THE PROPERTIES OF CONCRETEIN CORPORATING RED SAND AS FINEAGGREGATE

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ABSTRACT

The aggregate comprises a substantial portion of concrete. Including coarse and fine aggregates it is normally obtained from natural sources. Fine aggregate in India is usually extracted from River. As the demand for concrete production increases, more natural sand is needed. The need for fine aggregate should be addressed in an environmentally friendly manner, considering the diminishing sources of natural sand. Various industrial by-products, such as fly ash, ground granulated blast-furnace slag and silica fume, have been used in concrete to improve its properties. This also enables any environmental issues associated with their disposal. Another material that is available in large quantities and requiring alternative methods of disposal is the Bauxite Reside (Red Sand) from the Bayer process used to extract alumina from bauxite. Enormous quantity of Red Sand is generated worldwide every year posing a very serious and alarming environmental problem. Hence an investigation was carried out to establish its potential utilization as a sand replacement material in concrete. In addition to fresh properties of concrete containing Red Sand up to 100% by mass of Portland cement, mechanical and durability properties were determined. These properties indicated that Red Sand can be used to replace natural sand up to 100% by mass of cement to improve the properties of concrete without detrimentally affecting their physical properties. Combining these beneficial effects with environmental remediation applications, it can be concluded that there are specific applications where concretes containing Red Sand could be used.

Keywords: Bauxite Residue, Red Sand, Seawater neutralization, Utilization.

INTRODUCTION

CONCRETE

Concrete is the most commonly used construction material, and the demand for it will increase as the demand for infrastructure development increases. Unfortunately, Ordinary Portland Cement (OPC) production depletes significant amounts of natural resources as it is a high energy-intensive construction material to produce, third only after the production of steel and aluminium. Furthermore, natural aggregate constitutes a substantial portion of traditional concrete. The natural source of coarse aggregate is crushed rock; and fine aggregate is naturally extracted from sand quarries.

The production of one tonne of OPC also releases one tonne of carbon dioxide into the atmosphere. The worldwide cement industry is responsible for about 7% (and rising) of the world's total carbon dioxide generation. Apart from environmental issues associated with the concrete industry, traditional concrete is not very durable in harsh environments, such as exposure to freezing weather, sea water or sulphuric soils. Thus, it is essential to find methods to increase the durability of traditional concrete by using appropriate replacements for concrete constituents; e.g. aggregate. It is now believed that using more durable and less energy intensive construction materials is inevitable for the construction industry.

Importance

It is estimated that the present consumption of concrete in the world is of the order of 10 billion tonnes (12 billion tons) every year. Humans consume no material except water in such tremendous quantities. The ability of concrete to withstand the action of water without serious deterioration makes it an ideal material for building structures to control, store, and transport water. The ease with which structural concrete elements can be formed into a variety of shapes and sizes. This is because freshly made concrete is of a plastic consistency, which permits the material to flow into prefabricated formwork. After a number of hours, the formwork can be removed for reuse when the concrete has solidified and hardened to a strong mass. It is usually the cheapest and most readily available material on the job.

COMPONENTS OF MODERN CONCRETE

Concrete is a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregate. In hydraulic cement concrete, the binder is formed from a mixture of hydraulic cement and water.

Portland Cement

Portland cement is produced by mixing ground limestone, clay or shale, sand and iron ore. This mixture is heated in a rotary kiln to temperatures as high as 1,600 degrees Celsius. The heating process causes the materials to break down and recombine into new compounds that can react with water in a crystallization process called hydration .Cement is a finely pulverized, dry, material that by itself is not a binder but develops the binding property as a result of hydration. A cement is called ***hydraulic*** when the hydration products are stable in an aqueous environment.

River Sand

Sand has become a very important mineral for the expansion of society. Sand is a naturally occurring granular material composed of finely divided rock and mineral particles.

River sand is one of the world‘s most plentiful resources (perhaps as much as 20% of the Earth‘s crust is sand) and has the ability to replenish itself. River sand is vital for human well-being & for sustenance of rivers.

