International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-07, Issue-04, JULY 2021

A Study on Alternative Materials for Sustainable Construction

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Abstract **Sustainable construction is an emerging field of science that aims at incorporating the general sustainable development concepts into conventional construction practices. While the foundation of knowledge in this field is continuously expanding, sustainable construction is not yet standard industry practice. One major technical barrier that hinders enacting sustainable construction is the absence of an application framework that integrates both sustainability and construction practice at an operation level.**

This study is concentrating on large scale construction projects, as in this developing country these construction projects are facing so many issues like men, material and money management and all these are directly linked to on time delivery of the project. Therefore, considering a project, listing all the activities involved in construction and close study of each activity, to check any other sustainable method of construction for that particular activity and a comparison of the activity with conventional technique. Calculation of materials, labor and duration for every activity is conducted with respect to conventional technique. Also, this study aims at reduction of carbon footprints of construction project using sustainable methods of construction at each activity.

Keywords —GGBS – Ground granulated blast furnace slag, BCA - building and construction authority, BRC - bamboo reinforced concrete, PCC-Portland cement concrete, CSH - calcium silicate hydrates, GP - Granite powder.

I. INTRODUCTION

Sustainable construction is a living concept and varies in different scenarios based on people needs. Taken as the starting point, the definition above has been reinterpreted and expanded based on different approaches and priorities from country to country. In a study led by the international council for research and innovation in building construction carried out with the collaboration of experts from countries around the world. "Sustainable Construction is development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

a. Sustainable construction should also:

- Enhance living, working and leisure environments for individuals and communities.
- Consume minimum energy over its lifecycle.
- Generate minimum waste over its lifecycle.
- Integrate with the natural environment.
- Use renewable resources where possible.

b. Sustainable construction should NOT:

- Consume a large amount of resources during construction or Cause permanent damage to the natural environment.
- Cause unnecessary waste of energy, water or materials due to short life, poor design, inefficiency or low standard construction techniques.
- Create dependence on high impact transport systems with their associated pollution.
- Use materials from threatened species or environments.

Sustainable construction is defined as, "a way of building which aims at reducing negative health and environmental impacts caused by the construction process or building or by built up environment.

Sustainable development interconnects three socially concerned systems--environment, society and economy--with a systems approach seeking to achieve a range of goals as defined by the United Nations Development.

OBJECTIVES

- To identify the sustainable construction materials for each major activities of construction.

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- To compare the technique of conventional and sustainable construction in terms of carbon foot prints.
- To discover the primary factors which obstruct the utilization of sustainable construction materials

STATEMENT OF THE PROBLEM

India, one of the largest countries in the world, is home to over a billion people. The country's economy has been growing at a rapid pace and this has led to rampant urbanization giving way to numerous challenges like pollution and unsustainable construction practices. A sustainable use of natural resources plays an important role in the development of sustainable construction in a country like ours, which has a long history of sustainable and holistic living.

Thus, our study aims to identify the alternative sustainable construction material for all major activities of construction and detail study of it in comparison to conventional construction materials. Also to identify the hindrances for adopting sustainable construction materials in construction industries of Bangalore.

SUMMARY OF LITERATURE REVIEW

From the above literature review one can conclude that the sustainable materials such as rice husk, fine glass powder, bamboo, wood shavings, plastic wastes, agro wastes, straw bale etc. can be easily replace the materials used in the conventional method of construction without affecting their physical and mechanical properties from which we can have a healthy and safe environment.

Sustainable development has always played a major role in Singapore's national planning and development. Singapore has very fewer natural resources hence; it is difficult to form sustainable construction. All the materials for construction are to be imported which is more costly. Since 2007 the building and construction authority [BCA] together with the Singapore construction industry promoting the adoption of sustainable construction materials and practice. With the support and effort from the industry, public sector and research organizations, modest yet encouraging progress has been observed in terms of rising awareness and increasing use of recycled materials, Singapore Government is confident that the drive toward sustainable construction will gather pace in the years to come.

