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Cost Effective ECO-friendly Concrete Made by Assorted Alternative Material: A Review

[1]Thennavan N, [2]Tamil Selvan G, [3]Dharam Rasu R, [4]Vinuvarsith B and [5]Karthik R

[1,2,3,4]B.E., Scholar, Dept., of Civil Engineering, Syed Ammal Engineering College, Ramanathapuram.
[5]Dept., of Civil Engineering, Syed Ammal Engineering College, Ramanathapuram.

Abstract—*The Construction industry is one of the contributing factors to the Environmental related problem; this problem will be minimized by the utilization of the waste materials or industrial by-products from various industries as an alternative source for conventional concrete material. It can be a substitute of conventional concrete materials, the use of such material lead to sustainability in construction sector and conserve the natural resources. There are many environmental related problems created by Cement manufacturing industry, steel manufacturing industry and construction demolition wastes etc., will be solved in due course. The main objective of this paper is to review for achieving maximum benefit from industrial by-products and other waste materials. The purpose of this work is to make a cost effective eco-friendly concrete. This concrete has been made by non-conventional materials such as steel slag with recycled aggregate as a coarse aggregate, copper slag and quarry dust as a fine aggregate and Ground granulated blast furnace slag (GGBS) with small amount of cement as binding material in complete replacement of conventional material such as river sand, crushed stone and large quantity of cement. The strength is same compared to the conventional concrete. The final outcome of this paper to save natural resources used in construction industry and also to utilize waste material by way of industrial product as a replacement of conventional material.*

1. INTRODUCTION

We all know that concrete is an important construction material made of coarse aggregate, fine aggregate and binding material, Crushed stone and river sand are natural resources limited in quantities and production of cement adds CO2 to the atmosphere . As the use of concrete increases, natural resources decrease, and addition of pollution leads other environmental related problems. To minimize the above noted problems we propose the following supplementary and alternative materials for the production of concrete, we believe which will be cheaper than conventional concrete and almost equal to other engineering properties. Here Ground Granulated Blast furnace Slag (GGBS) is replaced for cement, the replacement level varying from 10% to 80%.Copper slag (CS) and crushed stone sand or Quarry Dust (QS) is replaced for fine aggregate(Natural river sand).Crushed old concrete from Construction demolition waste (CDW) with Steel slag aggregate (SSA) are replaced for coarse aggregate (crushed granite stone). Industrial by-products such as steel slag, copper slag, GGBS, construction demolition waste and quarry dust are available in large quantities, are used to make cost effective eco-friendly concrete. Since natural resource are scarce and to bring this new concrete technology into wider use, the government policy support is required, The scope of our research paper to save the natural resource, to utilize waste and by- product from other industries, minimize emission CO_2 in production of cement and a combination of assorted material leading to cost effective concrete

