Status of Agro-Industrial Waste Used to Develop Construction Materials in Andhra Pradesh Region – India

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ABSTRACT. In today’s world concrete is one of the major construction materials. With the growth in industrialization and urbanization the demand for the concrete has taken a new pace. Therefore, to fulfill the demand huge amounts of natural resources has to be exploited for the production of the cement because natural resources and raw materials are major constituents in the production. At the same time huge quantities of industrial and agricultural wastes are generating in developing countries and are posing serious risk to the environment as well as human health. So, by utilizing these wastes as a supplementary material in construction reduces the usage of natural resources in the cement as well as decreases the threat of wastes in the environment. Many researchers have proved the effective utilization of wastes in the construction industry as they are more reliable and promote sustainability. This paper reviews waste generation and its statistics as well as environmental implication caused by wastes. It also high lights the possible ways of wastes that can be used in construction, preparation of blocks, insulators etc. This study also provides summary of existing research about usage of Agri and industrial wastes in the construction industry. In addition, paper shows application of wastes in real time construction.

Keywords: industrialization, urbanization, supplementary, environment

1. INTRODUCTION

In last few decades’ economic development, urbanization, globalization has led to the improvement of social status and wellbeing of living for majority of people in various pockets of the world. Same time consumption of huge material resources results in accumulation of large amounts of waste to the environment. World Bank reports that the world generates 2.01 billion tons of waste every year and in that 33 percent is extremely harmful to the environment and human life. According to the World Bank estimates global waste may grow 70 percent by 2050 unless immediate action is taken. Globally, only 37 percent of the waste is disposed in landfill. Based on the volume of waste generated it is estimated 1.6 billion tonnes of CO₂ equivalent greenhouse gas (GHG) emissions are generated from the waste or is equal to 5 percent of global emissions. Solid waste related emissions are estimated to increase by 2.38 billion tonnes of CO₂ equivalent per year by 2050. [1]

India records world’s second largest population after China with a whooping share of 17 percent of the world’s population. In recent year’s huge population growth, urban areas density, and changes in culture have seen serious waste accumulation in India. As country faces serious environmental challenges associated with inadequate waste collection, transport, treatment and disposal. In recent times E- waste and plastic waste also pose a serious threat to the environment due the huge usage of electronic and single use plastic materials. 147,613 metric tonnes (MT) of solid waste are generated per day according to “Swachhata Sandesh Newsletter” by the mohua. [2]
As per Planning commission’s “Task force on waste to energy” India would generate 450000 tonnes per day (TPD) by 2031 and 1195000 TPD by 2050.[3]

Andhra Pradesh (A.P) is seventh largest state in India in terms of area. In population A.P stands at tenth position. Andhra Pradesh has large number of industries falling under red and orange categories which generate significant amounts of solid waste, thus, recently there is huge need for construction materials workforce. The conventional type of construction needs all the traditional raw materials. This automatically increases the carbon emissions which in reverse leads of global warming and climatic issues. Agriculture is the very vast in the state which generates huge wastes as a residue. High growth of population, increased people activity in both commercial and residential uses, enormous growth of free life style, increased Agri activities has increased the number of wastes that is generated in both town and cities. All these wastes are mentioned in Table 1. As per 2016 estimates India as generating 277.1 million tonnes of waste every year. It is estimates 377 Mt by 2030 and 543 Mt by 2050. Majority of the municipal, single use plastic waste is generated mostly in Asia when compared with all over the world. So, this kind of unfair and untreated disposals creates serious problem both to humans and environment. So, in recent years there has been vast research being conducted to battle these wastes and different innovate kind of studies are conducted to check their uses in construction applications. Specifically, in civil engineering the applications of different wastes are already started and in good pace of development. The use of fly-ash, mineral end products, recycled aggregates, Paper pulp wastes, plant fibre wastes, coffee sludge etc. are used.

Figure 1. Global Waste Composition
Table 1. Different Types of Wastes that has Probability of Their Usage in Construction.

| S. No. | Waste Type                      | Source                                      | Utilization                                      |
|-------|---------------------------------|---------------------------------------------|--------------------------------------------------|
| 1     | Agriculture waste (Organic wastes) | Bagasse, rice husk, oil palm fibers, straw bales, palm kernel shells, coconut shells | Ashes in the replacement of cement, white boards |
| 2     | Mineral wastes                  | Coal waste, marble waste, granite waste, copper, iron, steel tailings | Binders, substituting materials                   |
| 3     | Waste from industries (inorganic) | Fly ash, bottom ash, steel slag, copper slag, iron slag’s, paper sludge, | Paint, cement, bricks, blocks, coarse aggregates, woods |
| 4     | Construction demolition waste   | Sand, mixture aggregates                    | Sand can be used as fine aggregate, filling materials |
| 5     | Hazardous wastes                | Sludges from different treatments plants, Leather tannery wastes | Bricks, cement, blocks, tiles                     |
| 6     | Non-hazardous wastes            | Broken glass particles, ceramics, kiln dust, gypsum waste | Bricks, blocks, cement, Gypsum boards, plaster from gypsum |