Availability of construction materials are less. Hence by making use of natural resources, construction is carried out. Bamboo, it is a natural resource which has been used as a general building material from many years in other regions of the World, it has significant impact on conventional construction reducing steel and concrete as a primary material in structures. Bamboo is fast growing, low cost, and there is a broad distribution of growth and it is widely used as proportioning, because of its high strength to weight ratio. Under flexural loading, bamboo reinforced concrete (BRC) made with alternative materials (fly ash, GGBS, and m-sand) developed more flexural strength than the steel reinforced concrete a variation representing 6.5% strength gain.

In recent development, bamboo is being processed to typical reinforcement bar sizes which may be used instead of conventional steel bars. It was concluded that bamboo bars are suitable rebars for non-load bearing and light weight reinforced concrete flexural structures Bamboo has the potential to be used as substitute for the steel as reinforcement in structural members. The main aim of this is to provide I- shaped bamboo beam which will be stiffer and safer.

Straw bale is a waste product of agriculture that is often buried or burned by farmers. Buildings which are constructed using these straw bales instead of conventional materials can be a sustainable alternative in the energy evolution of building construction, due to its low embodied energy and excellent thermal performance. The straw bale constructions are not more expensive than those made with traditional materials and their prices could lower in the coming years with the increasing number of professional in this field.

The composite material of clay-straw has a valuable thermal property for the storage of heat and the regulation of temperature changes between day and night during the winter period and prove its ability of resisting to the warm and dry climate without any use of cooling or heating system. The analysis of thermal conductivity for the

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developed composite clay- straw mixture permits a decrease in the thermal conductivity by 48% for the 5% straw. The composite clay-straw improves more insulation of the envelope building and presents a good insulation material from the exterior ambiance. The addition of straw fibers has an important effect on the reduction of thermal diffusivity. During hottest period, the maximum of outdoor temperature exceeds 42 °C, although the maximum indoor temperature achieved is 35 °C for the walls with 100% clay and reduced to 28% for the walls with clay and straw bale (5%).

Sand is the one of the chief ingredients in concrete and mortar which can be replaced by other sustainable materials. The concrete mixtures with 5%, 10%, and 15% of sand replacements by waste plastic of vehicles exhibited ability to absorb a large amount of impact energy. The results show that the compressive stress, modulus of elasticity and splitting tensile stress decreases with increase in plastic content.

Mortars containing PVC waste have the advantage that their production is less polluting, as it does not involve high energy consumption. The materials developed by the replacement of sand recipe with PVC waste in different proportions show a decrease in mortar density with the increase of the sand replacement %, but they remain in the category of heavy mortars. Only the mortar obtained by the replacement of entire amount of sand with PVC waste falls into the category of light mortars. The best possible proportion of mortar is which contains max of 25% sand in the standard recipe is replaced by PVC. This mortar falls into mortar class M20, also having the best adhesion to substrate, it can be used as plastering mortar, but because of its reaction to open fire, it is not recommended to be used on internal surfaces.

Waste glass powder is another sustainable material which can replace sand up to a certain limit in mortar. The replacing of sand with glass powder in the controlled mixture of mortar increased the unit weight of mortar by 29% on the 60thday. A 10% replacement with glass powder enhanced the sulphate resistance compared to control mixes. Glass powder mortars compared with sand mortars had a good behavior in external exposure curing with MgSO4 solution, but there was decrease in compressive strength was observed for GP mortars specimens which are exposed to MgSO4. The presence of waste glass which replaced fine sand in the cement mortar significantly decreased the thermal conductivity of the cement mortar and also sorptivity coefficient without leading to mechanical deterioration. The incorporation of the Nano silica to cement mortars leads to further strength improvement.

Wood shavings is another material which can be used as aggregates in concrete for sustainable construction. The swelling and absorption tests show that the low values of the density of wood aggregates concrete materials can classify them as a light weight aggregate. The water absorption rates of the composite material appeared below 30%, Thus it can be used in contact place with water without risk of freezing and drying. Further research is needed to examine the durability of the composite material under variations of the temperature, humidity, creep loading etc. Wood waste ash at replacement percentage of 10% of the weight of cement in the concrete can be successfully used as additive in place of cement to produce structure grate concrete.

