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RESEARCH ARTICLE

EFFECT OF WASTE MINES REJECT IN CEMENT MANUFACTURING

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ABSTRACT

The environmental and economic concern is the biggest challenge concrete industry is facing. Advancement in utilization of wastes in concrete as a mixture reduces pollutants in environment and maximizes usage of natural resources(Shreekantet al., 2016). During the production of cement CO^2 is produced from clinkerizationwhich causes global warming (Andrew, 2018). By reducing clinker consumption environment can be protected(https://www.wbcsdcement.org). An attempt was made to partially replace the clinker with waste material Quarry dust with an aim not to lose the strength far from original concrete mix. From the observations of test results, clinker can be replaced with 15% of quarry dust in concrete. The physical and mechanical properties of materials used in concrete were investigated. For each replacement cubes were casted for measuring 7days and 28days compressive strength. The results have been discussed. Here mine's screen reject is used for partial replacement of clinker in cement manufacturing for studying the strength property of concrete. The aim of the experiment is to find the maximum content of mine's screen reject partial replacement of clinker without compromising with the quality and strength of concrete.

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INTRODUCTION

Concrete is an extraordinary and key structural material in the human history and is an artificial conglomerate stone made essentially of Portland cement, water, and aggregates. Concrete science is a multidisciplinary area of research offers the opportunity to enhance the understanding of concrete behavior, to engineer its properties and to lower production and ecological cost of construction materials (Lehne and Preston, 2018). Portland cement is the most important component of concrete and also most important binding materials in terms of quantity produced (Singh *et al.*, 2009). But cement manufacturing is one of the largest energy consuming unit of Industrial sector. It requires a huge amount of energy for clinkerization process which it derived from relying on conventional non-renewable fuels that are depleting on an alarming rate due to their overexploitation. For the production of Portland cement clinker, the average theoretical energy needed is 1750 kJ/kg. Similarly due to the growing awareness of Global Warming and air pollution effects, the regulatory bodies have enacted stringent norm on industries to limit and suppress their pollution contribution. Clinkerization emits out CO_2 gas excessively which is a major culprit for greenhouse effect & global warming and need to curb with deliberate efforts.

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Apart from high energy consumption, cement industry emits 7-10% CO_2. This carbon dioxide is emitted from the thermal decomposition of the limestone, combustion of fuels in the kiln as well as from power generation. Essentially there are number of ways to reduce CO_2 emissions and energy consumption from cement manufacture. The most obvious measure is to replace cement clinker with some low cost materials to make blended or composite cements. Another issue which cement industries are facing is improper handling and disposal of solid waste i.e. mine's screen reject which is consistently piling on the heads of mines as a challenge to dispose and manage. The use of quarry dust in concrete is desirable because of its benefits such as useful disposal of by products, reduction of river sand consumption as well as increasing the strength parameters and increasing the workability of concrete. Continuous generation of wastes from industrial by--products and agricultural residue, create acute environmental problems both in terms of their Treatment anddisposal. The construction industry has been identified as one that absorbs the majority of such materials as filler in concrete & appropriate utilization of these materials brings ecological and economic benefit. Mine's Screen Reject a by-product of stone crushing has been proposed as an alternative to sand that gives additional benefit to concrete. Quarry dust is used to increase the strength of concrete over concrete made with equal quantities of sand. Quarry dust has been used for different activities in the construction industry such as in road construction and manufacture of building materials such as light weight aggregates, bricks and tiles. High percentage of dust in the aggregate increases the fineness and the total surface area of aggregate particles. In this paper we have done the research on utilizing the Mine's screen reject which is a waste obtained from the stone crushing unit as a partial replacement of clinker for cement manufacturing. It accounts 25% of the final product from stone crushing unit. The mine's screen reject can cause significant environmental pollution when released directly into environment. To reduce the impact of the screen reject on environment and human being, the waste can be used either to produce new products or as process improviser in cement. Reuse of screen reject can save the natural resources and minimize environmental damage to achieve our goal towards sustainable development and solid waste management. Here mines screen reject is used for partial replacement of clinker to produce cement. The percentages of mine's screen reject for partial replacement are 0,5%, 10%, 15%. M15, M20, M25 grade. Concrete cubes of 150x150x150mm size were cast for conducting compressive strength test. From the experimental studies 15% of partial replacement of concrete with mine's screen rejects improved strength of cement.