2. SUPPLEMENTARY CEMENTITIOUS MATERIAL (SCM)

Huge quantity of end products is generated by various sectors such as agriculture, industry, mining, construction and demolition, municipal solid waste etc. Only limited numbers of wastes are utilized and rest of the waste are un-utilized which pose a serious threat to the environment. If they are not disposed properly, they may be hazardous to the human health. As these wastes are un-interrupted, they remain more days in the environment. The only solution to this waste accumulation is recycling of the wastes. Wastes such as bagasse ash, rice husk ash, GGBFS, fly ash, bottom ash, palm ash, have been extensively used in the construction sector as a supplementary cementations material. The usage of these end products as replacement of Portland cement partially or fully contributes to the solution of landfill problems. This reduction in cement usage helps in reducing the carbon emissions into the environment, costing and land filling problems. Supplementary cementitious materials are also used as pozzolanic materials and admixtures. These sometimes can create extra strength and other properties to the cement. These pozzolanic materials reduce the demand of usage of cement. These pozzolans are used worldwide and majorly used as additions or replacement of cement. During compressive strength these pozzolans are important and contribute in two ways as a reaction and fillers. Hence the demand of cement is reduced by usage of this pozzolanic material. Pozzolans mainly comprises of siliceous materials, and shows cement properties when combined with calcium hydroxide. High reactive silica is also used to produce high early strength cement. The acid-based reaction between calcium hydroxide and silica acid is the basis of pozzolanic reaction.

\[
Ca(OH)_2 + Si(OH)_4 \rightarrow Ca_2 + H_2 SiO_3^2^- + 2H_2O \rightarrow CaH_2SiO_4 \cdot 2H_2O
\]

As C-S-H (calcium-silica-hydrate) density is lower than that of calcium hydroxide and pure silica, this tends to swell due to the reaction; this reaction is also called as alkali silica reaction and occurs in concrete between pore water and silica aggregates.

Concrete is a mixture of cement, sand, coarse aggregate and water. Production of this cement purely requires lot of natural resources to be exploited and utilized. This also increases the threat the emissions of GHG’s. So, if cement is replaced with SCM then there would be changes in the emissions of GHG’s. The utilization of SCM in cement is a viable solution to partial cement
replacement. Supplementary cementitious materials are divided into different categories like artificial and natural resources. Agriculture end products, industrial end products, many types of wastes are utilized. The usages of these SCM reduce the emission consistently. These sometimes are also called as mineral based admixtures or pozzolans and these form cementitious properties when mixed with cement.

But independently they do not possess any cementation properties. These materials are also used to increase the properties of concrete in both fresh and hardened concrete. The major advantage of using a SCM is they reduce the quantity of cement to be used hence it is beneficial in economic, environmental terms, transportation, controlled combustion, waste generation reduction.

2.1 Agricultural Waste as SCM

Agriculture in Andhra Pradesh is major sector in the state about 60 percent or 46 lakh people are dependent on agriculture or allied sectors in the state. The important thing here is many materials from the farm is the major raw material in the industry. So here both agriculture and manufacture are dependent and generates more end products. To increase the usage of agriculture wastes and using environment friendly materials has increased its pace in recent advancements.[4]In many scenarios there is no way for these waste materials and just end up undisclosed. Some of the crop waste is already being utilized in the construction like rice husk, straw bales, bagasse etc. Here we are checking weather wastes like cotton, coffee, etc. can be used in construction.

![Agriculture wastes that can be used in construction](image)

Figure 2. Different types of Agriculture wastes generated in AP.