The agro wastes concrete containing ground nut shell, oyster shell, cork, rise husk ash and tobacco waste showed better workability than their counterparts did. Agro waste concrete containing bagasse ash, saw dust and oyster shell achieved their required strength by 20% replacement as fine aggregates. Bagasse ash as fine aggregate in mortar increased the resistance of chlorine penetration and cork in mortar showed better thermal resistance.

Sea weed is a promising natural polymer which has a cementitious material has a good binding property can be added to mortars to make polymer modified mortars. The research conducted in two parts, pre- experiment and main-experiment. Pre-experiment aimed to investigate the compressive strength of natural polymer modified mortar with seaweed gel and seaweed powder. The pre-experiment followed by main-experiment which investigated compressive strength and splitting tensile strength. The research has shown that natural polymer modified mortar

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with seaweed powder performed great compressive strength and splitting tensile with the optimum mix composition.

Rise husk is by- product taken from rice mill process, with approximately the ratio of 200 kg per one ton of rice, even in high temperature it reduces to 40 kg. Tests results indicated the positive relationship between 15% replacement of RHA with increase in the compressive strengths by 20%. Replacement with 25% rice hush ash result in drastic enhancement of the permeability properties of blended concrete compared to that of in ordinary concrete.

The performance of rice husk ash in concrete is of factors influencing the amount of silica added. This is because rice husk ash contains 85% to 95% weight percent of amorphous silica. Rice husk ash as a pozzolanic reactive material can be used to improve surface area of transition zone between the microscopic structure of cement paste and aggregate in the high-performance concrete.

Sustainable materials are having so many advantages in the construction field even then it is not applied in real scenario. There are some barriers which have to be considered during the selection of sustainable materials such as lack of training and tools, lack of awareness, lack of relevant laws and regulations, initial costs of sustainable features and lack of information about the benefits and savings of incorporating sustainable materials. These barriers have real or perceived impacts on the risk and project of various industry groups.

Sustainable construction can be an excellent opportunity for creative experiment in the industry. New materials are being used and as a result, more innovative techniques are being developed and implemented. Sustainable construction not only helps cut down on emissions released into the ozone, but also helps significantly reduce energy, water and cost of the construction. The literature review helped us to understand the availability and applicability of sustainable materials in construction so that we can reduce the negative impact of construction on the environment and also sustainable method of construction can lead to a longer lasting structures, monitory savings, waste reduction, better all-round efficiency and of course, is great for the environment.