As a resource, sand by definition is ‗a loose, incoherent mass of mineral materials and is a product of natural processes.' These processes are the disintegration of rocks and corals under the influence of weathering and abrasion. When sand is freshly formed the particles are usually angular and sharply pointed but they grow gradually smaller and more rounded as they become constantly worn down by the wind or water.

Importance of river sand in construction

In terms of particle size as used by geologists, sand particles range in diameter from 0.0625 mm (or ¹⁄16 mm) to 2 mm. The most common constituent of sand, in inland continental settings and non-tropical coastal settings, is silica (silicon dioxide, or SiO2), usually in the form of quartz, which, because of its chemical inertness and considerable hardness, is the most common mineral resistant to weathering.

Sand has become a very important mineral for our society due to its many uses. It can be used for making concrete, filling roads, building sites, brick-making, making glass, sandpapers, reclamations, and etc. It acts as a buffer against strong tidal waves and storm surges by reducing their impacts as they reach the shoreline.

Red Sand

Bauxite Residue

As the world largest producer of alumina, Australia generates large amounts of bauxite residue each year. Approximately 15 million tons of bauxite residue are produced by three refineries in Western Australia. Red sand- the coarse fraction of this residue-makes up to one-half of the bauxite residue.

In Tamilnadu MALCO Madras Aluminium company (MALCO) operates in Mettur dam, Salem. MALCO produces about 37% of INDIA's alumina. MALCO extracts alumina from bauxite ore at refinery in Tamilnadu located at Yercaud. They produce about 6 million tonnes of alumina each year which is 5% of world production. Aluminum is produced from alumina. Aluminium is a useful metal due to the range of properties it possesses. It has sufficient strength while being lightweight. It is also nontoxic and non-magnetic. It is very corrosion resistant; a workable metal; conducts electricity and reflects heat and light. The aluminium element comprises around 8 percent of the elements in the earth's soils and rocks, but is only found in chemical compounds in nature. Alumina is in turn produced from bauxite ore using the Bayer process, the widely used method for extraction of alumina.

the Bayer process was discovered by an Austrian chemist named Karl Bayer in 1887. The Bayer process used by alumina refineries involves four main stepsdigestion, clarification, precipitation and calcination as follows (Queensland Alumina Limited 2006)

Step 1: Digestion – Dissolving bauxite's alumina content

To turn bauxite into alumina, firstly the ore is ground and mixed with lime and caustic soda, then this slurry is pumped into high-pressure autoclaves or reactors and heated to form sodium aluminate solution. The reactions are:

$$2NaOH + Al_2O_3.3H_2O\ 2NaAlO_2 + 4H_2O$$

Equation 1-1, gives the1st Stage of Bauxite Digestion

$$2NaOH + Al_2O_3.H_2O\ 2NaAlO_2 + 2H_2O$$

Equation 1-1-1, gives the2nd Stage Bauxite Digestion

Step 2: Clarification and caustification – Settling out undissolved impurities

Settling allows the removal of waste tailings. Flocculants can be added to improve the rate of mud settling. This is then washed with slacked lime to allow the removal of insoluble carbonate with the mud. The reaction is:

$$Na_2CO_3 + Ca(OH)_2\ CaCO_3 + 2NaOH \quad (1.2)$$

Equation 1-2, gives Caustification

Step 3: Precipitation – Forming alumina crystals

The aluminium oxide which is

dissolved by the caustic soda is precipitated out of the pregnant liquor. Precipitation of crystals from the liquor allows alumina to be recovered. Alumina precipitates as the trihydrate ($Al_2O_3.3H_2O$), which is the reverse of the digestion of trihydrate. The reaction is:

$2NaAlO_2 + 4H_2O\ Al_2O_3.3H_2O + 2\ NaOH$ (1.3)

Equation 1-3, gives Precipitation

Step 4: Calcination – High temperature drying of alumina

The aluminium hydrate (Al2O3.3H2O) is then washed to remove the process liquor and caustic. This material is then calcined in a fluidised bed calciner to remove both free moisture and chemically bonded water at temperatures around 950-1100° C. Residual bauxite tailings refer to the bauxite waste removed after the digestion and clarification by filtration and decantation.