EXPERIMENTS

MATERIALS AND METHODS

Clinker, Waste mines reject and gypsumwas used. Clinker, waste screen mines reject and gyspum was obtained from JK LAKSHMI CEMENT LTD, Sirohi, Rajasthan, India., Standard sand (Ennor) (IS- 650) was procured from Tamil Nadu. India. The compositions of clinker, waste mines reject and gypsum are reported in Table 1 .Crushed sand and aggregate were used locally for manufacturing the different grade of concrete.

Figure 1. Clinker, Gypsum and Reject Used during the study

Table 1. Chemical composition of Clinker/Waste mines screen reject and gypsum

Parameters	Clinker	Mine's screen reject	Mixed gypsum
LOI %	0.46	26.17	20.03
SiO_2 %	21.81	21.23	20.13
Al_2O_3 %	5.67	8.04	7.27
Fe_2O_3 %	3.92	3.97	1.60
CaO %	64.12	34.98	31.01
MgO %	2.35	1.71	1.30
Na_2O %	0.33	0.27	0.55
K_2O %	0.84	0.69	0.96
SO_3 %	1.45	0.83	22.98
$CaSO_4.2H_2O$ %	-	0.014	0.021

Experiment

Mixed Proportion of different weigh ratio of Clinker, Mines Screen Reject and Gypsum for M 15, M 20, M 25 Grades concrete with partial replacement of clinker with mines screen reject (produced Cement) are defined in Table 2.

Table 2.

Grade Of Concrete	Weight Ratio (C:FA:CA)	Water Cement Ratio
M-15	1 : 1.92 : 2.84	0.60
M-20	1 : 1.53 : 2.32	0.50
M-25	1 : 1.3 : 2.29	0.45

C: Cement, FA: Fine Aggregate, CA: Coarse Aggregate

Preparation of concrete

The concrete mix of grade M 15, M 20 and M 25 was made as per IS 10262. The concrete design mix proportions are given in Table 2. Composition of different mixes is given in Table 1.Tilting drum mixer was used to mix concrete. The mixing was continued till the resulting concrete was uniform in appearance. The mould of cast iron of size 150 mm x 150 mm x 150mm was used. Casting was done in such a way so that no water escaped from the joints of mould during the filling and compaction of concrete. Mould oil was applied between the joints of the mould to prevent escaping of water. To prevent adhesion of the concrete to the interior surfaces of the assembled mould, a thin layer of mould oil was also applied on the Interior surfaces of mould. Compaction of concrete was done by using tamping bar of 16 mm diameter, 0.6 m long. Together fully compacted concrete cube, concrete was filled into the mould in three different layer sand number of strokes was 35 per layer The strokes of the bar were distributed in a uniform manner over the cross-section of the mould and covered the mould with a glass or metal plate to prevent evaporation. After 24 hours, the specimen was remoulded and kept in water tank for curing.

Table 3. Test results of 7 days compressive strength, (N/mm2) of M 15, M20, M 25 Grades concrete with Partial replacement of clinker with mines screen reject (produced Cement)

% Mines Screen Reject	M-15	M-20	M-25
0 (Control)	17.3	23.0	25.9
5 (Mix-1)	17.0	22.5	24.5
10 (Mix-2)	16.5	21.2	23.9
15 (Mix-3)	15.5	20.4	23.2

Slump Measurements

The slump of the concrete was determined as per IS 1199 standard. The slump cone was filled with fresh concrete in three different layers. Each layer was tamped 25 times using a bullet nosed metal rod of 610 mm long and16 mm in diameter. After completely filling the cone, extra concrete was removed and concrete surface was levelled. The mould was removed vertically upwards and the concrete cone subsided. This subsidence was termed as slump of concrete and was measured to the nearest of 10 mm.

Table 4. Slump (mm)

Time (Minutes)	Control	MIX-1	MIX-2	MIX-3
0	0	Collapse	Collapse	Collapse
60	60	180	Collapse	Collapse
120	120	165	175	180

Compressive strength

Each mix was placed in separate cubical mould of size 150 mm x 150 mm x 150 mm. The moulds were removed after 24 hours and concrete cubes were stored in water at 27^{o}C for curing. The cubes were taken out from the water prior to testing. The compressive strengths were determined for 3 cubes at 3, 7 and 28 days as per IS 4031.

