ISSN 2320-5407 International Journal of Advanced Research (2014), Volume 2, Issue 1, 473-484

ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

AN EXPERIMENTAL INVESTIGATION ON THE EFFECT OF ALTERNATE WETTING AND DRYING ON THE PROPERTIES OF CONCRETE PRODUCED BY RED MUD

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Manuscript Info

Manuscript History:

Received: 19 November 2013
Final Accepted: 25 December 2013
Published Online: January 2014

Abstract

The main objective of this experimental investigation is to find out the effect of replacement of cement by red mud in different percentage. The different percentage replacement of cement by red mud adopted in the experimentation are 0%,2%, 4%, 6%, 8%,10%,12%,14%,16%,18%,20%. Workability testing apparatus like slump cone, compaction factor apparatus to find slump, compaction factor. The strength characteristics like compressive strength, tensile strength, flexural strength, impact strength and shear strength are found for different percentage replacement. Also effect of alternative wetting and drying for 50 cycles is found on concrete produced by replacement cement by red mud. One cycle of alternative wetting and drying means subjecting the concrete to wetness for one day and drying for one day.

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–Héroult 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 oxidised 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.

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.

1.1 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 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.

2. Materials and Methodology

2.1 Materials

2.1.1 Cement

In this experimental work, Ordinary Portland Cement (OPC) 43 grade conforming to IS: 8112 - 1989 was used. The cement used was Bharathi cement from the local distributors.

2.1.2 Red Mud

Red mud is the iron rich residue from the digestion of bauxite. It is one of the major solid waste coming from Bayer process of alumina production. Generally Fineness of red mud is varies in between 1000-3000 cm2/gm. We collected red mud from Hindalco Industries Limited, Belgaum, Karnataka (INDIA).

2.1.3 Fine aggregates

Locally available river sand belonging to zone II of IS 383-1970 was used for the project work.

2.1.4 Coarse aggregates

Locally available Crushed aggregates confirming to IS 383-1970 are used in this dissertation.

2.1.5 Super plasticizer

Commercially available high performance super plasticizing admixture, Conplast SP430, conforms to ASTM C 494 (1992) was used to maintain the slump of the concrete.

2.2 Methodology

- Separately mix the cementitious materials (cement and red mud)
- Dry mix the sand and cementitious materials.
- Add coarse aggregate to it and mix it thoroughly to achieve cement particles on each and every coarse aggregate.
- Add the calculated quantity of water to the dry mix and mix thoroughly to get homogeneous mix.
- Moulds are cleaned and lightly oiled to the inner surface of the mould to prevent any bonding reaction between the mould and the sample.
- Place the moulds on the vibrating table and put the wet concrete mix inside the moulds in three layers.
- Vibrate the concrete both through table vibration and by hand compacting using tamping rod.
- Vibration should not be more, otherwise segregation will takes place.
- After filling the moulds with wet concrete, level the surface and give the designation to each specimen.
- Demould the specimen after 24 hours.
- Demoulded specimens are then kept for 28 days of curing in water.
- Tests on hardened concrete after 28 days of curing are conducted

➢ Compressive strength test on 150mmX150mmX150mm cube.
➢ Tensile strength test on 150mmϕX300mmL cylinder.
➢ Flexural strength test on 100mmX100mmX500mm beam.
➢ Shear strength test on L shaped specimen.

3. Experimental results

3.1 Mix Design for M30 grade concrete

According to IS: 10262 – 2009

Cement	=	413.33 Kg/m^3
Water	=	186.00 Kg/m^3
Fine aggregate	=	652.00 Kg/m^3
Coarse aggregate	=	1123.0 Kg/m^3
W/C	=	0.45

M30 was designed using IS method of mix design. The mix proportion for M 30 grade concrete is given in the following Table 3.1.

