the table of the vibration.
2. The following are the procedure.
3. Machine, and firmly hold in position by means of suitable clamps.
4.Place the entire quantity of mortar in the hopper of the cube mould and compact the same by Vibrations for period of about 2 minutes.
5.At the end of vibration, remove the mould together with the base plate from
6.Keep the filled moulds in the atmosphere of at least 90% relative humidity for 24 hours in the humidity chamber, after completion of vibration. Also maintain temperature at 27± 2°C **7.**At end of this period. Remove cubes from the moulds and immediately submerge in clean.
Fresh water and keep there until taken out just prior to breaking. After they are taken out and until they are broken, the cubes shall not allow to becoming dry.
8.Fresh water and keep there until taken out just prior to breaking. After they are taken out and until they are broken, the cubes shall not allow to becoming dry.

Testing

1. Place the test cube on the platform of compression testing machine without any packing between the Cube and the steel plates of the testing machine.
2. Apply the load on smooth surface on the cube steadily and uniform starting from zero at a rate of 35 N/mm2 till the cubes fails.
3. Test three such cubes at the end of three days of curing. Three cubes at the end of seven days of curing and if needed three cubes after 28 days of curing.
4. Record the crushing load.
5. Calculate the compressive strength of each cube by dividing crushing load by crushing area of the cube. The compressive strength shall be average

Dry mixing of ingredients

Casting of number of Mortar Specimens (Red Mud)

% replacement of Cement by Red Mud	3-days	7-days	28-days
Control mix	3	3	3
5%RM	3	3	3
10%RM	3	3	3
15%RM	3	3	3
20%RM	3	3	3
25%RM	3	3	3
30%RM	3	3	3
Total	21	21	21

Casting of number of Mortar Specimens (Red Mud + Copper slag waste)

% replacement of Cement by Red Mud & sand by Copper slag waste	3-days	7-days	28-days
Control mix	3	3	3

5%RM+10% CS Waste	3	3	3
10%RM10% CS Waste	3	3	3
15%RM10% CS Waste	3	3	3
20%RM10% CS Waste	3	3	3
25%RM10% CS Waste	3	3	3
30%RM10% CS Waste	3	3	3
Total	21	21	21

4.0 EXPERIMENTAL RESULTS& DISCUSSION

4.1 Compression Strength Results

Table 4.1: Test Results of 3 - Days Compressive Strength Mortar mixes (Red Mud)

% replacement of Cement by Red Mud	Days	Failure load (kN)	Compressive Strength (MPa)	
Control Mix	3	98.60	21.10	20.50
	3	98.50	20.30	
	3	99.10	20.20	
5%RM	3	108.60	22.20	21.40
	3	109.80	22.40	
	3	11.20	22.70	
10%RM	3	120.70	24.60	24.50
	3	121.90	24.90	
	3	117.10	23.90	
15%RM	3	125.40	25.60	25.70
	3	128.00	26.10	
	3	124.50	25.40	
20%RM	3	106.	21.8	22.3

		80	0	0
	3	112.70	23.00	
	3	108.80	22.20	
25%RM	3	98.60	20.10	19.80
	3	96.90	19.80	
	3	95.10	19.90	
30%RM	3	93.80	19.10	19.00
	3	91.80	18.70	
	3	94.60	19.30	

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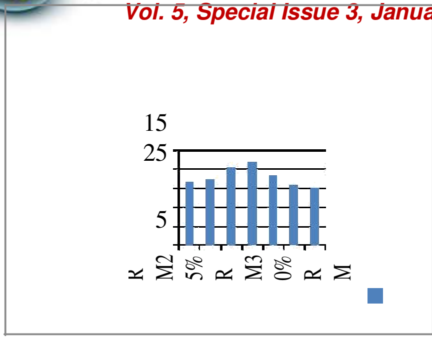

3-
Days

Replacements(%)

3-Days Compressive strength results of Red Mud

Observations:

The above graph indicates that the compressive strength of 3-days mortar mixes with various replacements of red mud. The optimum strength gained after 3-days curing period is at 15%RM replacements to cement.

Table 4.2: Test Results of 7 - Days Compressive Strength Mortar mixes (Red Mud)

% replacement of Cement by Red Mud	Days	Failure load (kN)	Compressive Strength (MPa)	
Control Mix	7	154.00	31.40	
				31.50
	7	152.10	31.00	
	7	157.20	32.00	
5%RM	7	157.40	32.10	
	7	155.80	31.80	31.70
	7	153.00	31.20	
10%RM	7	162.10	33.10	
	7	163.70	33.40	33.10
	7	161.40	32.90	
15%RM	7	172.20	35.10	
	7	170.50	34.70	34.60
	7	166.70	34.00	
20%RM	7	158.80	32.40	
	7	157.30	32.10	32.40
	7	159.80	33.60	
25%RM	7	143.10	29.60	
	7	147.10	30.00	29.70
	7	145.90	29.80	
30%RM	7	143.20	29.20	
				29.00
	7	141.60	28.90	
	7	142.10	29.00	

M)

25
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7-Days Compressive strength results of Red Mud
Observations:

- The above graph indicates that the compressive strength of 7-days mortar mixes with various replacements of red mud. The optimum strength gained after 7-days curing period is at 15%RM replacements to cement.

