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Application of Industrial and Agricultural Waste for Sustainable Construction

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Abstract: ***General increase in accumulation of unmanaged agriculture and industrial waste in the world has been a major concern. Increase in industrial activities has lead to commensurate increase in the amount of waste. An effective way to deal with this increasing waste is to use this waste for sustainable construction of roads, buildings etc.***
Industrial by product waste like slag, sludge, fly ash etc and agricultural waste can be used as construction materials. This article summarizes the different applications of industrial and agro waste that can be practiced to make sustainable construction to optimize the work and also suggests various approach to ameliorate the processing of waste materials.
The main aim of research is to enhance environmental effectiveness and to implement a comprehensive construction management plan. More precisely this study presents how can we reuse the increasing waste materials in a good way for creating sustainable construction structures and reduce the amount of waste decomposition which will lead to ecofriendly environment.
Keywords: sustainable, construction, industrial, agriculture, waste, environment, materials.

I. INTRODUCTION

In the past few decades, due to prodigious increase in the modernization, tons and tons of waste is produced. Every year the whole world has to face the waste accumulation issue. Industrial factory and agriculture produces by products of waste like sludge, slag, fly ash, glass, rice husk ash, bagasse, cement dust etc.
handling this waste is a major enviromental problems as it causes air pollution in which the dust and other fine particles are released in the atmosphere, and spreads toxic chemicals like cadmium, lead, mercury, boron, arsenic, selenium, hydrogen compounds etc, which are later dumped in rivers, oceans and landfills.
Protection of nature has become a major concern from the enviromental point of view. Construction field is a prominent field in handling these waste to reuse them as construction materials. Researchers are working working on producing prominrnt and effective construction materials from waste produced.
Concrete is a very cheap and easy to produce material as it is obtained from about 8% of water, 12% of cement and almost 80% of aggregate. Aggregates and water are available naturally but cement is produced in factory pollutes the enviroment, by liberating 480 kg of CO_2 to produce $1m^3$ of concrete. To reduce the cumsumption of cement and aggregate, different materials obtained from waste are studied.
The cement industry emits almost 7% of CO_2 which is almost 1.6 billion tons of CO_2 into the atmosphere to produce concrete. Materials used in traditional construction like concrete, hollow and solid blocks, tiles etc are produced by the natural resources. This is resulting into the continuous reduction of natural resources and hence affecting and damaging the environment. As a result issue related to enviromental convervation hs risen in our society past few years. The authorities in public, political and social sector are paying more attention to environment issues to protect it.
Many investigators and researchers are working to find different ways to reuse the waste to make environment friendly sustainable material.
The demand and cost of construction materials is increasing day by day, as a result there is scarcity of raw materials, hence to save the natural resources having an alternative construction material is a global concern. A research to manufacture a sustainable and eco-friendly construction material is going on. The study presents various materials to be used in construction prepared from solid waste.

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Sr no.	Type of solid waste	Source details	Recycling and utilization potentials
1	Mineral waste	Mining waste tailing from gold, zinc, copper, iron, and aluminium industries	Fine and course light weight aggregates, bricks, tiles
2	Hazardous waste	Galvanizing waste, tannery waste, contaminated blasting materials, metallurgical residues, sludge from waste waster and water treatment plant	Cement, tiles, boards, bricks, ceramics
3	Non-hazardous waste	Lime stone waste, kiln dust, lime sludge, waste gypsum, broken glass and ceramics, marble processing residues	Hydraulic binder, bricks, blocks, cement clinder, fibrous gypsum boards, super-sulfated cement, gypsum plaster
4	Organic agro-waste	Saw mill waste, cotton stalk, vegetable residues, jute sisal, ground nut shell, baggage, rice, wheat straw, husk	Root sheets, bricks, reinforced composites, polymer composites, coir fiber, acid proof cement, wall panels, cement boards, particle boards, insulation boards
5	Inorganic industrial waste	Steel slag, construction debris, coal combustion residues, bauxite red mud	Fine and course aggregate, concrete, bricks, tiles, paints, blocks, cements, wood substitue products.

Table 1 : types of solid waste, there sourses and recycling and utilization potentials

II. MAJOR SOLID WASTE AND THEIR POTENTIAL USE IN CONSTRUCTION MATERIALS

Due to technological innovations there has been increase in urbanization, population and living standards which has eventually lead to the increase in solid waste produced by industries, africultural fields etc. Above table shows the different types and sources of solid waste. Every year millons of tons of waste is generated. In India itself 960 million tons of solid waste is generated which include 350 million tons of organic agro-waste, 290 million tons of inorganic industrial and mining waste. Getting rid this solid waste has become a major problem in every country and the possibility of using this solid waste as construction material is of increasing importance.