Table 3.1: Mix proportion for M 30 Grade concrete

Sl. no	Grade of concrete	Cement	Fine aggregate	Coarse aggregate	W/C
1.	M 30	1.00	1.58	2.71	0.45

3.2 Workability test results:-Following table gives the workability test results of concrete produced by washed and unwashed red mud. Variations of slump and compaction factor are depicted in the form of graph as shown in fig 3.2.

Table 3.2 Workability test results

Percentage replacement of cement by red mud	With unwashed red mud		With washed red mud	
	Slump (mm)	Compaction factor	Slump (mm)	Compaction factor
0%	67	0.82	67	0.82
2%	70	0.83	72	0.85
4%	72	0.84	74	0.86
6%	75	0.85	76	0.87
8%	76	0.87	78	0.91
10%	78	0.89	80	0.94
12%	75	0.8	77	0.81
14%	73	0.78	75	0.79
16%	68	0.76	70	0.77
18%	65	0.75	67	0.76
20%	63	0.74	65	0.75

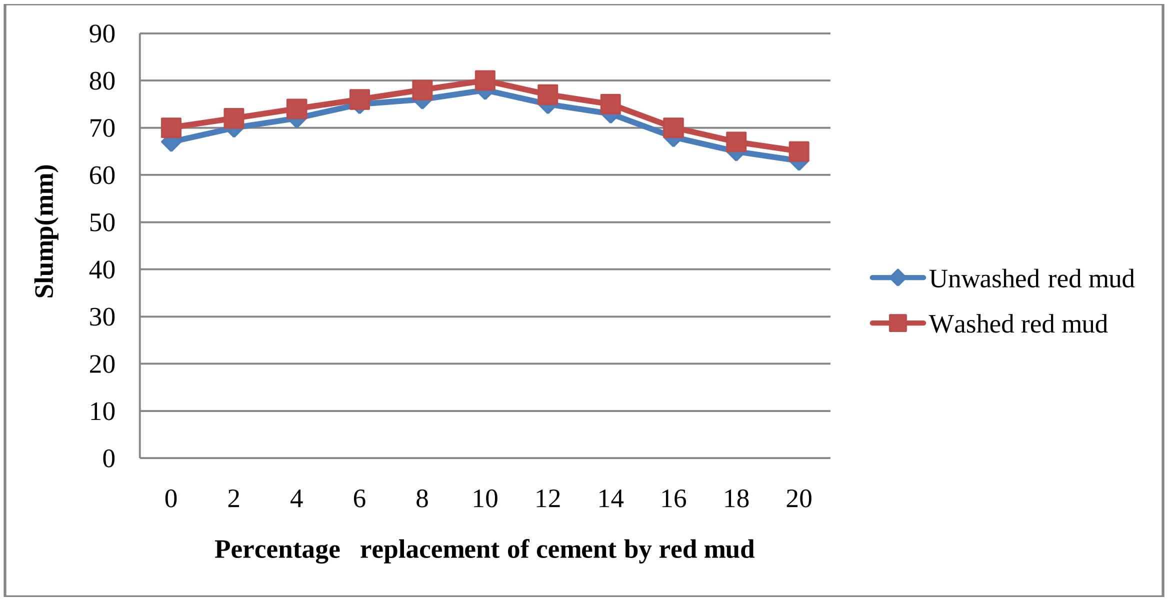

Fig 3.1 Variation of slump

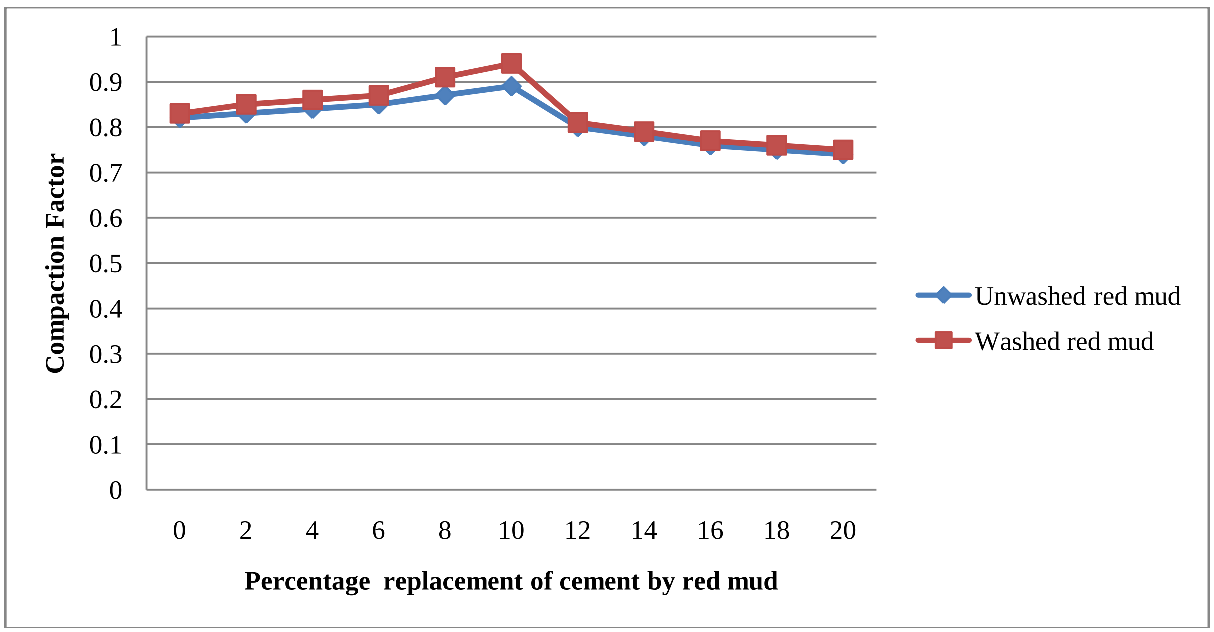

Fig 3.2 Variation of compaction factor

