THE PROPERTIES OF CONCRETEIN CORPORATING RED SAND AS FINE AGGREGATE

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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.

CONCRETE

Concrete is the most commonly used construction material, and the demand for it willincrease 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

Joseph Aspdin (1779-1835)patented the clay and limestone cement known as Portland cement in 1824.Joseph's son, William Aspdin‘skilnused to make the first genuine Portland cement. Portland cement was first used in the civil engineering project by Isambard Kingdom Brunel (1806-1859), as the lining of the Thames Tunnel.

Figure 1.1 Ordinary Portland Cement

While cement in one form or another has been around for centuries, the type we use was invented in 1824 in Britain. It was named Portland cement because it looked like the stone quarried on the Isle of Portland.

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.

The raw ingredients of Portland cement are iron ore, lime, alumina and silica. These are ground up and fired in a kiln to produce a clinker. After cooling, the clinker is very finery ground.

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 SiO_2), 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.

•Sand Constitutions

Sand is a naturally occurring granular material composed of finely divided rock and mineral particle

The composition of sand is highly variable, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz which because of its chemical inertness and considerable hardness, is the most common mineral resistant to weathering

Figure 1.2 River Sand

As per ISO 14688 grades sands are classified as fine, medium and coarse with ranges 0.063 mm to 0.2 mm, 0.25 mm to 0.50 mm and 0.63 mm to 2.0 mm respectively.

•Sand mining

Sand Mining is a coastal activity referring to the process of the actual removal of sand from the foreshore including rivers, streams and lakes

•Effects of Sand mining

Individuals and private companies are increasingly demanding sand for construction purposes and this has placed immense pressure on sand resources. It is a practice that is becoming an environmental issue as the demand for sand increases in industry and construction.

Sand mining is a direct and obvious cause of erosion, and also impacts the local wildlife. Disturbance of underwater and coastal sand causes turbidity in the water, which is harmful for such organisms as corals that need sunlight. It also destroys fisheries, causing problems for people who rely on fishing for their livelihoods. Erosion problems may worsen especially during severe storms and may also result in the alteration of our shorelines from streams or rivers upstream can reduce water quality for downstream users and poison aquatic life.

Geologists know that uncontrolled sand mining from the riverbed leads to the destruction of the entire river system. If sand and gravel is extracted in quantities higher than the capacity of the river to replenish them, it leads to changes in its channel form, physical habitats and food webs – the river‘s ecosystem. The removal of sand from the river bed increases the velocity of the flowing water.

Sand acts like a sponge, which helps in recharging the water table; its progressive depletion in the river is accompanied by sinking water tables in the nearby areas, adversely impacting people‘s daily lives, even their livelihood.

•Solution

Sand is required for development of Human being, but at the same time the threats posed due to sand mining can‘t be ignored. Hence decisive steps are to be taken & alternate solution to be found out for sand mining, without disturbing the environment. This problem is now solved to some extend by substituting or replacing river sand with Foundry sand, Quarry dust, mining waste(Iron, Bauxite,..) etc,…Further, adulterated sands, which is a mixture of sand from estuary and coastal land, also is freely used for the construction.

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.

Figure 1.3 Red Sand

The Bayer process was discovered by an Austrian chemist named Karl Bayer in 1887. The Bayer process used by alumina refineries involves four main steps digestion, 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:

$$2NaOH + Al_2O_3.3H_2O \; 2NaAlO_2 + 4H_2O \quad (1.1)$$

Equation 1-1, gives the1st Stage of Bauxite Digestion

$$2NaOH + Al_2O_3.H_2O \; 2NaAlO_2 + 2H_2O \quad (1.1.1)$$

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:

$Na_2CO_3 + Ca(OH)_2$ $CaCO_3 + 2NaOH$ (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 ($Al_2O_3.3H_2O$) 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.

PROPERTIES OF CONCRETE

When first mixed the water and cement constitute a paste which surrounds all the individual pieces of aggregate to make a plastic mixture. A chemical reaction called hydration takes place between the water and cement, and concrete normally changes from a plastic to a solid state in about 2 hours. Concrete continues to gain strength as it cures. Heat of hydration- is the heat given off during the chemical reaction as the cement hydrates

Figure 1.4 Hydration of Cement

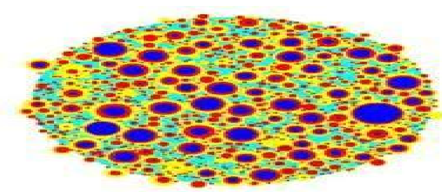

Image shown is a two-dimensional slice from a three-dimensional spherical computational volume. Unhydrated cement cores are dark blue. Inner C-S-H product is red. Outer C-S-H project is yellow. Water-filled space is light blue.