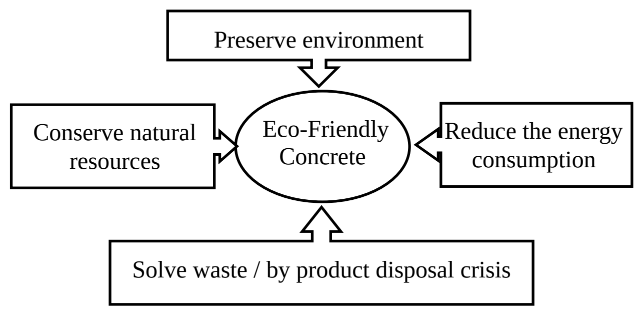

Fig. 1

2. REPLACEMENT CONCRETE MATERIALS AND THEIR PROPERTIES

2.1. Ground granular Blast furnace slag (GGBS)

Ground granular Blast furnace slag is used as subordinate cementitious material in concrete; GGBS is a by-product of iron producing industry. Iron ore, limestone and coke are fed into the furnace, and the consequential molten slag drifts above the molten iron at a temperature above 1500°C. This slag is periodically trap-fall as a molten liquid at it's to be used for manufacture of GGBS. It has to be rapidly quenched in large amount of water. The quenching optimize granules similar to coarse sand, Then slag is dried and grind to fine powder. The molten slag has a composition of 30% to 40% silicon dioxide (SiO2) and approximately 40% CaO, Mgo 6% to 9% which is close to the chemical composition of ordinary Portland cement. GGBS concrete has better water impermeability and as well as improved resistance to corrosion and sulphate attack [1]. The replacement of GGBS with Portland cement will lead to a significant reduction of consumption of cement, reducing carbon dioxide gas emission. GGBS is therefore an environmentally friendly construction material. The fineness in terms of specific surface area is found in lab using Blain's Air permeability apparatus as 3800cm2/gm. Supplementary Cementitious Materials in Concretes are in use for a reasonable long time due to the total economy in their making as well as their improved performance characteristics in aggressive environments. Due to low hydration rate during early age GGBS concrete, curing time should be extended than conventional concrete [2] the ground granulated blast-furnace slag (GGBS) used complied with BS 6699:1992. Typical chemical and physical properties provided by the manufacturer are shown in table [1]

Table 1: Properties of GGBS [1]

Calcium Oxide (CaO)	40%-52%
Silicon Dioxide (SiO2)	10%-19%
Iron Oxide (FeO)	10%-40% (70%-80%, FeO2, 20-30% Fe2O3)
Manganese Oxide (MnO)	5-8
Magnesium Oxide (MgO)	5-10
Aluminium Oxide (Al2O3)	1-3
Phosphorous Pent oxide (P2O5)	0.5-1
Sulphur (S)	<0.1
Metallic Fe	0.5-10

2.2. Quarry Dust (QS)

Natural river sand is used as fine aggregate in concrete. Due to administrative restrictions in India, the cost of rivers and has become two to three time higher than the cost of quarry dust / crusher dust even in places of river nearby. The function of the fine aggregate is to assist in producing workability and uniformity in the mixture. Now-a-days the natural river sand has become scarce and very costly. Hence we are forced to think of alternative materials. The Quarry Dust may be used in the place of river sand fully or partly. A comparatively good strength is expected when sand is replaced partially or fully with or without concrete admixtures. It is proposed to study the possibility of replacing sand with locally available crusher waste without sacrificing the strength and workability of concrete. This is obtained by crushing the stone boulders of size 100 to 150mm in the stone crushers. The particles size below 4.75mm are called as quarry dust [5, 6]

Table 2: Properties of the materials [5],

River sand	Quarry sand
Specific gravity : 2.53	Specific gravity : 2.57
Fineness modulus : 3.08	Fineness modulus : 2.41
Density : 1.63gm/cc	Density : 1.85gm/cc
Voids ratio : 0.55	Voids ratio : 0.42

2.3. Copper slag (CS)

Copper slag is one of the by-products obtained from copper manufacturing industries. To produce every tons of copper, approximately 2.2–3.0 tones copper slag is generated as a by-product material. And fine aggregate replacement material in concrete depends upon the properties of the material [8]. Slags containing <0.8% copper are either discarded as waste or sold cheaply. Several studies have been reported by investigators from other countries on the use of copper slag in cement concrete and mortar. The copper slag is a black glassy particle and granular in nature and has a similar particle size range like sand. The bulk density of granulated copper slag is varying from 1.9 to 2.15 g/cc. The free moisture content present in the copper slag was found to be less than 0.5% and the presence of silica is about 26%, which is desirable since it is one of the constituents of the natural fine aggregate used in normal concreting operations.Table:3 shows the physical properties of copper slag. The specific gravity and water absorption for copper slag and sand were determined as per IS 2386 Part III [7].