METHODOLOGY

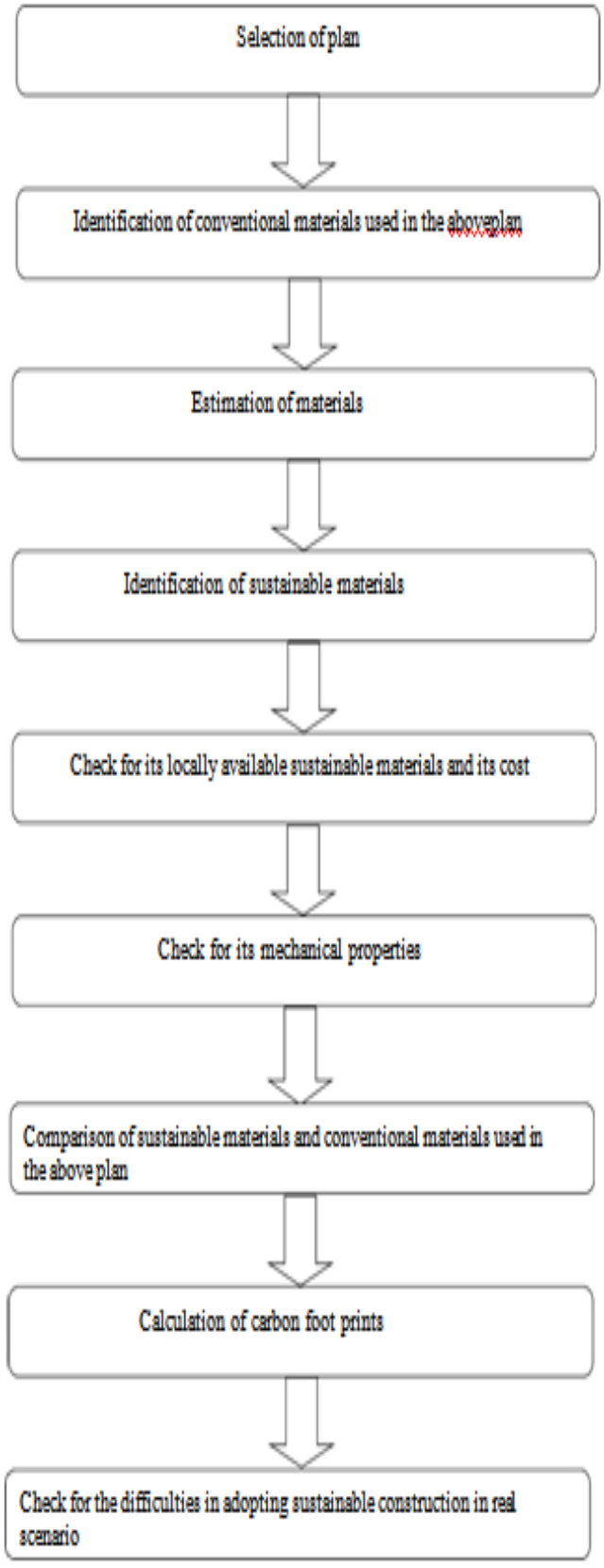

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Table.1:SUMMARY OF MATERIAL QUANTITY ESTIMATION:

Sl. No.	PARTICULARS	UNIT	RATE/m3	QUANTITY	AMOUNT
1	Footing concrete	m3	3745	35.10	131483.2
2	Pedestal concrete	m3	3834	4.308	18548.8
3	Plinth beam concrete	m3	3745	11.83	44307
4	Column concrete	m3	3834	17.28	66251.5
5	Slab concrete	m3	3834	178.29	683563.8
6	Beam concrete	m3	3834	32.84	125940
7	Concrete block work	m3		357.58	
8	Plastering	m3	3745	3.18	11909.1

List of sustainable materials which are used for replacement

FLY ASH:

- Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by flue gases and collected by electrostatic precipitation.
- It can replace the cement quantity around 15% to20%.

GGBS:-Ground Granulated Blast-furnace Slag

- GGBS is a by-product from the blast furnaces manufacturing iron.
- Dried and ground to a fine powder, GGBS can be used to make quality and sustainable concrete.
- Based on the mix design code book GGBS can replace 25%-50% of cement in concrete

RICE HUSK:

- Rice husk is used for replacement of cement because it contains 85-95% weight percent of amorphous silica
- It is a pozzolanic reactive material can be used to improve surface area of transition zone between the microscopic structure of cement paste and aggregate.
- Rice husk can replace the cement up to 15-25%

GRANITE DUST:

- It is a waste material from the granite polishing industry, can be used as a filler material in concrete.
- It improves compressive, tensile, workability and flexure characteristics of concrete.
- It can replace cement in concrete up to10-20%.

Table.2: RATES OF LOCALLY AVAILABLE SUSTAINABLE MATERIALS

LIST OF LOCALLY AVAILABLE SUSTAINABLE MATERIALS.	PRICE PER KG
Fly Ash	1.2rs
GGBS	3.1rs
Rice Husk	4rs
Granite dust	4rs

Replacement of cement by fly ash:

Replacement of cement by fly ash:

Fly ash can be used as prime material in many cement-based products, such as poured concrete, concrete block, and brick. One of the most common uses of fly ash is in Portland cement concrete pavement or PCC pavement.

The four most relevant characteristics of fly ash for use in concrete are loss on ignition (LOI), fineness, chemical composition and uniformity. LOI is a measurement of unburned carbon (coal) remaining in the ash and is a critical characteristic of fly ash, especially for concrete applications.

Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately ignites, generating heat and producing a molten mineral residue

Fly ash is a fine powder that is a byproduct of burning pulverized coal in electric generation power plants. Fly ash is a pozzolan, a substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water, fly ash forms a compound similar to Portland cement. This makes fly ash suitable as a prime material in blended cement, mosaic tiles, and hollow blocks, among other building materials. When used in concrete mixes, fly ash improves the strength and segregation of the concrete and makes it easier to pump.