In the past few years the solid waste has been gone under considerable development to make recycled products. Waste such as fly ash, blast furnace slag, sludge, recycled aggregates, waste tea, red mud etc have shown tremendous success in this research area.

A. Fly ash

Fly ash is basically left over residue from power plants. It is a by-product from muncipal solid waste incinerators. Fly ash is highly dispersible. It contains about 60% to 80% of aluminosilicate and ferriferrous glassy spherical particles, , mullite quartz and unburned metamorphic fuel (Malhotra and Ramezaniarpour, 1994; Diamond, 1986), and irregularly shaped grains of amorphous clay. Fly ash mainly consist of silicon dioxide which is 52.11% and aluminium oxide which is 23.59%. Instead of portland cement, fly ash is used in concrete because it is cost effective. Fly ash has high strength of concrete because of its pozzolanic properties and its small spherical particles makes the concrete more effective.

Advantages of using fly ash as raw material for bricks as the saves the firing energy due to the presence carbon content. Several studies about fly ash reveals that use of fly ash in fired bricks effectively saves land, energy and decreases the environmental pollution. A study conducted by Kumar (2002, 2003) states that hollow and solid bricks can be manufactured by using fly ash with lime and phosphogypsum, which are of more sufficient strength than conventional burnt clay bricks and blocks and can also replace them.

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Fig 1: Fly ash bricks

B. Granulated blast-furnace slag

Blast furnace slag is actually produced from the manufacturing of steel and iron, and holds intrinsic hydraulic properties. It is used to make some of the construction materials such as portland slag cement and super sulfated cement. A large quantity of Granulated blast-furnace slag is used in the manufacturing of portland slag and super sulfated cements. The use of GGBS with cement improves the final strength, microstructure and durability of hardened concrete. Ground granulated blast furnace slag provides protection against sulfate attack and chloride attack. To measure the resistivity of the concrete samples bulk electrical resistivity test is used. Higher the resistivity, higher is the ion transfer resistivity and hence higher is the durability. This durability of GGBS can be improved by 50% of GGBS in concrete. Also if concrete is made with GGBS, it continuous to gain strength over time, and shows double the strength in 28 days over a period of 10 to 12 years.

Fig 2: Ground granulated blast furnace slag

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C. Phosphogypsum

Phosphogypsum is a by-product of phosphate fertilizer produced from phosphate or fluoratite. Approximately 280 million tons of phosphogypsum waste is generated every year out of which 6 million tons of phosphogypsum is produced in India itself. 30 million tons of phosphogypsum waste is generated in Korea and about 22 million tons is generated in China. Phosphogypsum waste is very difficult to store. Is it usually deposited in rivers and seas hence polluting the enviroment. It would be very worthy if phosphogypsum would be used as construction materials. Due to the presence of undesirable impurities like P_2O_5, florides, organic matter and alkalis, untreated phosphogypsum waste cannot be used as construction material. However, phosphogypsum is reused as a secondary binder with lime stone and cement. It is used as a substitute for natural gypsum in the manufacturing of portland cement to set control. Phosphogypsum is used in the production of artificial aggregates for soil and road stabilization. Phosphogypsum is also used as a raw material for plaster and wallboard after calcination or purification process.construction material such as Bricks and blocks can be manufactured by combining phosphogypsum with fly ash and lime.

Fig 3: Phosphogypsum blocks

D. Palm oil Fuel Ash

Palm oil fuel ash is a waste material produced from the combustion of palm oil industry waste to generate electricity. It is basically a agro-waste material. When the oil from the oil palm fruit is extracted, both shells and husks are burnt in boiler to create steam for turbine to generate electricity used in palm oil mills. The product obtained after burning, the ash is known as palm oil fuel ash. This POFA is discarded in open field which gives rise to pollution and environmental problems. Several studies were conducted to make effective use of POFA waste in construction.

Researches conducted stated that the POFA posses good pozzolanic activity and is adequately inactive, hence it can be successfully used as cementing material to produce concrete. Ungrounded POFA has partially replaced OPC (ordinary portland cement), the only thing to remember is the ungrounded POFA should not be used with a content more than 10% of cement by weight because of its low pozzolanic property. Hussin and Ishida (1999) used 20% to 40% of ground POFA by weight of ordinary portland cement in concrete and found out that the modulus of elascity, compressive strength, shrinkage, poisson's ratio, and creep of concrete were comparable to that of OPC concrete up to 30% replacement of cement.