Table 3: Physical Properties of Copper Slag [7]

Physical properties	Copper slag
Particle shape	Irregular
Appearance	Black and glassy
Type	Air cooled
Specific gravity	3.37
Percentage of voids	43.20%
Bulk density	2.08 g/cc
Fineness modulus	3.43
Water absorption	0.3–0.4%
Moisture content	0.1

2.4. Recycled aggregate (RCA)

RA is extracted through the processing of the debris generated from demolished concrete structures and other construction debris such as waste concrete, rejected precast concrete members, broken masonry, concrete road beds and asphalt pavement, leftover concrete from ready mix concrete plant and the waste generated from different laboratories. RAs may be of different types such as brick aggregate, glass aggregates, asphalt and bitumen aggregate, concrete aggregates, tiles and marbles recycled from flooring, finishes and ceramic products. Aggregate typically processed by the crushing of parent or old concrete such as demolished waste concrete is regarded as recycled concrete aggregate (RCA). Generally RCAs are mixed with bricks, tiles, metals and other miscellaneous such as glass, wood, paper, plastic and other debris. The concept of use of RA from demolished concrete structures was introduced into practice dates back to the time of World War II in Europe. Earlier it had been used as unbound sub base materials for pavement. Now-a-days it is being used for construction purposes also [12].

2.4.1. Recycling process

Recycling is an act of processing the used material for further utility in developing new value added products. The integral technique behind recycling process includes the breaking of demolished concrete to produce smaller size fragments by subjecting to a series of performances such as removal of contaminants (reinforcement, wood, plastic etc.), different stages of screening, and sorting. Higher quality aggregates can also be processed in steps with time and effort involved in stock piling, crushing, pre-sizing, sorting (pre-crushing and post crushing), screening and contaminant elimination depending upon the level of contamination and the application for which the recycled materials will be used. Demolition debris can be crushed by several crushers such as jaw crusher, hammer mill, impact crusher, and cone crusher or manually by hammer, Different crushers have different consequences on the physical and mechanical properties of RAs depending upon the effectiveness of crushing processes, and consequently it affects the concrete performance also. Jaw crushers are mainly used for primary crushing as it can crush oversized concrete pieces into comparable size for secondary crushing. Impact crushers are preferred for secondary crushing as they produce a better quality of aggregate with less adhered mortar content. Desirable grading for RAs can be achieved by crushing through primary crushers successively through secondary crushers. The selection of crushers at various stages depends on several factors such as maximum feed size, quality of output, desirable particle size and shape of the various fractions, and amount of fines produced. These days with the help of mobile crushing plants and some portable equipment, recycling facility can be established on site for immediate use of product and also the freight distance can be reduced. Along with the above mentioned dry processes, wet processing technique for RA provides better quality aggregate with less organic and inorganic impurity. However, in some developed countries like Japan, China, USA and Netherland, the researchers have developed some advanced processing techniques to minimize the adverse effect of RA. By adopting these methods, high quality aggregates can be produced by removing the adhered mortar without losing the integrity of original coarse aggregate. Some of these techniques are nitric acid dissolution method, presoaking treatment, freeze–thaw method, thermal expansion method, microwave heating method, heating and rubbing method, mechanical grinding method and ultrasonic treatment method etc., [12].

2.4.2. Recycled aggregates properties

RA, derived from C&D waste generally consists of natural coarse aggregate and adhered mortar. The old clinging mortar mostly contains fine aggregate, hydrated and un-hydrated cement particles. The quality of RA mostly depends on the methods of recycling process to be adopted but the properties of RA mainly depend on the water/cement (w/c) ratio of the original concrete from which it is obtained. The most distinguished feature of RA is its old adhered mortar which makes it porous due to high mortar con-tent, inhomogeneous and less dense. The volume of the residual mortar in RA varies from 25% to 60% according to the size of aggregate. Some researchers have reported in their studies that around 20% of cement paste is found attached to the surface of RA for particle size range from 20 to 30mm. Reported that RA extracted from crushing of waste concrete consists of 65–70% natural coarse and fine aggregate and 35–30% of cement paste by volume [12].