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strength and segregation of the concrete and makes it easier to pump.

Applications for Fly Ash:

- Fly ash can be used as prime material inmany cement-based products, such as poured concrete, concrete block, and brick. One of the most common uses of fly ash is in Portland cement concrete pavement or PCC pavement. Road construction projects using PCC can use a great deal of concrete, and substituting fly ash provides significant economic benefits. Fly ash has also been used as embankment and mine fill, and it has increasingly gained acceptance by the Federal Highway Administration.
    - The rate of substitution—of fly ash for Portland cement—typically specified is 1 to 1 1/2 poundsofflyashfor1poundofcement.Accordingly,theamountoffineaggregateint
    - concrete mix must be reduced to accommodate the additional volume of the fly ash.

Composition:

Fly ash consists primarily of oxides of silicon, aluminum iron and calcium. Magnesium, potassium, sodium, titanium, and sulfur are also present to a lesser degree. When used as a mineral admixture in concrete, fly ash is classified as either Class C or Class F ash based on its chemical composition.

Replacement:

Typically, 15 percent to 30 percent of the portland cement is replaced with fly ash, with even higher percentages used for mass concrete placements. An equivalent or greater weight of fly ash is substituted for the cement removed. The substitution ratio for fly ash to portland cement is typically 1:1 to1.5:1.

Benefits:

Fly ash can be a cost-effective substitute for Portland cement in many markets. Fly ash is also recognized as an environmentally friendly material because it is a byproduct and has low embodied energy, the measure of how much energy is consumed in producing and shipping a building material. By contrast, Portland cement has a very high embodied energy because its production requires a great deal of heat. Fly ash requires less water than Portland cement and is easier to use in cold weather. Other benefits include:

- Produces various settimes
- Cold weather resistance
- High strength gains, depending onuse
- Can be used as an admixture
- Considered a non-shrink material
- Produces dense concrete with a smooth surface and sharp detail
- Great workability.

GGBS- Ground Granulated Blast Furnace Slag:

Ground-granulated blast furnace slag (GGBS) is a admixture which can be used as a sustainable material which is highly cementations' and high in CSH (calcium silicate hydrates) which is a strength enhancing compound that increases the strength, durability and appearance of the concrete. The main components of blast furnace slag are CaO (30-50%), SiO2 (28-38%), Al2O3 (8-24%), and MgO (1-18%). In general, increasing the CaO content of the slag results in raised slag basicity and an increase in compressive strength.

GGBS is used to make durable concrete structures in combination with ordinary Portland cement and other pozzolanic materials The main use of GGBS is for the superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years

GGBS (also known as GGBS or GGBFS) is manufactured from blast furnace slag, a by-product from the manufacture of iron. It is obtained by quenching molten iron blast furnace slag immediately in water or stream, to produce a glassy granular product that is then dried and ground into a fine powder (GGBS).As GGBS cement is slightly less expensive than Portland cement, concrete made with GGBS cement will be similarly priced to that made with ordinary Portland cement.GGBS (Ground Granulated Blast-furnace Slag) is a cementitious material

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whose main use is in concrete and is a by-product from the blast-furnaces used to make iron. The iron ore is reduced to iron and the remaining materials form a slag that floats on top of their on.

USES:

It is a granular product with very limited crystal formation, is highly cementitious in nature and, ground to cement fineness, and hydrates like Portland cement. GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials.

Advantages of GGBS concrete:

Good workability which helps in better placing and compaction.

Due to the less heat of hydration the temperature rise will be less avoiding the risk of thermal cracking in large volume of concrete.

High resistance to chloride attack which reduces the risk of corrosion in concrete.

Rice Husk Ash:

Combustion of rice hulls affords 'rice husk ash' (acronym RHA). This ash is a potential source of amorphous reactive silica, which has a variety of applications in materials science. Most of the ash is used in the production of Portland cement.[1] When burnt completely, the ash can have a Blaine number of as much as 3,600 compared to the Blaine number of cement (between 2,800 and 3,000), meaning it is finer than cement.

Rice husk ash has long been used in ceramic glazes in rice growing regions in the Far East, e.g. China and Japan.[2] Being about 95% silica, it is an easy way of introducing the necessary silica into the glaze, and the small particle size helps with an early melt of the glaze.