2.1.1 Rice husk. Rice husk is material that is generated after the grains that are produced went through a process called “DE husking”. In this process huge amounts of husk are generated. As this is a biodegradable material many farmers tend to burn these materials which creates a serious environmental pollution. So, use of these materials in cement replacement can be helped in decreasing the air pollution as well as could easily be replaced in cement pozzolanic material replacement. This material is collected from the rice mills nearly 200 kg of husk is generated for every ton of rice. Even in controlled burning it generated 40 kg of rice husk ash (RHA). In his paper HE explained that the test results indicated positive results with 15 % replacement of cement with RHA which increased 20 % compressive strength. But more than 20% addition decreased its strength by 4.5% HE also
explained chloride penetration increased with more than 25% addition. [5] Presoaked rice husk can also be used in construction as a construction material Kumar P et al., in their study explained the usage of soaked rice husk in terms of slump, tensile and compressive strength and durability properties and determined that by mixing RHA in at low specific surface with equal weight of water the cellular pores in RHA gets saturated with water and RHA will be in surface dry condition. This helps in reducing water demand and reducing the amount of plasticizer to be used. [6]

2.1.2 Palm. Palm is one of the important oil crops in the state of Andhra Pradesh. Mostly it is cultivated in the districts east Godavari, west Godavari, Vishakhapatnam districts of the state. There are different types of wastes evolved once the oil is extracted. They are Oil palm shells (OPS), palm oil clinker (POC), palm oil fuel ash (POFA). After the extraction of the oil these are disposed or burnt without any controlled environment resulting in huge environment and health hazard. In recent years much research is happened in the area of palm fibers as an alternative building material. MOHAMMAD et al., (2015) stated that Oil palm shells have been already use as coarse aggregate and it acquired nearly 56 Ma for 56 days. He also said that 30 grade oil palm shell concrete is possible without adding any cement material. The maximum modulus of elasticity is found to be 18.6 GPa.

[7] Raut et al., (2017) in their research about thermally efficient eco-friendly bricks described about the usage of palm ash and palm fibres in bricks. He also stated that 1% wt. od oil palm fibres the compressive strength was found to be 7.21 MPa and thermal conductivity is 0.39 W/mK. The incorporation of palm fibre also helps in maintaining old Thermal conductivity and usage of eco-friendly materials [8]

2.1.3 Coffee Grounds. Coffee in Andhra Pradesh is grown in the regions of Vishakapatnam, maredumilli, chintapalli agency areas. Coffee here is grown due to its low climatic conditions and hilly area regions. Many processing units just process the beans to the powder or liquid form and import them. But there is a huge sludge that is generated in which it is left for free. So, D. Eliche-Quesada et al., (2011) in their article they mentioned that the end product or waste that is generated from the raw coffee is used in clay bricks. In their research they mentioned that usage of coffee ground (1-5 wt-%) in preparing the bricks has been effective for pore formation and increased insulating properties as coffee sludge is an organic material. And they also mentioned that clay bricks with more amounts of coffee sludge (3-5wt-%) showed lower density and higher porosity. Best results have been found with bricks having 3wt-% coffee grounds showing good mechanical, physical and thermal properties. [9][10]

2.1.4 Sugar cane. India is one of the largest producers of sugar cane in the world. Every year nearly 300 million tonnes of sugar cane is cultivated in India. Andhra Pradesh is one of the major sugar canes growing state in the country. After the processing is done huge waste is generated in the form of bagasse. Till date the bagasse is burnt and is used as a supplementary material in the cement. The bagasse is burnt at a temperature of 700 to 800 degrees and ash is produced and is ground at 150 microns to suit the performance. (Shruthi H R et al., 2013) in their research conducted experiments by preparing different types of mixes with M25 grade concrete. The compressive strength at 10% replacement is note at 24.99 at 7 days and 44 Mpa at 90 days. With increase in days the strength also increases.[11] S. Deepika et al., 2017 in their study focused on performance evolution of bagasse ash in improvement of strength and durability. They reported of presence of porous and carbon rich particles lead to higher water absorption and lower the strength.[12] Extensive research is required in the area of sugar cane bagasse ash.

2.1.5 Wood waste ash. In recent years growing concern about global warming has led to huge increase of alternative materials for construction. This led to growing demand for lightweight materials and wood waste dust has shown some promising features. There are many sources of wood end products like saw dust, ply wood industry end products etc. Several studies which used wood as SCM has analyzed wood waste ash as the alternative cement substituting material. Burnt wood waste has many properties in one research it is said that burnt wood waste is highly irregular in shape and has highly
porous properties [13] various wood has different types of properties. So, the source should be defined and categorized before using as a cementitious material because this would affect the pozzolanic activity. Low weight and specific gravity of wood weight indicate the reduction in the unit weight of concrete.[14] It has been reported that compressive of blocks increased by curing time. The optimum is note at 15% cement replacement at 21 days curing time.[15]