2.5. Steel slag aggregate (SSA)

Residual slag from Steel manufacturing, one of the most common industrial wastes, is a by-product of steel production. It is a non-metallic ceramic material. Steel slag aggregate, different form blast furnace slag, is also an inevitable by-product which is up to 20% of the production of crude steel in steelmaking process. The annual yield of steel in India has ranked first among the world, nearly 20 to 25 million tons of steel slag is generated in 2013. These waste materials are otherwise not useful and so have been dumped as landfill in the surrounding area of the industry. Steel slag aggregate is almost similar to coarse aggregate and its properties.

Table 4: Physical Properties of Steel Slag and Granite stone [16]

Properties	Steel slag	Stone Aggregate
Specific gravity	2.61	2.8
Loose density	1382kg/m3	1395 kg/m3
Compacted Density	1520kg/m3	1580 kg/m3
Crushing strength	26%	36.52%
Impact strength	12.86%	9.03%
Water Absorption	0 – 3	0.5

2.6. Chemical admixture (CA)

Modified Polycarboxylic ether based super plasticizer is to give Resistance to segregation and bleeding even at high workability, and Mixes require >20% water reductions

3. PREVIOUS TECHNICAL LITERATURE REVIEW

We have obtained following information and data from the scholar acknowledged. These are used as foundation for this technical review paper

According to K. Ganesh Babu et al, - GGBS can be used varying proportion resulting in various compressive strength, level of replacement varying from 10% to 80% but optimum use rang is 50% and 65% of replacement of cement to gives the desirable strength compared between conventional concrete for his experimental results, it is proved that GGBS can be used as an alternative material for cement to certain extant, reducing cement consumption and thereby reducing the cost of construction.

Referring to Saud Al-Otaibi – the use of 60% GGBS as replacement of Portland cement decreases the porosity of ordinary Portland concrete mixture, since GGBS acts as a filler material

According to Khalifa S. Al-Jabri et al – the copper slag is used as a partial replacement of the fine aggregate with various combinations. The efficiency of copper slag is more than 70% improvement in compressive strength, compared to the conventional mixture at 50% replacement of copper slag as fine aggregate, decreasing permeable voids with replacement of 50% copper slag. Above 50% of copper slag substitution lead to decrease the mechanical properties of concrete, such as compressive, tensile and flexural strength of concrete compared to conventional mixture. When copper slag replacement quantity increases up to 40%, the surface water absorption will be increased.

With the reference to G.Balamurugan et al, - quarry dust is a replacement for fine aggregate. Split tensile strength, compressive strength and flexural strength are higher at 50 % replacement of natural sand by quarry dust. The percentage of increase in strength is obtained when compared with conventional concrete. The Quarry dust can be utilized in concrete mixture as a quality substitute instead of river sand to an optimum strength at 50% replacement.

Reading through to Sonali K. Gadpalliwar et al. - Mix combination gradation of 45% Quarry dust and 55% Natural Sand meet the grading limits of IS: 383, But it has been found that on adding more percent of Quarry Dust i.e. 60% Quarry dust and 40% Natural Sand in concrete gives maximum compressive strength. Concrete gets maximum increase in compressive strength at 60% quarry sand replaced by natural sand for M40 grade of concrete [6].

With due acknowledgment to E. Anastasiou et al, -The combination of CDW with SSA, which give excellent coarse aggregate properties. SSA is partly recovering strength loss of CDW and also improves the concrete microstructure by providing good aggregate-binder bonding [13].