The rice paddy milling industries give the by-product rice husk. Due to the increasing rate of environmental pollution and the consideration of sustainability factor have made the idea of utilizing rice husk.

The reasons behind the usage of rice husk as an alternative for cement in concrete manufacturing are explained in the following sections.

- About 100 million tons of rice paddy manufacture by-products are obtained around the world. They have a very low bulk density of 90 to 150kg/m3. This results in a greater value of dry volume.
- The rice husk itself has a very rough surface which is abrasive in nature. These are hence resistant to natural degradation. This would result in improper disposal problems.
- So, a way to use these by-products to make a new product is the best sustainable idea. Among all industries to reuse this product, cement, and concrete manufacturing industries are the ones who can use rice husk in a betterway.

The rice husk ash has good reactivity when used as a partial substitute for cement. These are prominent in countries where the rice production is abundant. The properly rice husk ashes are found to be active within the cement paste. So, the use and practical application of rice husk ash for concrete manufacturing are important.

The following properties of the concrete are altered with the addition of rice husk:

- The heat of hydration is reduced. This itself help in drying shrinkage and facilitate durability of the concrete mix.
- The reduction in the permeability of concrete structure. This will help in penetrationof chloride ions, thus avoiding the disintegration of the concrete structure.
- There is a higher increase in the chloride and sulfate attack resistance
- The rice husk ashes in the concrete react with the calcium hydroxide to bring more hydration products. The consumption of calcium hydroxide will enable lesser reactivity of chemicals from the external environment.

Applications of Rice Husk Ash:

The rice husk ash is a green supplementary material that has applications in small to large scale. It can be used for waterproofing. It is also used as the admixture to make the concrete resistant against chemical penetration.

The main applications of rice husk ash in the construction are:

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- High-performance Concrete
- Insulator
- Green concrete
- Bathroom floors
- Industrial factory floorings
- Concreting the foundation
- Swimming pools
- Waterproofing and rehabilitation

Granite powder:

Granite Powder and Iron Powder are industrial byproducts generated from the granite polishing and milling industry in powder form respectively. These byproducts are left largely unused and are hazardous materials to human health because they are airborne which can be easilyinhaled.

The test results showed clearly that granite powder of marginal quantity, used as partial sand replacement has beneficial effects on the compressive strength and split tensile strength, modulus of elasticity. The highest compressive strength was achieved in samples containing 25% granite powder. Granite powder, a waste material from the granite polishing industry, is a promising material for use in concrete similar to those of pozzolanic materials such as silica fume, fly ash, slag, and others. These products can be used as a filler material (substituting sand) to reduce the void content in concrete.

Replacement:

0, 25 and 50% as a replacement of sand used in concrete. Mixes incorporating 0% granite powder, or 25% granite powder, or 25% granite powder were designated as GP0, GP25 and GP50 respectively. Cement was replaced with Silica fume, fly ash, slag and superplasticizer for each concrete mixes.

The concrete containing polished granite waste, substituted up to 20% of natural coarse aggregate could be recommended for all applications and the substitution from 20% to 40% could be recommended for non-structural applications, pavement etc.

Granite powder, a waste material from the granite polishing industry, is a promising material for use in concrete similar to those pozzolanic materials such as silica fume, fly ash, slag, and others. These products can be used as a filler material (substituting sand) to reduce the void content in concrete. Granite that contains more quartz and less mica has better construction properties.

From the test results it was found that concrete at the level of 15% partial replacement of cement with granite dust powder has better workability and high compressive strength of 7 days and 28 days curing. The granite dust powder is free of cost. Hence it seems to be economical.

The compressive strength of granite powder concrete was increased when admixtures were used. The compressive strength of GP25 is 2 to 9% higher than that of GP0 for all the days of curing. The other mixes with higher than 25% GP showed lesser compressive strength than the mix with the river sand.

The particles of granite dust are irregular, angular and porous and have rough and crystalline surface texture. The particle size is nearly similar to fine sand. Granite dust particles have interlocking characteristics. The specific gravity of granite dust varies from 2.36 to 2.72 depending upon its source stone.