AIM OF THE RESEARCH

The aim of this thesis is to evaluate the properties of concrete mixtures made with red sand as a fine aggregate. Making workable, high strength and durable concrete containing red sand can lead to the usage of bauxite residue in the future and paves the way to gradually replacing conventional concrete with less energy-intensive construction materials. Therefore, identifying, testing and enhancing the mechanical and durability features of red sand concrete has been the main objective of this research.

SIGNIFICANCE

This project aims to reduce the impact of bauxite tailings on the environment, through investigating potential industrial applications for this by-product as a construction material. Successfully demonstrating that red sand concrete meets the relevant Indian Standards will effectively convert a byproduct into a valuable construction material. This would significantly reduce the amount of bauxite residue that requires disposal, storing and monitoring.

Furthermore, with the ever increasing demand for quality construction materials, materials such as natural sand are becoming scarse. If red sand can be shown to be an acceptable substitute for natural sand, it will provide valuable new material for the construction industry; and will improve the sustainability of construction operations by reducing the need to mine a natural resource.

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.

•More importantly, for application in severe environments, it offers improvements in performance for the durability characteristics(water absorption) assessed. Sea water neutralized Red Sand can also achieve similar strengths to traditional concrete and has good durability and a lack of workability when combined with a Red Sand.

•Physical and chemical properties of Red Sand indicate it has similar characteristics to Natural Sand.

•Based on the results of all of the marine grade concrete mixes, the indication is that Red Sand performs better as a replacement of fine aggregate.

As such, Red Sand showed ability to replace natural materials, when combined with a 10 mm coarse aggregate. Using Red Sand in low strength concrete showed that they do have potential to be used in industry and these material can be a viable sustainable solution to reduce Red Sand stockpiles.

FURTHER STUDIES

Further research is required to explore other aspects of Red Sand concrete. Because of the improved durability performance of Red Sand observed in this investigation, it is recommended that future research is focused on Red Sand for this application. The results presented in this thesis gave an indication of the strength (compressive and tensile) and durability characteristics (water absorption), however in order to enable Red Sand concrete to become accepted as a common construction material, the following experimental studies can be conducted in future with respect to Red Sand concrete-

•The effect of addition of red sand on the durability characteristics of commercial concrete.

•The effect of high temperature on the properties of M20 concrete with red sand.

•The effect of addition of red sand on the shrinkage and the creep properties of concrete.

•Behavior of Red Sand when combined with supplementary cementitious materials (SCM);

•Use of admixtures would be of value if deemed feasible.

•Economic viability of using Red Sand as a fine aggregate in marine grade Concrete.

•Finding an optimal mix by varying the water/cement ratio.

There are many long term effects that need to be assessed when considering a new aggregate for concrete, particularly one that originates from a waste product. Long term effects that need to be assessed are:

•An environmental impact statement should also be conducted. This would explore if there is any leaching from the standard mix design and any possible environmental impact.

•Effects of using Red Sand on the creep properties of the concrete as the creep results in this research hardly showed a clear trend.

•Fatigue tests in parallel to creep tests to show the suitability of concrete in severe condition;

•A second alkali aggregate reactivity test (different from the one performed in this investigation) as recommended by HB 79; and

•Potential long term reactions between Red Sand and steel reinforcement.

In modern concrete practice the use of admixtures and SCM‘s has become widespread, particularly in marine and other high performance concrete. To be commercially useful, Red Sand would have to be able to be used with admixtures and

SCM‘s. Investigation into the reaction of using these admixtures and SCM‘s with Red Sand need to be carried out. In particular the sands need to be trialed more comprehensively with water reducers so that the cement content of the concrete can be reduced to an economic level.

The scope of the commercial mixes should be extended as the driving force behind using Red Sand in industry is whether or not it can be done economically. An assessment needs to be made on whether or not Red Sand can be obtained at a cost that makes it viable in industry. In this assessment, consideration needs to be given to the offset in cost as a result of reduced admixture requirements. Since Red Sand is a bulk material, a large factor for consideration is the transport cost, thus while the sand may be economical to use in locations close to the stockpile areas, it may not be economical for locations some distance away.

The Red Sand should be trailed with a denser grading of coarse aggregate. The coarse aggregate grading used in this assessment was gap graded, with a large difference between the coarse aggregate and the fine aggregate. Trials with a coarse aggregate graded from 4 and 7 mm to 10, 14 and 20 mm should be assessed. The particle size distribution of the sands, particularly the Low Iron Sand, should be adjusted to find an optimal grading, perhaps with fewer fines, to conform to IS grading curves.

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