3.3 **Compressive strength test results:-**Following tables give the compressive strength test results of concrete produced by washed and unwashed red mud and when subjected to 50 cycles of alternate wetting and drying.

Table 3.2 Overall results of compressive strength when subjected to alternate wetting and drying

Percentage replacement of cement by red mud	Compressive strength of concrete produced by unwashed red mud	Percentage increase or decrease of compressive strength w.r.t reference mix	Compressive strength of concrete produced by washed red mud	Percentage increase or decrease of compressive strength w.r.t reference mix	Percentage increase of compressive strength of concrete produced by washed red mud over unwashed red mud
0% (ref mix)	41.63	-	41.63	-	0
2%	41.78	+ 0.36	41.93	+ 0.72	+ 0.35
4%	41.93	+ 0.72	42.07	+ 1.05	+ 0.33
6%	42.22	+ 1.41	42.37	+ 1.77	+ 0.35
8%	42.52	+ 2.13	42.67	+ 2.49	+ 0.35
10%	42.81	+ 2.83	42.96	+ 3.19	+ 0.35
12%	41.19	- 1.05	41.48	- 0.36	+ 0.70
14%	40.00	- 3.91	40.59	- 2.49	+ 1.47
16%	38.22	- 8.19	39.11	- 6.05	+ 2.32
18%	36.74	- 11.74	37.19	- 10.66	+ 2.32
20%	34.67	- 16.71	34.96	- 16.02	+ 0.83

