Utilization of recycled aggregate, plastic, glass waste and coconut shells in concrete - a review

A Gupta¹, N Gupta², A Shukla³, R Goyal⁴ and S Kumar⁵

¹Assistant Professor, DOCE, GLA University, India
²Assistant Professor, DOCE, GLA University, India
³PhD Scholar, DOCE, GLA University, India
⁴Dean, NICMAR, NCR, India
⁵Associate Professor, JC Bose University of Science and Technology, YMCA, Faridabad, India
E-mail: ankur.gupta@gla.ac.in

Abstract
It is evident that the exploitation of waste increases insignificantly every year worldwide and is not recycled as per the need of the environment. Recycling of waste consumes a lot of energy and also leads to environmental pollution. In recent years, managing the waste which is causing a lot of environmental issues is one of the critical problems faced by the world. This waste mainly includes constructional demolition waste, agricultural waste, glass and plastic waste. All these cause a problem to dispose of after they have been used once. In order to deal with such a situation, the application of such waste in concrete production has become a great means of managing them. These wastes can be utilized as a partial or complete replacement of certain ingredients of the concrete. The recycling of these waste materials in concreting not only helps in managing solid waste but also renders the occurrence of natural resources. This review paper will provide an understanding of the adoption of waste materials as a resource during concrete production.

Keywords: Waste Materials, Recycled Aggregates, Plastic, Glass Waste, Coconut Shell.

1. Introduction
As the population is increasing, waste is also increasing every year at a faster rate. These wastes can be degradable and non-degradable. Non-biodegradable waste remains for long-lasting years due to non-decomposition of matters, causing a problem of solid disposal. The problem of waste handling and management occur all over the world, especially in countries which are densely populated. In the recent scenario, some of the waste like plastic, demolished concrete and glass has been adopted as a building material[1]. Hence, utilizing a subsequent amount of waste as an ingredient of the concrete has reduced the load on the natural source of the ingredients of concrete, such as aggregates and sand, to a reasonable percentage. In the field of construction, concrete is the world’s second last consumed material around the globe and is preferred in almost all civil engineering works[2].

2. Aims and Objectives
Aggregates constitute around 3/4th part of concrete element hence it will be advantageous to reuse them in construction and saving environmental impact due to liberation of heat evolved within it in the form of hazardous gases[3]. The major source for the emission of CO₂ in the atmosphere is the cement production which is one of the key ingredient for the production of concrete. Reuse of the waste materials of the construction and agriculture sectors such as demolished concrete, plastic, glass,
coconut shells etc. is a beneficial footstep to cater for these reusable aggregates[4]. In addition, acquiring the recycled aggregate is much easier due to low cost and wide availability than the natural resources. Also, the landfill with these types of wastes has become a source of air, water and soil pollution. Now a day’s use of such, industrial and agricultural wastes are considered as substitute replacements of some proportion of the conventional aggregates of concrete.

3. Materials and Methods
The cost of materials used in construction is growing tremendously. In our country, the price of a cement bag goes on increasing from Rs. 125 to Rs. 350 for a single bag from 1995-2015. The exploration of the river’s sand is banned due to shortages of the natural source because of many environmental hazards. Increased interest in environmental protection and development of a sustainable environment has led some governments to emphasis on alternate resources. Destroyed areas and commercial shut down are the main sources of recycled waste where it can be found in an abundant quantity. Recycled aggregates are desirable from preserving natural sources perspective and finally preserving natural sources for a later stage which ultimately reduces the trouble of disposal. Recycling as a simple process involves the collection of these sources from the sites, transporting to the desired locations, crushing and graining to the desired degree and shapes which fulfil the basic and desired properties. Since the use of these products can be frequently done in road pavement construction hence it should be considered as one of the alternatives.

3.1 Recycled Concrete Aggregate
These waste material is bringing down to the desired shape and size and reflecting approximately the same properties as that of aggregate and these are not affected by original concrete quality. However aggregates of this concrete show lesser specific gravity and greater porosity in concrete to natural aggregates. This concrete loses workability fast due to the porous nature of these aggregates. Hence demanding more water to achieve the same workability. A good quality recycled aggregate shows good results that are necessary for the concrete such as crushing and impact value, and Los angles abrasion value[5]. An interchange of aggregate by 40% shows no or little change in terms of the compressive strength but at higher percentages causes decline in the compressive strength and complete substitution shows a fall of up to 28% in strength directly and also other results may increase such as workability, greater drying shrinkage, creep and modulus of elasticity and greater water absorption when compared to the traditional cement concrete. From the strength viewpoint, the utilization of such aggregates may be considered for the construction of roads, bridges, sub-structural elements etc. Following are the experimental works on the utilization of recycled aggregates in concrete[5–10]