Bauxite residue can be later separated into two fractions, according to size.

The coarse fraction or ―red sand‖ has a particle size in excess of 90μm. The other portion, ―red mud‖ constitutes approximately half of the residue.

Disposal of this huge amount of residue requires vast areas of land. The disposal process should address environmental issues considering the fine particles of red sand and prevent the residue from contaminating the ground water and soil. The other challenges are:

- The high alkalinity of the generated residue
- The costs associated with monitoring and storage
- Attempts have been made for disposing bauxite residue in an environmentally friendly manner.

LITERATURE REVIEW

BAUXITE RESIDUE

SuchitaRai,K.L.Wasewar,J.Mukhopadhyay, Chang KyooYoo and HasanUslu (2011),

"Neutralization and utilization of red mud for its better wastemanagement", The worldwide alumina production is around 58 million tonnes in whichIndia count for 2.7 million tonnes . The Indian aluminium sector is characterised bylarge integrated players like Hindalco and National Aluminium Company, and the newly started Vedanta Alumina Ltd. The other producers of alumina includeIndian Aluminium Company, now merged with Hindustan Aluminium Company, Bharat Aluminium(BALCO)andMadrasAluminium (MALCO) the erstwhile PSUs, which have been acquired by Sterlite Industries.

Consequently, there are only three main primary metal producers in the sector namely BALCO, National Aluminium Company (NALCO) and Hindalco.

Glenister DJ, Thornber MR (1985),

"Alkalinity of red mud and itsapplications for management of acid wastes", Neutralization of red mud will help toreduce the environmental impact caused due to its storage and also lessen significantly the ongoing management of the deposits after closure. It will also open opportunities for re-use of the residue which to date have been prevented because of the high pH. As per the Guidelines of Australian and New Zealand Environment and Conservation Council (ANZEX) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), the liquor being strongly alkaline with a high pH, requires neutralization to a pH below 9 with an optimum value of 8.5-8.9 before becoming environmentally benign. Neutralization of red mud to pH around 8.0 is optimal because the chemically adsorbed Na is released, alkaline buffer minerals are neutralized and toxic metals are insoluble at this pH.

Palmer Sara J, Nothling M, Bakon K, Frost R (2010),"Trends in red mud utilization-A Review", when seawater is added to caustic red mud, the pH of the mixture isreduced causing hydroxide, carbonate or hydroxyl carbonate minerals to be precipitated. Average seawater contains 965 gm of water and 35 gm of salts. The concentration of various salt ions in seawater is 55% Chlorine (Cl^-), 30.6% sodium (Na^+), 7.7% sulphate (SO_4^{-2}), 3.65% magnesium (Mg^{2+}), 1.17% calcium (Ca^{2+}), 1.13% potassium (K^+) and 0.7% others.

McConchie D, Clark M, Hanahan C (2000),

"Theuse of seawater neutralized bauxite refinery residues in the management of acid sulphate soils, sulphidic mine tailings and acid mine drainage", Seawater neutralization does noteliminate hydroxide from the system but converts the readily soluble, strongly caustic wastes into less soluble, weakly alkaline solids. The carbonate and bicarbonate alkalinity of the waste is removed primarily by reaction with calcium to form aragonite and calcite.

Virotec (2003),

"Dealing with red mud-By-product of the Bayer processfor refining

aluminium", the neutralizing effect of the calcium and the magnesium ions isinitially large but decreases rapidly as pH 8.5 is approached and calcium and magnesium carbonates precipitate. Neutralization is considered to be complete when the liquid that can be separated from the treated red mud has a pH less than 9.0 and a total alkalinity less than 200 mg/l and decant of seawater neutralized red mud can be safely discharged to the marine environment. The composition and characteristics of bauxite residue vary in different parts of the world. This is due to both the differences in chemical and physical properties of bauxite as well as differences in the processing of the residue. As such, research performed on red sand not from the Darling Range is generally not applicable.