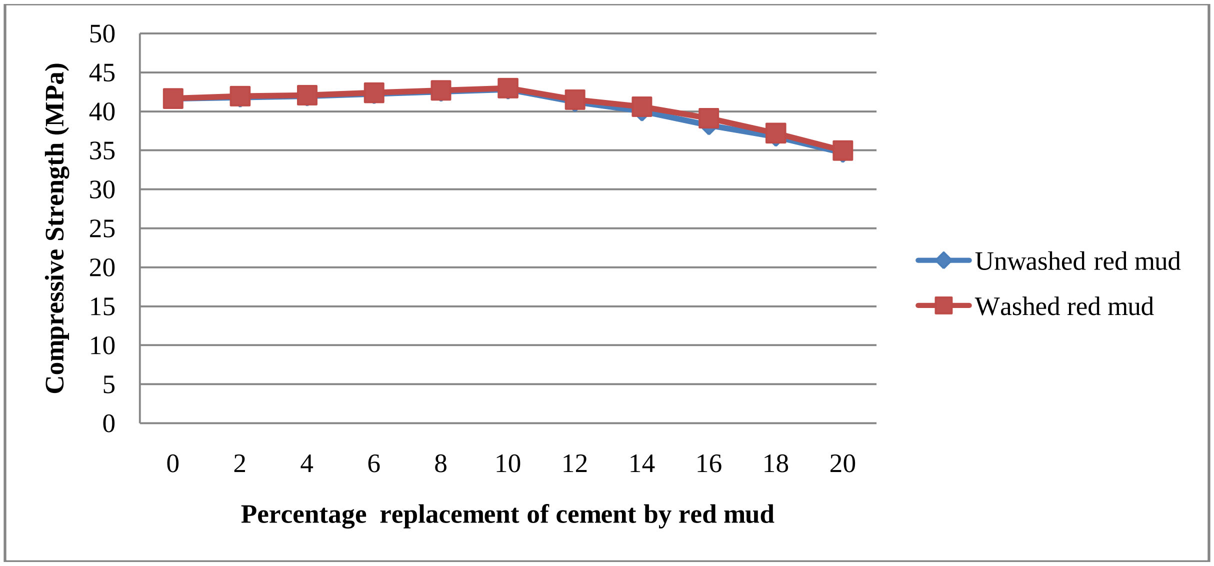

Fig 3.3 Variation of compressive strength

3.4 Tensile strength test results: - Following tables give the tensile strength test results of concrete produced by washed and unwashed red mud and when subjected to 50 cycles of alternate wetting and drying.

Table 3.3 Overall results of tensile strength when subjected to alternate wetting and drying

Percentage replacement of cement by red mud	Tensile strength of concrete produced by unwashed red mud	Percentage increase or decrease of tensile strength w.r.t reference mix	Tensile strength of concrete produced by washed red mud	Percentage increase or decrease of tensile strength w.r.t reference mix	Percentage increase of tensile strength of concrete produced by washed red mud over unwashed red mud
0% (ref mix)	3.68	-	3.68	-	0
2%	3.72	+ 1.08	3.77	+ 2.44	+ 1.34
4%	3.77	+ 2.44	3.87	+ 5.16	+ 2.65
6%	3.82	+ 3.80	3.96	+ 7.60	+ 3.66
8%	3.87	+ 5.16	4.01	+ 8.96	+ 3.61
10%	3.91	+ 6.25	4.05	+ 10.05	+ 3.58
12%	3.39	- 7.88	3.68	0	+ 8.55
14%	3.35	- 8.96	3.58	- 2.71	+ 6.86
16%	3.25	- 11.68	3.49	- 5.16	+ 7.38
18%	3.21	- 12.77	3.30	- 10.32	+ 2.80
20%	3.11	- 15.48	3.16	- 14.13	+ 1.60