2.1.6 Corn cob ash (CCA). Maize or corn is one the important cereal crop and is extensively grown in India. India estimates nearly 21,800 thousand tonnes of production. The ash which is produced after burning the waste crop residue is called as Corn cob ash (CCA). Maize in India is used in many ways the major utilization as a cereal crop, feed for cattle, ethanol production etc. The end product for this crop is very high such that checking feasibility for utilization is done in many studies. Many studies were conducted for using corncob ash as a cementitious material. Previous studies they excluded chemical compositions of the CCA which made it suitable for using the material as a pozzolanic material.[16] CCA is suitable material for using as a SCM because it has both the contents of silicon dioxide and aluminum oxide. One study suggested that in mass concreting and is use in low rate of heat development. So CCA blended cement is useful in low heat cement.[17]

2.1.7 Coconut fiber. Coconut fiber has been used in reinforcement as an inorganic compound from many decades. Fibers are majorly divided into natural and artificial that is manmade. The use of natural fiber in reinforcement has been utilized by many countries’ way long. The major reason behind the usage is they are very cheap and are abundantly available. In the southern state like Andhra Pradesh the coconut fiber is abundantly available. Only minute amount is used in the application and rest of the coconut fiber is ended at landfill polluting the environment. Many studies stated different reason for the usage of fibers in concrete. These materials reduce the dependency on nonrenewable resources, lowers greenhouse gas emissions.[18] Majid Ali, et. Al., (2015) he studied the dynamic and mechanical properties of coconut fiber reinforce concrete the mix proportion and the fibre content is of length 2.5, 5 and 7 is investigated. The strength increased with curing time for 28 day curing time the compressive strength reported is 27.46. [19]

2.2 Industrial Wastes as SCM

2.2.1 Fly ash. Fly ash is the end product that is produced in thermal power stations when the coal is burned at higher degrees to produce the electricity. The disposal of fly ash in India alone accounts for nearly 26,304 ha (65000 acres) this consumes a huge parcel of land. According to a study by Manoj Kumar Tiwari et.al., (2016) it is estimated that only 33% of fly ash is utilized and the rest is finding their way into landfills [20]. Generally, these fly ashes used in the construction of buildings, roads, road embankments and in many scenarios, governments have made it mandatory to utilize fly ash in construction. When this ash is released outside without any control it creates serious economic and health hazards. Studies on this fly ash showed good applications in cement replacement in construction building materials. Generally, there are two types of Ashes Fly ash (FA) and Bottom Ash (BA). It contains aluminosilicate and ferriferrous particles. The pozzolanic properties present in the fly ash improve the strength of concrete and helps in improving its workability.

2.2.2 GGBFS. GGBFS or ground granulated blast furnace slag is a byproduct of iron manufacturing industry. Iron ore, coke and lime stone are introduced into the blast furnace and burned and slag flows at a temperature of 600 to 1500 degrees. And this material show inherits hydraulic properties. Recent advancements show high usage of GGBFS in replacement for Portland cement even super sulfated cement is also produced in India. Currently due to the manufacture of the cement is one of the big players in the carbon dioxide emissions in India. So, if cement is replaced with supplementary pozzolanic materials it would decrease the carbon emissions gradually.[21]

2.2.3 Steel slag. Steel slag is the byproduct of steel industry. There are three types of steel slags that are generated from the BOF- basic oxygen furnace, EAC-Electric arc furnace, and ladle furnace steel
refining process. Slag’s which are generated from these types of processes are named by way they are
generated. Various researches show the advancements of steel slags in manufacture of bricks. Bricks
generally are most important components in the construction activity. In various studies the results
indicated that the water absorption of bricks increased with increase in steel slag contents. [22]

2.2.4 Construction and demolition waste. Construction and demolition (C&D) are waste that is
generated from the dismantling of already existing building that are being scrapped for
newer constructions. Majority of the waste that is generated in the town ad cities generally ends up in
municipal landfills or other areas where in very little is used in the application of construction. Due to
this uncontrolled disposal of all the construction debris, they would be high damage to the ecosystem
and environment as these materials contains heavy toxins and harmful chemical that may be dangerous
to the environment. According to a report by center for science and environment India utilizes only
1% of its C&D waste for construction.[23]As our current review is specifically about Andhra Pradesh.
The state generates 58400 TPA in 7 major municipalities in the state where huge construction activity
is taken place. The C&D waste can be largely used in construction works applications. This can be
used in concrete, production of M-sand, pavements, roads etc.