BAUXITE RESIDUE IN CONCRETE

Wahyuni (2005),

"Sustainable use of residual bauxite tailings sand (red sand) in concrete" assessed the effects of substituting natural yellow sand with Red Sand(Unprocessed Red Sand-URS) on the low strength concrete. She also looked at using different percentages of fly ash as cement replacement. It was found that concrete using Red Sand as fine aggregate had a low workability in comparison to an equivalent mix using natural sand. This low workability resulted in poor compaction of the concrete, adversely affecting the durability. Specifically the concrete had high water permeability and chloride diffusion. In terms of strength, it was found that the mixes performed similarly to concrete using natural sand as fine aggregate. Research by Wahyuni suggests that using URS in concrete may incur workability issues. Furthermore the use of URS does not add any benefit in terms of strength or durability to the concrete.

Kavehsoltaninaveh (2008),

"The Properties Of Geo Polymer ConcreteIncorporating Red Sand As Fine Aggregate" also utilize the red sand in geopolymerconcrete. This thesis concluded that the moisture content of red sand prior to use has a great inf luence on the workability of geopolymer concrete mixture: in order to achieve the desired workability, red sand must be in SSD condition.sand has been found to reduce the compressive strength of geopolymer concrete.

MajidGhiafehDavood(2008),

"Long Term Stability Of Concrete Made

From Red Sand" the main objective of this research was to investigate the possibility ofusing the coarse fraction of bauxite residue (red sand) as a fine aggregate substitution in concrete mix design suitable for marine environment. The opportunity to achieve low strength concrete using this potential resource for construction applications was also investigated. The tests for alkali aggregate reactivity showed that the Red Sands were ―non-reactive‖, being significantly less reactive than the Natural Yellow Sand. This suggests that alkali silica reaction will not be a problem if the aggregate

PeerapongJitsangiam (2008),

"Sustainable Use of a Bauxite Residue (redsand) in terms of Roadway Materials" Stabilized red sand is a viable option for use as a base course material in road construction in Western Australia. The stabilized red sand exhibits resilient modulus and permanent deformation characteristics that exceed that of the commonly used material for road bases.

Barbhuiya S.A, Basheer P.A.M., Clark M.W., Rankin G.I.B (2011),

"Effects of seawater-neutralized bauxite refinery residue on properties of concrete",fresh properties of concrete containing seawater-neutralized BRR up to 20% by mass of Portland cement, mechanical and durability properties were determined. These properties indicated that seawater-neutralized BRR can be used to replace natural sand up to 10% by mass of cement to improve the durability properties of concrete without detrimentally affecting their physical properties. Combining these beneficial effects with environmental remediation applications, it can be concluded that there are specific applications where concretes containing seawater-neutralised BRR could be used.

RESULTS

INTRODUCTION

Results presented in this chapter consist of the control mixes plus mixes that incorporated red sand. Results of mechanical properties of the concrete specimens, including compressive, indirect tensile, the durability testing result (water absorption) are presented and discussed. Test results for various mix are presented and discussed.

All bauxite residue derivatives are characterized in terms of chemical analysis, physical properties, mineralogical composition, alkali aggregate reaction, aggregate soundness and other properties. The results obtained from compressive testing for mixes 2-6 (mixes with high proportions of red sand) have been included, the excess water demand the fine red sand concrete mixes required, and hence significant increases in water cement ratio.