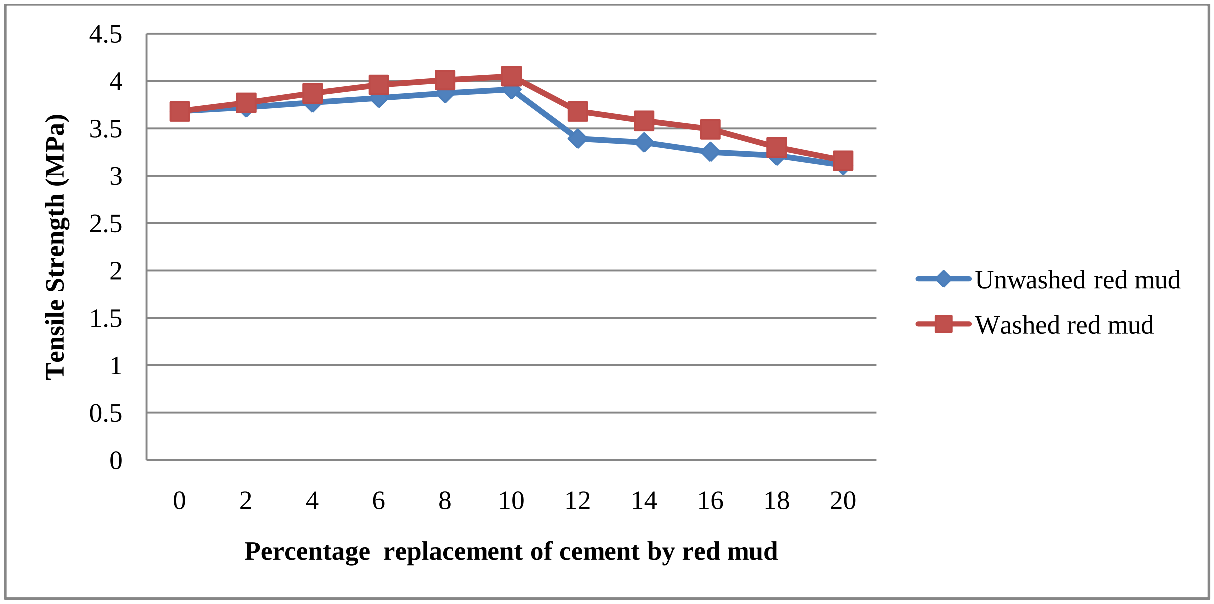

Fig 3.4 Variation of tensile strength

3.5 Flexural strength test results: - Following tables give the flexural strength test results of concrete produced by washed and unwashed red mud and when subjected to 50 cycles of alternate wetting and drying.

Table 3.4 Overall results of flexural strength when subjected to alternate wetting and drying

Percentage replacement of cement by red mud	Flexural strength of concrete produced by unwashed red mud	Percentage increase or decrease of flexural strength w.r.t reference mix	Flexural strength of concrete produced by washed red mud	Percentage increase or decrease of flexural strength w.r.t reference mix	Percentage increase of flexural strength of concrete produced by washed red mud over unwashed red mud
0% (ref mix)	8.00	-	8.00	-	0
2%	8.17	+ 2.12	8.67	+ 8.37	+ 6.11
4%	8.67	+ 8.37	9.17	+ 14.62	+ 5.76
6%	9.00	+ 12.5	9.33	+ 16.62	+ 3.66
8%	9.67	+ 20.87	9.83	+ 22.87	+ 1.65
10%	10.00	+ 25	10.17	+ 27.12	+ 1.70
12%	8.50	+ 6.25	9.33	+ 16.62	+ 9.76
14%	8.33	+ 4.12	8.83	+ 10.37	+ 6.00
16%	8.17	+ 2.12	8.67	+ 8.37	+ 6.11
18%	7.83	- 2.12	8.50	+ 6.25	+ 8.55
20%	7.50	- 6.25	7.67	- 4.12	+ 2.26