Table 5. Test results of 28 days compressive strength (N/mm2) of M 15, M20, M 25 Grade concrete with partial replacement of clinker with mines screen reject (produced Cement)

% Mines Screen Reject	M-15	M-20	M-25
0 (Control)	23.5	31.2	35.5
5 (Mix-1)	23.0	30.5	34.0
10 (Mix-2)	22.3	29.2	33.5
15 (Mix-3)	21.0	28.0	33.0

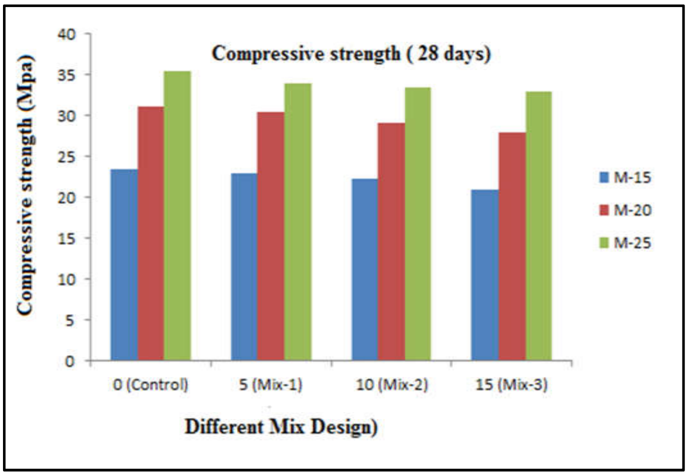

Figure 2. Compressive strength of 28 Days (Different Mixes)

1.2.1Flexural Strength

To conduct the flexural strength test as per BS 1881-118, beam samples of size 500 mm×100 mm×100mm were cast and cured in water for 7 and 28 days. For each mix proportion, three similar samples were prepared. Freshly mixed concrete was filled in three layers in beam moulds. Each layer was compacted manually by giving 150 strokes using a 25mm diameter steel tamping rod. The hardened beams were placed on the automatic universal testing machine after 7 and 28 days curing. Two additional loading rollers were placed on the top of the beam as shown in Fig.2. The load at a rate of 200 m/s was applied without shock. To calculate the flexural strength of beam, the following formula was used:

21 2*plfdd*□

where p= breaking load(N), d1 and d2= lateral dimensions of cross section(in mm)

Table 6. (Flexural Strength)

Days	Control	MIX-1	MIX-2	MIX-3
7 Days	3.95	4.6	4.9	5.4
28 Days	6.4	6.8	6.9	7.3

Water permeability

Water permeability test was carried out to measure passage of water in the concrete test specimen under pressure as per DIN 1048 part 5. A test specimen, cylindrical in shape, 200 mm in diameter and 120 mm height was cast from the fresh concrete just like a test cube for compressive strength measurement. The test specimen was wet cured for 28 days. After 28 days of curing, test specimen was fitted in the machine and a pressure of 1 bar for 48 hours followed by 3 bar for 24 hours and then 7 bar for 24 hours were applied as per requirement of DIN 1048 part 5. The specimen was splited into two halves. Penetration of water was measured. The maximum value of water penetration was the permeability of concrete.

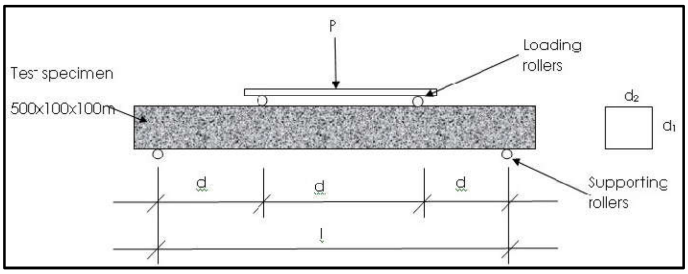

Figure 3. Set up for Flexural strength test

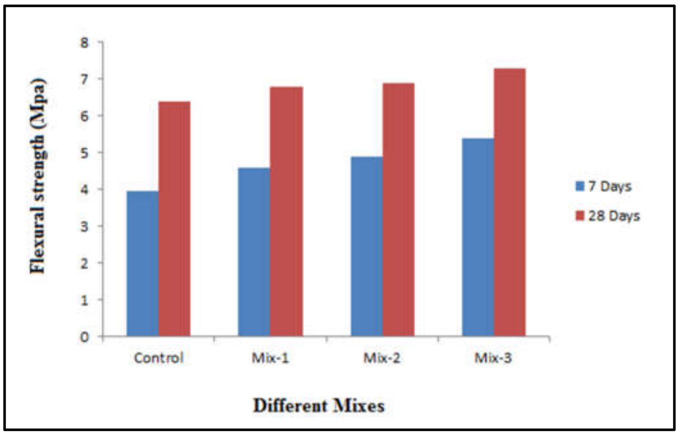

Figure 4. Flexural strength of different Mixes

Table 7. (Water permeability)