Hussin and Awal (1996, 1997) stated that it is possible to use 40% of ground POFA without affecting the concrete strength. It is also known that it is possible to use 20% of ground POFA as cement replacement level with durability factor of atleast comparable to that of ordinary portland cement. POFA is not only used as normal concrete but is also used in special concrete such as aerated concrete, high perfomance concrete and high strength concrete. High strength concrete made with POFA shows that the concrete carrying up to 30% of ground POFA gave more compressive strength than ordinary portland cement concrete in later ages. Researchers have claimed that we can use POFA in other construction materials as well like brick and stone mastic asphalt.

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Fig 4: Palm oil fuel ash

E. Rice Husk Ash

Rice husk ash is by product of rice mill industry which is obtained by burning husk of rice paddy. Non-crystalline amorphous rice husk ash is obtained by controlled burning of rice husk at 500^{o}C to 800^{o}C which is grey or whitish in colour. Rice husk ash particles have celluler structures with very high surface area. Rice husk ash contains upto 95% of amorphous silica and has excellent pozzolanic activity because of high surface area and silica content. The use of RHA in construction materials was accelarated after Metha's findings in 1973. Rice husk ash can also be used in concrete and mortor with good workability. High strength and high perfomance concrete was made using rice husk ash as a supplementry cementing material.

Rice husk ash can be used for production of delf consolidating high perfomance concrete with improved durablity and hardened properties. RHA reduces the porosity, and increases the flexural, tensile and compressive strengths of concrete. Rice husk ash also improves the corrosive resistance and durablity of concrete. Rice husk ash can successfully used in construction materials like blocks and bricks.

Fig 5: Rice husk ash bricks

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F. Constuction and Demolition Debris

Construction and demolition debris is a type of waste that comes from construciton sites which is eventually thrown away. As the the construction industry is growing, day by day more and more Construction and demolition debris are produced which generates more and more solid waste. Construction and demolition debris are mainly disposed on landfills or dumped openly in open areas. Use of this construction and demolition debris as construction materials would be very beneficial from the environmental point of view. Construction and demolition debris mainly consist of concrete rubble. Construction and demolition debris also contains sand, bricks, timber, tiles, plastic, dust, paper, cardboard and metal as well. After seperating the construction and demolition debris, concrete rubble is crushed and used substitute for natural course aggregate which is now known as recycled course aggregate(RCA). RCA can also be used in manufacturing of concrete and is also utilized in roads and airport pavement construction. Also it is used in manufacturing of good structural concrete along with condensed silica fume, fly ash etc.

Fig 6: construction and demolition debris

III. OTHER SOLID WASTE AND THEIR POTENTIAL USE AS CONSTRUCTION MATERIALS

Textile industry produces waste material such as textile effluent treatment plant (ETP) sludge. Upto 30% of textile effluent treatment plant can be used instead of cement for the production of non structural construction materials, although the setting process id delayed by addition of sludge. Kavas (2006) executed a research of using boron waste in the production of red mud brick. The mechanical properties of brick were upgraded by the addition of boron waste. Quarry waste, which is a by-product obtained by manufacturing of aggregates by crushing processof rocks in rubble crusher units. Quarry waste is widely used as a surface finisher material in construction industry. Quarry waste can also be used as an alternative for natural sand to reduce the overall construction cost of the project. Organic fibers produced from solid waste like date palm, oil palm, bamboo, coconut, suger palm, vegetable waste and sugarcane. These fibers are more inert then steel and glass fibers and are also cheaper and natural. Coconut fiber is used with portland cement to produce fiber cement board. Date palm consist of fibrous structures which consist of four types of fibers. All these four fibers can be utilized to produced construction materials. Limestone powder, cotton, waste ceramics tiles, kraft pulp production residues are also used in the production of bricks.