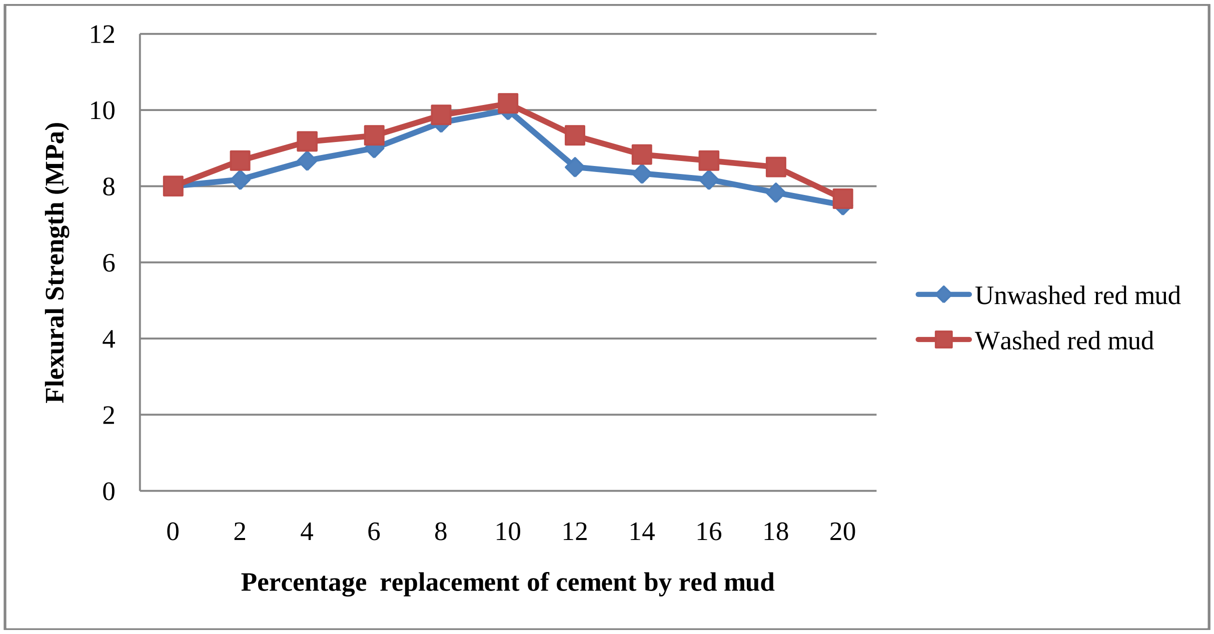

Fig 3.5 Variation of flexural strength

3.6 Shear strength test results: - Following tables give the shear strength test results of concrete produced by washed and unwashed red mud and when subjected to 50 cycles of alternate wetting and drying.

Table 3.5 Overall results of shear strength when subjected to alternate wetting and drying

Percentage replacement of cement by red mud	Shear strength of concrete produced by unwashed red mud	Percentage increase or decrease of shear strength w.r.t reference mix	Shear strength of concrete produced by washed red mud	Percentage increase or decrease of shear strength w.r.t reference mix	Percentage increase of shear strength of concrete produced by washed red mud over unwashed red mud
0% (ref mix)	5.00	-	5.00	-	0
2%	5.19	+ 3.80	5.37	+ 7.4	+ 3.46
4%	5.37	+ 7.40	5.56	+ 11.2	+ 3.53
6%	5.56	+ 11.2	5.74	+ 14.8	+ 3.23
8%	5.74	+ 14.8	5.93	+ 18.6	+ 3.31
10%	5.93	+ 18.6	6.11	+ 22.2	+ 3.03

12%	5.19	+3.8	5.56	+ 11.2	+ 7.12
14%	5.00	0	5.37	+ 7.4	+ 7.4
16%	4.81	- 3.8	5.00	0	+ 3.95
18%	4.07	- 0.18	4.44	- 11.2	+ 9.09
20%	3.70	- 26	4.07	- 18.6	+ 10