Control	13 mm
MIX-1	5.6 Mm
MIX-2	4.5 mm
MIX-3	3.7 mm

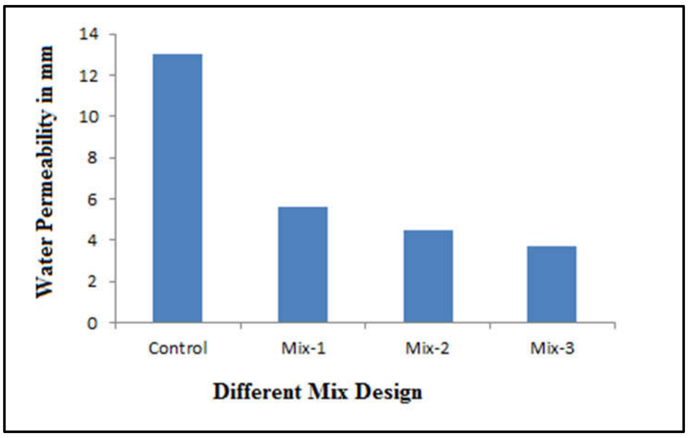

Figure 5. Water permeability of different mixes

Rapid Chloride Penetration Test

In rapid chloride ion permeability test as per ASTM C 1202, specimens used were in the cylindrical form (diameter 100 mm). Test values were normalized using the ratio of the standard to the actual cross-sectional areas and kept in the apparatus (Fig.3). One end of the specimen was exposed to NaCl whereas the other end to NaOH solutions. A potential of 60V was applied across the specimen and the current was measured for 6 hour after an interval of 30 minutes. Due to chloride ion penetration into the concrete, the conductivity and current increased to some extent. The total charge passing through the specimen (in Coulombs) was calculated and was found to be high at the completion of the test, indicating higher permeability.