Slump Test

Table Workability Experienced of Concrete Mixes

Mix	M1	M2	M3	M4	M5	M6
Average Slump	**85**	**80**	**50**	**65**	**50**	**60**

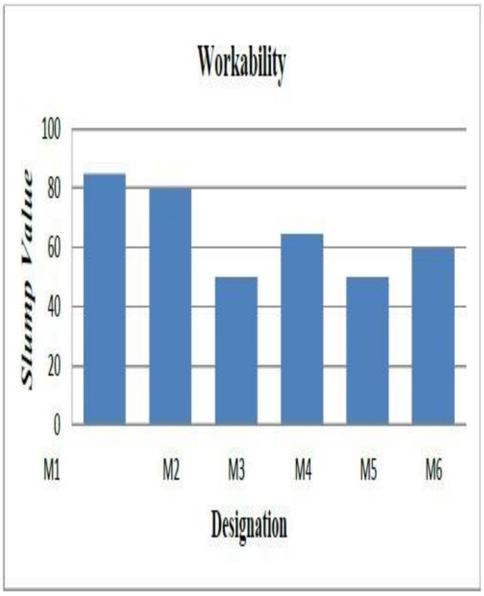

Figure WORKKABILITY OF VARIOUS MIXES

COMPRESSIVE STRENGTH

Table Detail of compressive strength of mixes

RS content %	Mix designation	3 day N/mm²	7 day N/mm²	28 day N/mm²
0	**M1**	**24**	**30**	**35**
25	**M2**	**25**	**37.5**	**40**
50	**M3**	**28**	**39.5**	**45**
75	**M4**	**29.5**	**39.5**	**46**
100	**M5**	**32**	**40**	**54**
100	**M6**	**34**	**45**	**60.5**

In 3 days compressive strength of mix M2 is 0.01% higher than mix M1 and mix M3 is 0.03% higher than mix M2 and mix M4 is 0.015% higher than mix M3 and mix M5 is 0.025% higher than mix M4 and also mix M6 is 0.02 % higher than mix M5 but slump value of the mix is decreased when increasing the red sand content.

In 7 days compressive strength of

mix M2 is 0.075% higher than mix M1 and mix M3 is 0.02% higher than mix M2 and mix M4 and mix M3 got same strength and mix 5 is 0.005% higher than mix M4 and also mix M6 is 0.05 % higher than mix M5.

In 28 days compressive strength of mix M2 is 0.05% higher than mix 1 and mix M3 is also 0.05% higher than mix 2 and mix M4 is 0.01% higher than mix 3 and mix M5 is 0.08% higher than mix 4 and also mix M6 is 0.065 % higher than mix M5 but slump value of the mix is decreased when increasing the red sand content.

SPLIT TENSILE STRENGTH

The tensile strength of concrete is only a fraction of its compressive strength and it is often taken as zero in the design of concrete structures. Despite this there are situations where the ability of concrete to resist low tensile stresses is utilised. One example statedin Concrete Structures (Warner et al. 1998) is the ability of the tensile stress of concrete to control beam deflections ―where the tensile stresses contribute significantly to the overall beam stiffness‖. The tensile reinforcement in concrete does not actually start working until the concrete in that area cracks under tensile stresses, thus transferring the load to the steel. So while the tensile strength of concrete may be taken as zero in many design calculations for simplicity / conservativeness, in reality it does affect the behaviour of concrete structures.

Mixtures M1 to M6 were made with different percentages of red sand. For each mix, specimens were tested for compressive strength after 3, 7 and 28 days after casting. The average of three cylinder was taken as the mean split tensile strength. In 3 days split tensile strength of mix 1 and mix 2 is same but mix M3 is 0.0015% higher than mix M2 and mix M4 is 0.0007%higher than mix M3 and mix M5 is 0.0007% higher than mix M4 and also mix M6 is 0.0007 % higher than mix M5 but slump value of the mix is decreased when increasing the red sand content.

In 7 days compressive strength of mix M1, mix M2 is same and mix M5,mix M6 is also same, but mix 3 is 0.0008% higher than mix M2 and mix M4 is 0.0002% higher than mix M3 and mix M5 is 0.0005% higher than mix M5.