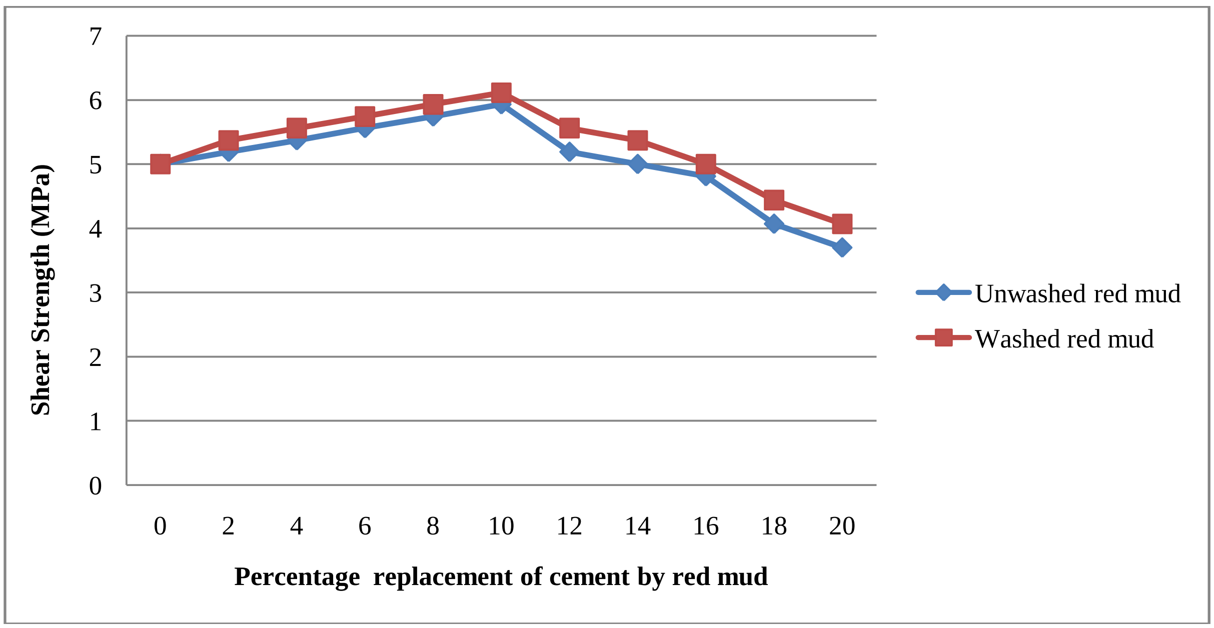

Fig 3.6 Variation of shear strength

4. Observations and Discussions

1. It is observed that the workability of concrete as measured from slump and compaction factor for concrete produced by replacing the cement by washed red mud goes on increasing up to 10% replacement. After 10% the workability starts decreasing.

This is due to the fact that at 10% replacement level the washed red mud will induce flow properties because of its smooth texture and fineness. More than 10% addition of washed red mud results in stiff concrete, since washed red mud starts absorbing water from the concrete.

Therefore it can be concluded that the workability of concrete is higher at a cement replacement level of 10% by washed red mud. Beyond this replacement level workability decreases drastically.

2. It is observed that the workability of concrete as measured from slump and compaction factor for concrete produced by replacing the cement by unwashed red mud goes on increasing up to 10% replacement. After 10% the workability starts decreasing.

This is due to the fact that at 10% replacement level the unwashed red mud will induce flow property because of its smooth texture and fineness. More that 10% addition of unwashed red mud results in stiff concrete, since without washed red mud starts absorbing water from the concrete.

Therefore it can be concluded that workability of concrete is higher at a cement replacement level of 10% by unwashed red mud. Beyond this replacement level, workability decreases drastically.

4. It is observed that the compressive strength of concrete produced by replacing cement by unwashed red mud and when subjected to alternative wetting and drying for 50 cycles goes on increasing up to 10% replacement levels. There after compressive strength start decreasing. It is found that at 10% replacement level the percentage increase in compressive strength is 2.83% as compared to the reference mix.

This may be due to the fact that at 10% replacement level of cement by unwashed red mud, the pozzolonic reaction is high and it may fill all the gaps there by increasing compressive strength.

Thus it can be concluded that the compressive strength of concrete produced by replacement of cement by unwashed red mud and when subjected to alternative wetting and drying goes on increasing up to 10% replacement level.

5. It is observed that the tensile strength of concrete produced by replacing cement by unwashed red mud and when subjected to alternative wetting and drying for 50 cycle goes on increasing up to 10% replacement levels. There after tensile strength start decreasing. It is found that at 10% replacement level the percentage increases, in tensile strength is 6.25% as compared to the reference mix.