According to Hisham Qasrawi et al -The use of RCA as coarse aggregate in concrete mixes resulted in a decrease in the strength depending on the replacement ratio and the grade of concrete. The use of steel slag as 67% replacement of RCA enhanced the strength. Therefore, it is recommended to replace part of RAC by steel slag. The use of RCA has an adverse effect on the air content in concrete especially for replacement ratios exceeding 25%. The presence of slag did not solve the problem. The percentage reduction in compressive strength is more than that in flexural strength when RCA or slag is incorporated. However, the strength reduction in slag-containing mixes is much less and thus can produce better structural concrete. The use of RCA has a severe effect on the workability of concrete. The use of slag as 67% replacement did not solve the problem. RCA has an adverse effect on the modulus of elasticity of concrete irrespective of the w/c ratio or the RCA replacement ratio. On the other hand, the use of SSA with RCA resulted in an increase in the modulus of elasticity of recycled aggregate concrete (RAC). Because of the usefulness of using steel slag in RCA mixes, it is recommended to include it as a possible simple and environmentally safe method to enhance the mechanical properties of RCA hardened concrete. [14]

4. PRESENT SCOPE OF RESEARCH

The present review paper explains for the state-of the art report on the usage of industrial by-product and waste as construction materials in developing the new concrete.

We obtained a lot of information from past research papers, regarding the advantage and disadvantage of waste material used in the concrete. It is studied and an economical and new compromise is reached. The resultant concrete is quality wise same as conventional concrete.

According to the past technical literature review, the main component of concrete – cement is partially replaced by GGBS from 10% to 80% giving various strength. Second Component - fine aggregate – natural river sand is replaced either by 65% quarry dust or 50% copper slag. The final component coarse aggregate – crushed stones of various sizes is replaced by RCA 33% with 67% steel slag.

The following flow chart to represent the Present research scope:-

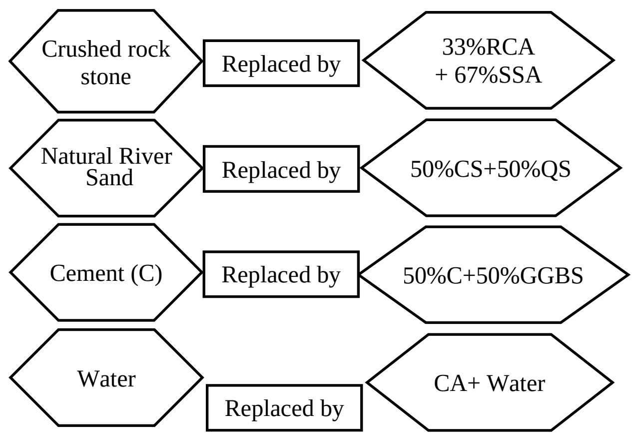

Fig. 2

In our present scope of research we suggest 50% GGBS with 50% cement, which gives the quality of ordinary Portland cement thereby minimizing 50% manufactured cement and using the by-product 50%with result in cost reduction and waste management. For the fully replacement of river sand – fine aggregate we recommend to use 50% quarry dust with 50% copper slag. This is a complete replacement of river sand there by saving the natural resource river and its connected problems. For the complete replacement of coarse aggregate it is done by 33% RCA with 67% SSA, there by fully eliminating destruction of rock and using the industrial by-product steel slag. This kind of combination of material to make concrete is possible that gives all the quality of conventional concrete. Comparison between the conventional and Eco-friendly concrete

5. CONCLUSION

The concrete in construction industry plays major part, the natural materials required for concrete are becoming scarce, and another important material cement production leads to pollution. At the same time so many industrial wastes and by products are piling up in large quantities. The past and present scholars are studying and researching alternative or replacement material for concrete in various combinations. By our study scholars have tried replacement of one material for one material in various proportions, the results analyzed with reference to engineering properties. By going through these data, we will do a trail mix of concrete in above said combination as per fig 2. It will give almost equal engineering properties of conventional concrete.

The various combination and proportion of material required for this new concrete technology can be easily done by RMC plant which is not possible in the past, Batching plant are computer controlled, different material can be stored and regulated precisely by computerized system. Concrete produced in controlled atmosphere are tested and then produced. We will sure of concrete quality that is produced

1. Long term behavior (mechanical and durability performance) of new concrete is not well known. Thus more research needs to be conducted in this area
2. Proper modeling relationship should be established between compressive strength, split tensile strength and flexural strength of this new concrete.

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