2.2.5 Plastic waste. Plastic waste or single use plastic waste possesses serious harm to the
environment. According to UNEP 5 trillion single use bags are used every year and today we produce
300 million tonnes of plastic waste very year.[24] Today many international organizations and
institutes are working towards battling the plastic wastes. For commercial purposes industries choose
plastic because of their low cost, high available and less regulated. Hence there are huge piles of single
use plastic wastes lying in the landfills. Point of concern here is these plastic wastes takes hundreds of
years to degrade in the soil. The major threat posed by the plastic wastes is to the marine environment.
The maximum usage of wastes in the construction process ill helps in maintaining sustainability.
Sheelan M. Hama et.al, (2017) have studied the properties of self-compacted concrete by
incorporating the plastic waste in the concrete.[25] One study by M A Kamaruddin et.al, (2017) in
their research stated that plastic can be converted into aggregates which can be replaced by coarse
aggregate and used in the construction. He also described that concrete with this type of plastic
aggregates was light in weight when compared with conventional concrete. [26]

2.2.6 Rubber. Waste rubber which is emanated from industries like tyres industries, bottling industries,
vehicle factories etc. are major concern to the environment because they are bio degradable in
nature.In many parts of country these rubber tyres and rubber materials are used as a fuel for fuel such
tat it causes serious air pollution. Many researches were done for incorporating this rubber into the
construction. Applications include cementitious concrete, granular materials, asphalt concrete etc. It is
estimated that every year waste general generation is equal to 1.5 billion whole tyres.[27] Majority of
this rubber replacement in concrete is used in replacement in asphalt and bitumen, high strength
concrete, railways, soil stabilization, unbound pavements, sub-basalt layers, seismic systems, flow
able concrete fill.[28]

3. USE OF WASTE BASED CONSTRUCTION MATERIALS IN REAL CONSTRUCTION

By using different kinds of agricultural and industrial wastes significant research studies have been
conducted and new types of construction materials have been done. However, in real time usage of
these kinds of materials are literally limited. More research is needed to study the behavior and
performance and to encourage their real time applications. Table 3 shows some of the real time
applications.
Table 2. Application of wastes in real time construction

| S. No. | Waste name          | Construction Material          | Application In Real Time                                                                 |
|--------|---------------------|--------------------------------|-----------------------------------------------------------------------------------------|
| 1      | Fly ash             | High volume fly ash concrete   | Raichur PWD works dept undertook high volume fly ash concrete by replacing 50% cement with fly ash. |
| 2      | Bottom ash          | Aggregates                     | Neyveli lignite corporation, Chennai, India has built building using bottom ash instead of sand.[29] |
| 3      | Rice husk ash       | Concrete                       | VNC rice husk ash concrete [30]                                                          |
| 4      | GGBFS               | High performance concrete      | Majority of the ready-mix plants in the state are using GGBFS as a primary replacement constituent and admixture. |
| 5      | Bamboo fibre        | Reinforcement                  | VIP pantry for Raj Bhavan in Bangalore, in 2000                                           |
| 6      | Quarry waste        | Aggregates                     | Base layer of flexible pavement, Sobradinho, Brasilia, Brazil                             |
| 7      | Construction and demolition waste | Recycled aggregates     | Majority of constructions in India are following practices of using C&D waste [31]         |

3.1 Need for utilization of waste

There are numerous ways the solid waste can be utilized. They can be used as aggregates, cement replacement, reinforcements, insulation blocks etc. Extensive research studies have been done utilizing solid wastes. Majority of the research focused on the physical and mechanical properties and some about the durability. Limited research is upon the insulation and sustainability. However, much research is necessary to confirm the beneficial effects of solid wastes on key properties. In this context the following research needs have been identified for further investigation.
1. Large scale utilization of different types of wastes in construction.
2. Optimization of various waste materials for the production of new construction materials.
3. Investigation on waste materials to produce high durable construction materials.
4. Investigation various waste materials to produce environmentally friendly construction materials.
5. Effects on various exposure conditions.
6. Cost benefit analysis
7. Insulation and heat transfer analysis
8. Life cycle assessment of structures when built with these materials.

4. CONCLUSION

During different activities like agriculture, industrial activities, mining huge quantity of wastes are generated. This is very difficult for the authorities to recycle or they require large parcels of land to store or process the wastes. There is a scope for setting up new industries for manufacture of supplementary construction materials. Environmentally friendly, cost effective, sustainable and alternative materials produced form these wastes will show high potential in market as well as do well to the environment by reducing manufacturer of cement. Researchers are consistently being concerned about the concept of sustainability. Which is important to the environment and to the society. The utilization of agricultural and industrial wastes is needed to make the construction industry more environmentally friendly. Therefore, the knowledge and the research on the other useful waste material as a supplementary cementitious material in concrete will act as a valuable contribution for sustainable construction.
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