% replacement of Cement by Red Mud	Days	Failure load (kN)	Compressive Strength (MPa)	
Control Mix	28	217.10	44.30	43.20
	28	214.20	43.71	
	28	217.80	44.44	
5%RM	28	206.10	42.06	42.08
	28	205.80	42.00	
	28	206.80	42.20	
10%RM	28	216.60	44.20	44.03
	28	214.70	43.80	
	28	216.10	44.10	
15%RM	28	221.80	45.26	45.63
	28	221.10	45.12	
	28	227.90	46.51	
20%RM	28	213.70	43.60	43.16
	28	209.80	42.81	
	28	211.20	43.10	
25%RM	28	200.00	40.80	40.40
	28	199.00	40.61	
	28	195.10	39.80	
30%RM	28	195.10	39.80	40.03
	28	197.10	40.22	
	28	196.60	40.12	

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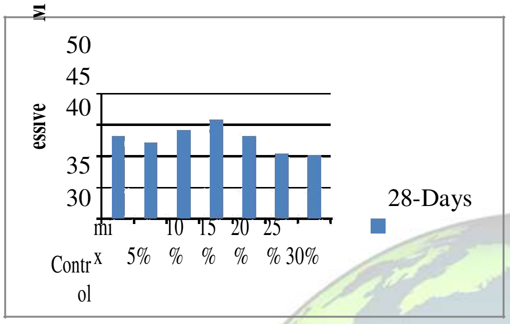

Percentage replacement of cement by red mud

Fig 4.3: 28-Days Compressive strength results of Red Mud

Observations:

The above graph indicates that the compressive strength of 28-days mortar mixes with various replacements of red mud. The optimum strength gained after 28-days curing period is at 15%RM replacements to cement.

Table 4.4: Test Results of 3 - Days Compressive Strength Mortar mixes (Red Mud+Copper slag Waste)

% replacement of Cement by Red Mud	Days	Failure load (kN)	Compressive Strength (MPa)	
Control Mix	3	98.60	21.12	20.53
	3	99.50	20.53	
	3	99.10	20.22	
5%RM+10% CS Waste	3	116.80	23.83	24.11
	3	119.60	24.40	
	3	118.10	24.10	
10%RM+10% CS Waste	3	125.30	25.57	25.38
	3	123.80	25.24	
	3	124.20	25.32	
15%RM+10% CS	3	125.50	25.81	26.11
	3	128.4	26.40	

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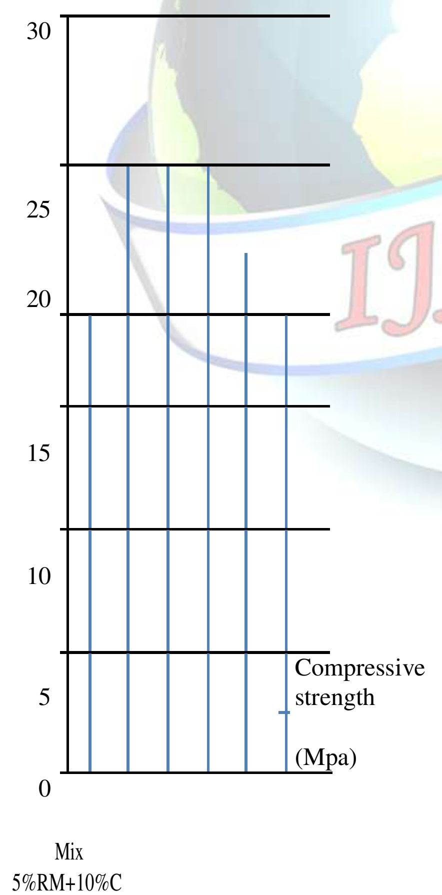
		0		
Waste	3	129.60	26.34	
20%RM+10% CS Waste	3	108.40	22.12	22.37
	3	110.80	22.61	
	3	109.80	22.40	
25%RM+10% CS Waste	3	104.20	21.26	20.68
	3	99.80	20.36	
	3	100.10	20.42	
30%RM+10% CS Waste	3	98.40	20.08	20.12
	3	99.50	20.30	
	3	98.00	20.00	

- After 15% replacement the compressive strength gradually decreasing.