| S.No | Author & Country | Ref. No. | Material Replaced | % Replacement | Examined Properties |
|------|------------------|---------|------------------|---------------|---------------------|
| 1.   | Asif Husain Majid Motouq Assas | [5]     | Coarse Aggregates | 0, 25, 50, 75 and 100 | Water Absorption, Sieve Analysis, Crushing value, Los Angeles Abrasion, Workability, Compressive Strength. |
| 2.   | N.Sivakumar S.MuthuKumar V.Sivakumar | [6]     | Coarse Aggregates | 0, 10, 20, 30, 40 and 50 | Acid Resistance, Water Absorption, Workability, Compressive and Tensile strength |
| 3.   | Mirjana Malasev Vlastimir | [7]     | Coarse Aggregates | 50 and 100 | Compressive and Flexural Strength, Drying Shrinkage, |

TABLE 1. Utilization of recycled aggregates in concrete.
3.2 Plastic Waste:
Plastic has very low biodegradability hence it remains for up to thousands of years in the earth’s crust hence its amount increases gradually and finally stored in bulk quantity, causing a problem of disposal resulting in land and water pollution and thereby creating a challenge for the disintegration of non-recyclable thin plastic waste around the world[11]. Even today around 15% of total plastic waste remains untreated. A number of researches were piloted to identify the variations in the properties of the concrete by analysing the behaviour of non-recyclable waste on when it is used as a substitute for aggregates. The application of this waste into concrete helps in managing environments aspect. Enhanced tensile strength of system can be acquired by just aiding of this powdered form of plastic. However, the plastic as aggregates in concrete reduces its compressive strength as compared to the conventional cement concrete. Hence the use of plastic may be preferred where loads are insignificant like drainage boundary, street roads etc[12].

![Diagram](image-url)

**Figure 1.** Stages of acquiring plastic bags [13]

Literature survey shows that a substantial number of studies have also been conducted on the utilization of plastic as aggregates in concrete. Table 2 below shows the studies based on substitution of fine aggregates by plastic in concreting [14–18].
TABLE 2. Substitution of fine aggregates by plastic in concreting.

| S.No. | Author & Country                  | Ref. No. | Material Replaced | % Replacement | Examined Properties                                                                 |
|-------|-----------------------------------|----------|-------------------|---------------|-------------------------------------------------------------------------------------|
| 1.    | M B Hossain, P Bhowmik Bangladesh | [14]     | Fine Aggregate (Sand) | 0, 5, 10, 20  | Compressive & Tensile Strength, Unit weight, Stress-strain Behaviour and Water Absorption |
| 2.    | MastanVali N A.P India            | [15]     | Fine Aggregate (Sand) | 0, 5, 10, 15, 20 | Split Tensile and Compressive Strengths                                               |
| 3.    | Youcef Ghernouti, Bahia Rabehi, Algeria | [16] | Fine Aggregate (Sand) | 10, 20, 30, 40 | Flexural, Compressive Strengths and UPV                                               |
| 4.    | M.Mahesh, B.Venkat Narsimha Rao, India | [17] | Fine Aggregate (Sand) | 20            | Split, Tensile and Compressive Strengths                                             |
| 5.    | M.M.Rahman, M.A. Mahi, T.U.Chawdhary Bangladesh | [18] | Fine Aggregate (Sand) | 0, 3, 7, 20, 30 | Water Absorption, Porosity and Compressive Strength                                    |

3.3 Glass Waste:
Enormous quantities of glass waste are generated every year world-wide. Glass is one of those non-biodegradable materials that cannot be easily decomposed. The production of glass involves liquefying the complexes like SiO2, CaCO3 etc. at an elevated temperature and then cooling it to make it stiffened which results in a crystalline transparent material. The inherent properties of glass are somewhat identical to fine aggregates vis. sand. Hence it can be thought of as a possible alternative of fine aggregates, mainly sand. This may lead to preserving rivers and land. Utilization of this waste in the production of concrete will help a lot in overcoming the problem of its safe disposal. This step will ultimately cause a reduction in the release of carbon-di-oxide and some other degrading gases[19]. The application of glass waste by replacing cement with some parts of it in concrete will result in eco-friendly, economic construction and energy-saving step[20]. The glass will undergo two main reactions, in which one is beneficial while others damage the concrete. These reactions are the alkali-silica reaction and pozzolanic reactions. The concrete structure is damaged to a great extent due to alkali-silica reaction[21]. If the water to cement ratio is not the subject matter the around 27% increase in strength can be achieved as compared to conventional batch if 20% of cement content is replaced by glass waste[22]. However, beyond 20% substitution is under research[23]. Table 3 below shows the experimental work done on replacement of cement by the powdered glass in concrete mix[24–27]