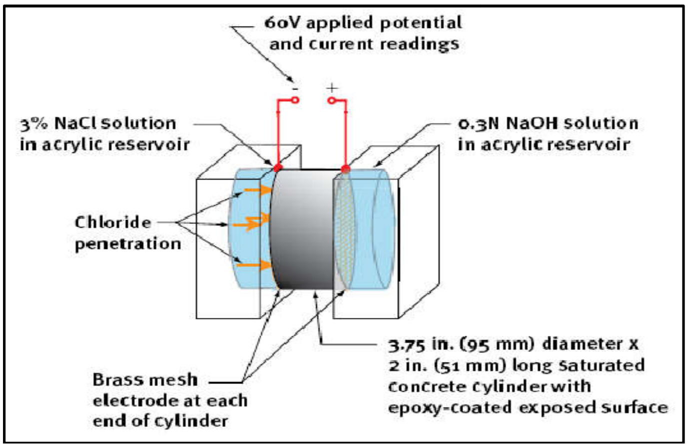

Figure 6. Rapid Chloride Ion Permeability Apparatus

Table 8. RCPT Test

Control	Mix-1	Mix-2	Mix-4
890	832	806	765

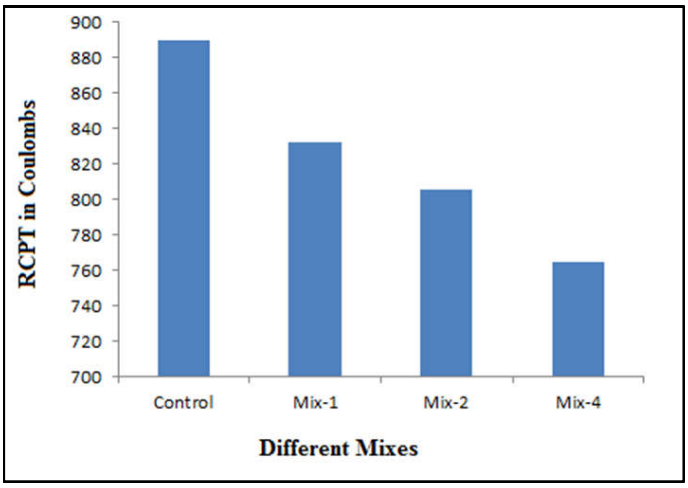

Figure 7. RCPT of different mixes

RESULTS AND DISCUSSION

In order to determine the appropriate dose of waste mines reject, compressive strength of concrete at 28days of hydration was determined in the presence of 0,10 and15wt % waste mines reject (Figure 2).The results showed that 15wt % mines reject gave most reasonable value. Slump values of all the mixes are given in Table 4. The results of slump test showed that all the mixes were in workable condition for 2 h.The change in compressive strengths with time are given in Table 2. It appears that use of 15% waste mines present in the concrete is responsible forimproved workability and low early strength (may be up to 28 days) 25 . It is well establishedthat during hydration of PC, Ca(OH)2 is formed which after 7 days react with pozzolans togive additional amounts of calcium silicate hydrate is given below.

C3S + 6H □□C3S2H3 + 3Ca(OH)2 (1)

Ca(OH)2 + (SiO2 + Al2O3) □□C3S2H3 + Other components (2)

15 % waste mines reacts with calcium hydroxide (free lime), a byproduct of thecement hydration process and converts it into hydrates of calcium aluminates and calcium alumino silicates. Hardened PC contains a distribution of pore sizes depending on the initial water-to-cement ratio (w/c) and the degree of cement hydration. The pores in cement-based materials consist of four types of pores: (a) gel pores (radius-0.5–10 nm), (b) capillary pores(radius-5 to 5000 nm), (c) macro pores due to deliberately entrained air and (d) macro pores due to inadequate compaction. In general permeability of concrete is reduced in the presence15 % waste mines because of reduction of pores in cement paste. RCT also show less for adding 15 % waste mines, which shows much durable concrete. Flexural strength also increased in 15 % waste mines mix design, which is useful for infra concrete.

CONCLUSION

Global warning and energy crisis & emission of green gases from industrial process and its adverse effect on climate has changed the mind set of people. Use of more and more environment friendly material and industrials wastes like quarry dust in construction industry is of paramount importance. A number of studies have been conducted concerning the protection of natural resources, prevention of environmental pollution and contribution to the economy by using the waste material. Attempts are being made to replace a part of Portland cement by suitable industrials wastes to minimise the emission of CO_2 pollution and at the same time to improve the quality of cements.Mines Screen Reject creates remarkable problem for environment so it has been used this reject material in cement manufacturing and found good results during my studies. The materials were blended with cement in various ratios, trying to find appropriate quality cements without compromising of cement quality. With this experimental test and results it would like to conclude:

- Based on experimental investigation, it is found that quarry dust can be used as an alternative material to the clinker.
- Clinker can be replaced with quarry dust up to 15% without much loss in compressive strength.
- Considerable decrease in compressive strength was observed from 15% cement replaced with quarry dust.
- 15% cement replaced with quarry dust can be used for plastering, flooring, repairing and tile fixing work.
- The physical and chemical properties of quarry dust satisfy the requirements of the Clinker.
- It is found that the quarry dust improves the mechanical properties of concrete.
- Usage of quarry dust also reduces the cost of concrete because it is a waste material from quarries.
- It also reduces the problems of disposal hence provide a sustainable approach to solid waste management
- The replacement of the clinker with quarry dust decreases the workability of the concrete due to absorption of the water by quarry dust.

- The ideal percentage of quarry dust as partial replacement of clinker is 15%.
- With increase in quarry dust content, percentage water absorption increases.
- With increase in quarry dust content, percentage water absorption increases.
- With increase in quarry dust content, average weight decreases making quarry dust concrete light weight.
- Workability of concrete mix decreases with increase in quarry dust content.
- Use of quarry dust in cement manufacturing can prove to be economical as it is non useful waste and free of cost.
- Use of quarry dust in cement manufacturing will eradicate the disposal problem of quarry dust and prove to be environment friendly thus paving way for greener concrete.
- Use of quarry dust in cement manufacturing will preserve natural resources particularly river sand and thus make concrete construction industry sustainable.

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