Table.3: COST COMPARISION OF MATERIALS THOSE ARE REPLACED:

Materials	Cost of Cement without Replacement in Rs	Cost of Cement with Replacement in Rs			
		10%	15%	20%	25%
Fly Ash	743976	-	632382	59518284	
rice husk	743976	-	632382	-	559841
GGBS	743976	-	-	-	557984.2
Granite powder	743976	669580.4	-	595182.8	-

CONCLUSION

Sustainable construction includes techniques that contribute in creating a healthy environment for the future. Perhaps the most popular sustainable construction technique is the use of green building materials. These are sustainable materials sourced from renewable sources and are also recyclable when the building has reached its lifespan. Construction is the necessary process for the man kind at the same time it

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has some drawbacks like pollution which is created during the production of conventional materials like cement, aggregates, admixtures etc. It is necessary to find the solution since it is mainly affecting the environment; Therefore, sustainable method of construction is rapidly gaining momentum on a large scale.

The amount of greenhouse gases mainly CO2 released into the atmosphere as a result of the activities of a particular individual, organization or community is called as carbon footprint. In our project we are mainly focusing on construction activities which may lead to the release of CO2 into the atmosphere which may cause environmental pollution. Hence, we are concentrating on replacing conventional materials by sustainable materials such as rice husk, bamboo, recycled aggregates, waste glass powder, straw bale, sea weed, wood shavings etc. so that the construction method will be ecofriendly

REFERENCES

[1] J. James and P. K. Pandian, "Industrial wastes as auxiliary additives to cement/lime stabilization of soils," Advances in Civil Engineering, vol. 2016, Article ID 1267391, 17 pages, 2016.

[2] P. N. V. Jayanthi and D. N. Singh, "Utilization of sustainable materials for soil stabilization: state-of- the-art," Advances in Civil Engineering Materials, vol. 5, no. 1, pp. 46–79,2016.

[3] G. Kuntikana and D. N. Singh, "Contemporary issues related to utilization of industrial byproducts," Advances in Civil Engineering Materials, vol. 6, no. 1, pp. 444–479,2017.

[4] P. Chindaprasirt , P. Kanchanda , A. Sathonsaowaphak, and H. T. Cao, "Sulfate resistance of blended cements containing fly ash and rice husk ash," Construction and Building Materials, vol. 21, pp. 1356– 1361, 2007.

[5] Gauld , Jasen and Lesurf Stephen , the effective use of GGBS slag to reduce greenhouse gas emissions, Research Concrete Journal, 2006,34,741-744.

[6] Eslayed, A.A, influence of silica fume, GGBS, and High slag cement on water permeability and strength of concrete. Jordan Journal of CivilEngineering.,2011,5,245-257.

[7] Anand Kumar B.G. , Effective utilization of GGBS and supplementary cementitious materials in construction industry. International Journal of Advanced Technology in Civil Engineering., ISSN:2231- 5721,2012 ,107-14.

[8] Arshad A, Shahid, I, Anwar, U.H. C, Baig, and M. N, Khan, S.andShakir, K: 2014,The Wastes Utility in Concrete, Int. J. Environ. Res., 8(4): 1323-1328, ISSN: 1735-6865,pp.1323-1328.

[9] Deepak Bansal, Ramkishore Singh and Sawhney R.L, 2014,Effect of construction materials on embodied energy and cost of buildings—A case study of residential houses in India up to 60 m2 of plinth area, Energy and Buildings, Vol.69, pp260-266.

[10] Elisa, Adorni ., Eva, Coisson., and Daniele, Ferretti.,2013, "In situ characterization ofarchaeological adobe bricks", Construction and Building Materials, Vol.40, pp1-9.

[11] ACI Committee 232, "Use of fly ash in concrete" ACI document 232.2R, Farmington hills, MI1996.

[12] Balgoh ,A., "High- reactivity Metakaolin," Concrete Construction,p.604, July1995.

[13] Berry,E.E. and V.M. Malhotra, fly ash in concrete, Canada Centre of Mineral and Energy Technology(CANMET),Ottawa,1986.

 DOI : 10.35291/2454-9150.2021.0397 © 2021, IJREAM All Rights Reserved.