IV. CONCLUSION

Ample amount of solid waste is generated from various industrial, agricultural, mining and domestic activities as by-products which causes major environmental damage and pollution. Eco-friendly, efficient and cost effective materials can replace these other material which produces more waste can consume a lot of natural resources. These materials keep a potential to be used in urban as well as rural areas. A detailed engineering, psycho-chemical, thermal, minerological and morphological knowledge is required to effective utilize the solid waste as an alternative in construction industry. If the durability perfomance of these solid waste is not good then despite of their good properties they will not be used. High technology centers are required to maximize the use of solid waste construction materials in the real world. From the environmental point of view use of this alternative materials will benefit the enviroment and save our natural resources from diminishing and will conserve them. This solid waste which has proven to be an effective alternative construction material obtained from industries, agricultural fields have a very good future in the construction industry as they are cost efficient. Hence the construction companies and entrepreneurs are encouraging to manufacture more and more sustainable construction materials from industrial and agro-waste to make it more eco-friendly, energy efficient and cost efficient.

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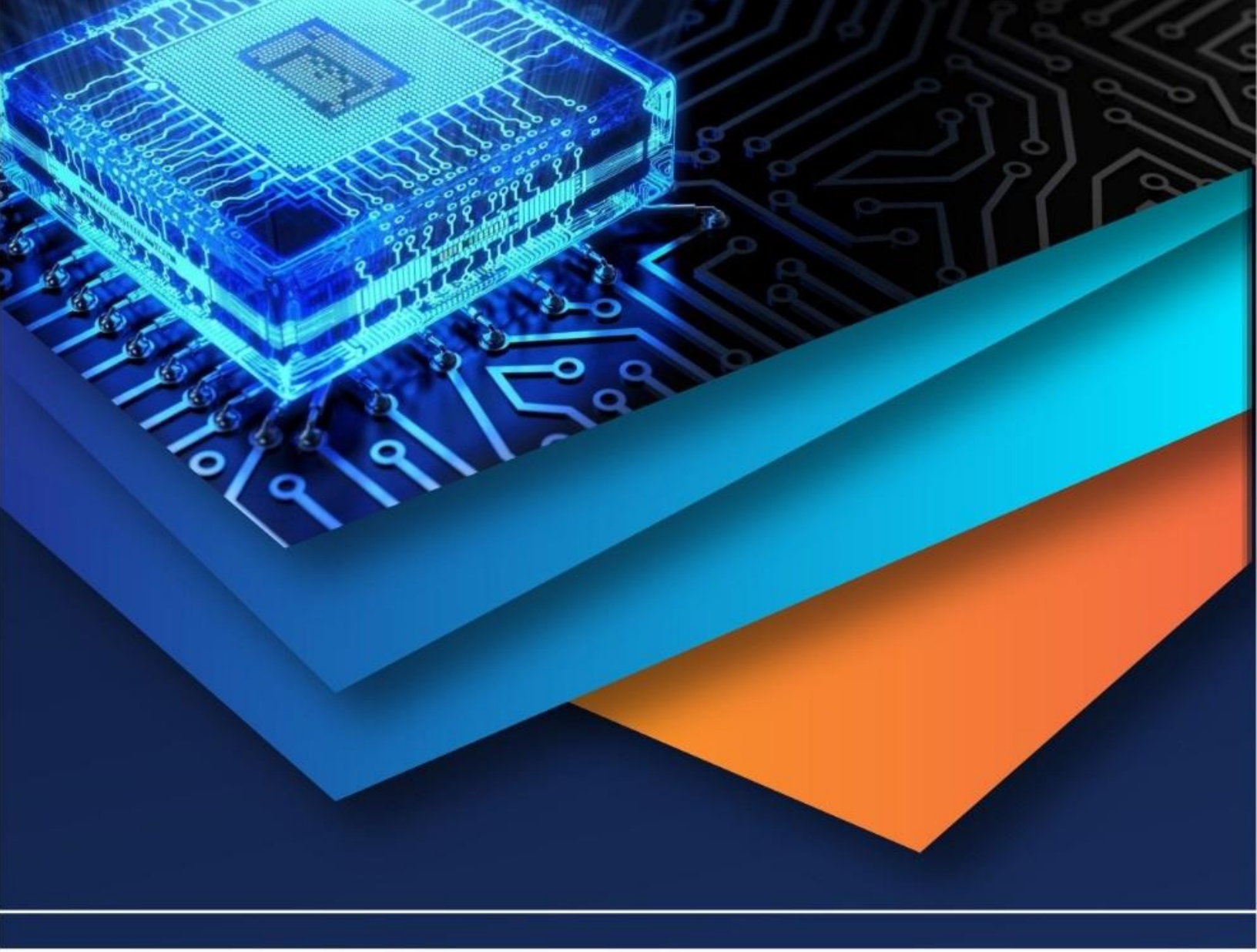

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