% replacement of Cement by Red Mud	Days	Failure load (kN)	Compressive Strength (MPa)	
Control Mix	28	217.10	44.30	.43.20
	28	214.20	43.71	
	28	217.80	44.44	
5%RM+10%CS Waste	28	219.50	44.79	44.10
	28	221.20	45.14	
	28	218.60	44.61	
10%RM+10%CS Waste	28	219.60	44.81	44.63
	28	216.10	44.10	
	28	220.50	45.00	
15%RM+10%CS	28	221.10	45.12	45.75
	28	228.50	46.03	

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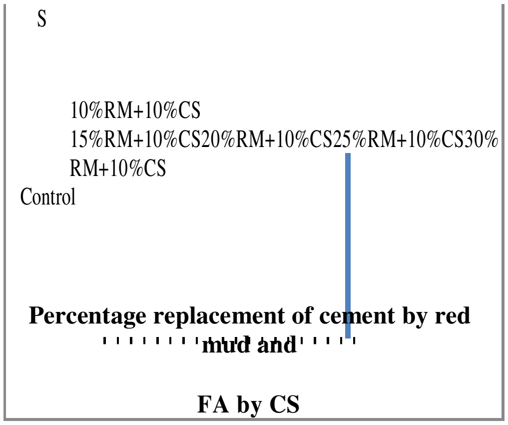
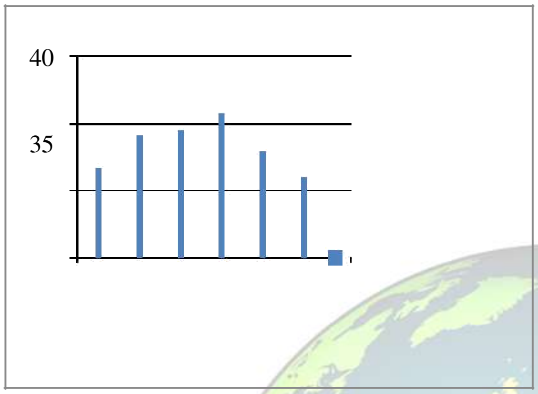


	28	200.10	40.83	
Waste	28	223.00	45.51	
Waste	28	209.10	42.67	
20%RM+10%CS	28	210.10	42.87	42.80
	28	210.30	42.91	
25%RM+10%CS	28	199.40	40.70	40.77
Waste	28	199.90	40.80	
30%RM+10%CS Waste	28	195.00	39.80	
	28	196.50	40.10	40.24
	28	200.10	40.83	

Table 4.5: Test Results of 7 - Days Compressive Strength Mortar mixes (Red Mud+Copper slag Waste)

% replacement of Cement by Red Mud	Days	Failure load (kN)	Compressive Strength (MPa)	
Control Mix	7	154.00	31.42	
	7	152.10	31.04	31.51
	7	157.20	32.08	
5%RM+10%CS Waste	7	168.10	34.30	
	7	164.60	33.59	33.90
	7	165.80	33.80	
10%RM+10%CS Waste	7	167.60	34.20	
	7	166.70	34.02	34.27
	7	169.50	34.59	
15%RM+10%CS Waste	7	176.80	36.06	
	7	172.60	35.22	35.56
	7	173.50	35.40	
20%RM+10%CS Waste	7	160.70	32.80	
	7	158.00	32.24	32.70
	7	162.10	33.08	
25%RM+10%CS Waste	7	150.10	30.63	
	7	150.80	30.77	30.75

	7	151.10	30.84	
30%RM+10% CS Waste	7	147.50	30.10	30.07
	7	146.20	29.83	
	7	148.50	30.30	



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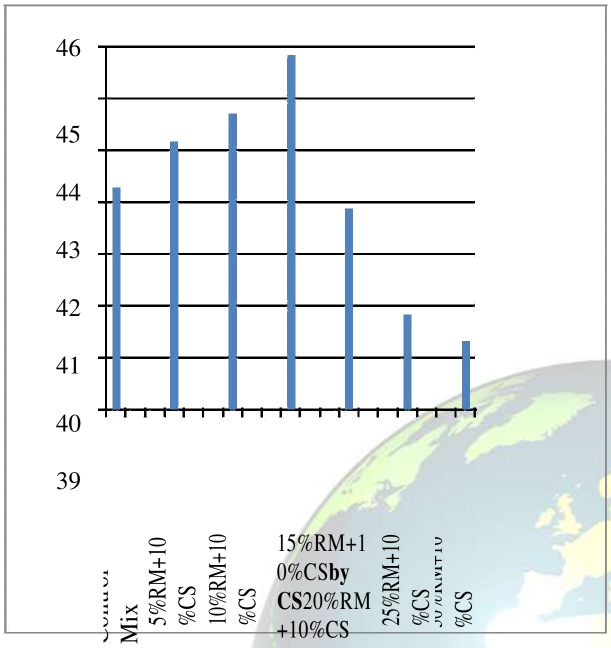

Percentage replacement of cement by red mud and FA

Control5%RM+10%CSMix10%RM+10%CS15%RM+10%CS20%RM+10%CS25%RM+10%CS30%RM+10%CS

compressive

strength (Mpa)

Percentage replacement of cement by red mud and

FA by CS

Table 4.6: Test Results of 28 - Days Compressive Strength Mortar mixes (Red Mud+Copper slag Waste)

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