Table 3. Replacement of cement by the powdered glass in concrete.

| S.No. | Author & Country                  | Ref. No. | Material Replaced | Mix Proportion | Examined Properties                                           |
|-------|-----------------------------------|----------|-------------------|----------------|---------------------------------------------------------------|
| 1.    | G.M.Sadiqual Islam, M.H.Rahman, NayemKazi, Bangladesh | [24]     | Cement            | 15 and 20      | Compressive Strength, Flow Test, Water Absorption             |
| 2.    | GunalaanVasudevan, Seri Ganis Kanapathypillay, Malaysia | [25]     | Cement            | 10, 15, 20     | Compressive Strength, Bulk Density                            |
| 3.    | J.M.Khatib, E.M.Negim, Malaysia | [26]     | Cement            | 10, 20, 30, 40 | Compressive Strength and UPV                                 |
| 4.    | Sayisetti Rajaiah, AVS Sai Kumar and T.Shirisha, India | [27]     | Cement            | 10, 20, 30     | Compressive strength at age of 7, 14 and 28 days              |
3.4 Coconut Shells:
The increased cost of the ingredients of the concrete is a prime factor in moving towards the alternatives in construction. Coconut shell, when utilized as a source of aggregate in concrete production, serves the purpose of managing the waste generated by these shells and hence preventing the degradation of the environment, decreasing potential use of natural resources hence conserving sources[28]. In this paper, inherent properties like density, workability and compressive strength with the partial replacement of aggregates with the coconut shell are studied[29]. In construction industry cement concrete is the vital material due to its inherent properties such as versatility, economy, durability and ease of construction. Therefore the application of some commercial and agricultural waste becomes popular in the recent years[30]. Coconut shell is the outer cover of the coconut which can be used as reinforced material, aggregate or in powder form, having a particle size between 20 mm.- 600 micron and density nearly about 1.6 gm/cm³. These shells can be used as an external agent to enhance the concrete properties due to their higher modulus rigidity[31].

![Figure 2. Broken coconut cover](image1)

![Figure 3. Shredded conut outer shell](image2)

Table below shows the experimental work done on replacement of coarse aggregate by coconut shells [32–37]

| S.No. | Author & Country       | Ref. No. | Material Replaced | % Replacement | Examined Properties               |
|-------|------------------------|----------|-------------------|---------------|-----------------------------------|
| 1.    | E.A.Olanipekun, K.O.Olusola O.Ata Nigeria | [32]     | Coarse Aggregates | 0, 25, 50, 75 and 100 | Compressive Strength, Water Absorption, Density, Unit Weight and Sp.Gravity |
2. B. Damodhara Reddy, S. Aruna Jyothy, A.P India [33] Coarse Aggregates 0, 10, 15, 20 and 25. Also cement was replaced by fly ash Workability, Compressive Strength, Flexural Strength, Split Tensile Strength

3. Amarnath Yerramala, Ramachandrudu C Anantpur, India [34] Coarse Aggregates 0, 10, 15 and 20 Compressive Strength, Flexural Strength, Split Tensile Strength, Water Absorption, Permeability

4. Parag S. Kamble, Sandhya R. Mathapati, Pune, India [35] Coarse Aggregates 10, 15 and 20 Compressive Strength, Water Absorption, Density, Cost Analysis

5. Abdullah Anwar, Sabilh Ahmad, Syed Aqueel Ahmed [36] Coarse Aggregates 0, 5, 10, 20, 30, 40 and 50 Compressive Strength at 7, 14 and 28 days of curing

6. Jerin M. George, Ashish Babu, George Franco, Kerala, India [37] Coarse Aggregates 0, 25, 50 and 100 Compressive Strength, Flexural Strength, Split Tensile Strength and Workability

4. Conclusions
Based on the literature survey, the following conclusion can be made:
1. Utilizing the recycled waste, glass, plastic waste and coconut shell as a partial replacement of coarse, fine aggregates and cement in concrete may lower down the need of the original ingredients of cement concrete and it also serves as a means to manage these environmental wastes.
2. Recycled concrete aggregates may cause a reduction in compressive strength if it is used beyond 40%. It also increases creep and drying shrinkage of the concrete.
3. Absorption of water of recycled aggregate increases from 1.5% to 4.6% causing more water demand but some artificial plasticizers can be used to overcome this loss of water.
4. From the study, it is evident that the strength of such concrete made up of recycled aggregate is not lesser of 90% in contrast to conventional concrete.

Hence, these wastes as a source can be used as a partial replacement of aggregate which ultimately saving the natural resources and hence this study is providing the guidelines for the user to opt these waste materials in concrete production.

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