This may be due to the fact that at 10% replacement level of cement by unwashed red mud, the pozzolonic reaction is high and it may fill all the gaps there by increasing tensile strength.

Thus it can be concluded that the tensile strength of concrete produced by replacement of cement by unwashed red mud and when subjected to alternative wetting and drying goes on increasing up to 10% replacement level.

6. It is observed that the flexural strength of concrete produced by replacing cement by washed red mud and when subjected to alternative wetting and drying for 50 cycles goes on increasing up to 10% replacement levels. There after flexural strength start decreasing. It is found that at 10% replacement level the percentage increase in flexural strength is 27.12% as compared to the reference mix.

This may be due to the fact that at 10% replacement level of cement by washed red mud, the pozzolonic reaction is high and it may fill all the gaps there by increasing flexural strength. Thus it can be concluded that the flexural strength of concrete produced by replacement of cement by washed red mud and when subjected to alternative wetting and drying goes on increasing up to 10% replacement level.

7. It is observed that the shear strength of concrete produced by replacing cement by unwashed red mud and when subjected to alternative wetting and drying for 50 cycle goes on increasing up to 10% replacement levels. There after shear strength start decreasing. It is found that at 10% replacement level the percentage increase in shear strength is 18.6% as compared to the reference mix.

This may be due to the fact that at 10% replacement level of cement by unwashed red mud, the pozzolonic reaction is high and it may fill all the gaps there by increasing shear strength.

Thus it can be concluded that the shear strength of concrete produced by replacement of cement by unwashed red mud and when subjected to alternative wetting and drying goes on increasing up to 10% replacement level.

5. Conclusions

1. Workability of concrete is higher at a cement replacement level of 10% by washed red mud. Beyond this replacement level workability decreases drastically.

2. Workability of concrete is higher at a cement replacement level of 10% by unwashed red mud. Beyond this replacement level workability decreases drastically.
3. Workability of concrete produced by replacing washed red mud is higher as compared to concrete produced by unwashed red mud.
4. Compressive strength of concrete produced by replacement of cement by unwashed red mud and when subjected to alternative wetting and drying goes on increasing up to 10% replacement level.
5. Compressive strength of concrete produced by replacement of cement by washed red mud and when subjected to alternative wetting and drying goes on increasing up to 10% replacement level.
6. Concrete produced by replacing cement by washed red mud and when subjected to alternative wetting and drying exhibit higher compressive strength as compared to that of concrete produced by replacing cement by unwashed red mud.
7. Tensile strength of concrete produced by replacement of cement by unwashed red mud and when subjected to alternative wetting and drying goes on increasing up to 10% replacement level.
8. Tensile strength of concrete produced by replacement of cement by washed red mud and when subjected to alternative wetting and drying goes on increasing up to 10% replacement level.
9. concrete produced by replacing cement by washed red mud when subjected to alternative wetting and drying show higher tensile strength as compared to that of concrete produced by replacing cement by unwashed red mud. This is true for all replacement level.
10. Flexural strength of concrete produced by replacement of cement by unwashed red mud and when subjected to alternative wetting and drying goes on increasing up to 10% replacement level.
11. Flexural strength of concrete produced by replacement of cement by washed red mud and when subjected to alternative wetting and drying goes on increasing up to 10% replacement level.
12. Concrete produced by replacing cement by washed red mud and when subjected to alternative wetting and drying exhibit higher flexural strength as compared to that of concrete produced by replacing cement by unwashed red mud.
13. Shear strength of concrete produced by replacement of cement by unwashed red mud and when subjected to alternative wetting and drying goes on increasing up to 10% replacement level.
14. Shear strength of concrete produced by replacement of cement by washed red mud and when subjected to alternative wetting and drying goes on increasing up to 10% replacement level.
15. Concrete produced by replacing cement by washed red mud and when subjected to alternative wetting and drying exhibit higher shear strength as compared to that of concrete produced by replacing cement by unwashed red mud.

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