In 28 days compressive strength of mix M2 is 0.0035% higher than mix M1 and mix M3 is also 0.0007% higher than mix M2 and mix 4 is 0.0024% higher than mix M3 and mix 5 is 0.0103% higher than mix M4 and also mix M6 is 0.0077 % higher than mix M5 but slump value of the mix is decreased when increasing the red sand content. Finally it resulted that the mix M6 have higher split tensile strength when compare to the other mix M5.

Table Details of split tensile strength

RS content %	Mix designation	3 day N/mm²	7 day N/mm²	28 day N/mm²
0	**M1**	**2.68**	**3.39**	**3.54**
25	**M2**	**2.68**	**3.39**	**3.89**
50	**M3**	**2.83**	**3.47**	**3.96**
75	**M4**	**2.9**	**3.49**	**3.96**
100	**M5**	**2.97**	**3.54**	**4.10**
100	**M6**	**3.04**	**3.54**	**4.24**

Comparison of Split Tensile Strength For Various Mixes

SUMMARY AND CONCLUSION

GENERAL

With natural sand deposits the world over drying up, there is an acute need for a product that matches the properties of natural sand in concrete.

In the last 15 years, it has become clear that the availability of good quality natural sand is decreasing. With a few local exceptions, it seems to be a global trend. Existing natural sand deposits are being emptied at the same rate as urbanization and new deposits are located either underground, too close to already built-up areas or too far away from the areas where it is needed, that is, the towns and cities where the manufacturers of concrete are located.

ENVIRONMENTAL ISSUES

Environmental concerns are also being raised against uncontrolled extraction ofnatural sand. The arguments are mostly in regards to protecting riverbeds against erosion and the importance of having natural sand as a filter for ground water.

The above concerns, combined with issues of preserving areas of beauty, recreational value and biodiversity, are an integral part of the process of most local government agencies granting permission to aggregate producers across the world.

This is the situation for the construction industry today and most will agree that it will not change dramatically in the foreseeable future. Crushed aggregate is replacing natural sand and gravel in most countries.

ANALYSIS OF RESULT

The main objective of this research was to investigate the possibility of using the coarse fraction of bauxite residue (red sand) as a fine aggregate substitution in concrete mix design suitable for commercial environment. The opportunity to achieve low strength concrete using this potential resource for construction applications was also investigated.

The impact on concrete mix design and properties of manufactured concrete were evaluated with a series of laboratory standard tests. The tests conducted in this research were just a few of those possible for assessing the strength and durability behavior of concrete mixes. From the results obtained, the following conclusions are made:

- In order for satisfactory performance in a concrete incorporating Sea water Neutralized Red Sand gave target compressive strength results in excess of the Indian standard requirement, that is 20 MPa, and they were capable of producing adequate compressive strengths for a M20 grade concrete.In comparison to concrete using Natural Sand, concrete using Red Sand achieved similar strength characteristics greater than that of the control mix. Partially replaced red sand by the weight of natural sand also showed improved strength in the tests.
- In the case of Red sand replaced concrete mixes (M2, M3, M4, M5, M6), the slump recorded slightly lower values than desirable, especially with the Natural Sand mixes(M1).
- Concrete using Sea water Neutralized Red Sand also showed similar strength characteristics, there were some durability concerns for Sea water Neutralized Red Sand mixes with 12 mm, 10 mm and graded coarse aggregate. The compressive strengths of Red Sand mixes were higher than that of Natural Sand. It seems the trends for all coarse aggregate were almost the same regardless of the fine aggregate used.

- Compressive strength of concrete increased with the increase in sand replacement with different replacement levels of red sand. However, at each replacement level of fine aggregate with red sand, an increase in strength was observed with the increase in age.

- Split Tensile Strength also showed an increase with increase in replacement levels of Red Sand with fine aggregate. Split Tensile Strength also increased with increase in age.

- In the case of M20 concrete mixes, all Red Sand mixes performed similarly better than the control mixes, however there were some concerns in regards to durability indicators.

- From the results obtained, it can be deduced that Red Sand used in M20 grade concrete can achieve increased strengths to an equivalent mix using Natural Sand.

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