Concrete with Alternative Aggregates - Green Concrete

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Abstract - *Concrete is the most largely consumed construction material worldwide. The Portland cement and concrete is a major consumer of natural resources. Rate of development of infrastructure has increased year by year. Regular use of aggregates for making concrete cause depletion of natural resources like rock, minerals etc. we know these natural resources are limited and cannot be developed further again and again. Besides of this the production of raw materials used in concrete such as aggregate and Portland cement requires a significant amount of energy input and causes various environmental problems (e.g., emission of greenhouse gases). The "green" concrete is defined as the concrete produced by utilizing alternative and/or recycled waste materials which are eco-friendly so that can reduce energy consumption, environmental impact, and use of natural resources. One of major issues associated with "green" concrete are what can be alternatives/waste for replacing conventional aggregate and how the alternative/waste materials affects concrete properties compared with the conventional Portland cement concrete. Another important issue is "the benefits and barriers of producing "green" concrete" by replacing conventional aggregate. This paper first discusses suitability /potential benefits of using alternative and/or waste materials as aggregate in concrete production, followed by a review of previous studies on "green" concrete. This paper further investigates what are the different alternative/waste materials that can be used as aggregate by replace conventional aggregate in concrete production, followed by a review of previous studies on "green" concrete. In last it discusses barriers in using alternative/waste materials.*

Key words: **alternative aggregate, waste recycle, coarse aggregate, green, conventional**

1. Introduction

Concrete industry is a major consumer of natural resources like rock, minerals, potable water and fossil fuel, which is increasing year by year resulting of this faster rate of depletion of such natural resources. Concrete contains four basic ingredients: water, cement, fine aggregate (sand) and coarse aggregate. Manufacturing of concrete and its production have a significant adverse impact on the environment because the manufacturing of the main constituent of concrete, Portland cement is responsible for emission of about 7% of total global anthropogenic CO_2. The production of concrete also releases GHGs, which includes the emission from mining of raw materials, transportation, construction, maintenance, demolition and disposal processes at the end of life of infrastructure constructed with concrete. In the light of limited natural resources and adverse impact on the global climatic change, the concrete industry plays a vital role by encouraging the technology for the use of greener concrete for prolonged service life, reduction in energy required, and minimum production of GHGs emission from manufacturing and transportation of materials and products of concrete.

The use of supplementary cementitious materials (SCMs) in place of conventional cement and recycled/ alternative aggregates and other industrial wastes could reduce the environmental impacts of concrete production. In this study, we are focusing on aggregates from recycled waste streams or other non-conventional aggregate materials (e.g., lightweight aggregate). These are defined as alternative aggregate (AA). We achieve our purpose by using agricultural and industrial wastes as replacement materials in the concrete industry. It has dual advantages of cost reduction and a better way of waste disposal. The material recovery from the conversion of these wastes into useful materials benefits both the environment and the conservation of natural resources.

2. Role of Aggregate in Concrete

Even though aggregate typically accounts for 70% to 80% of the concrete volume, it is commonly thought of as inert filler having little effect on the finished concrete properties. However, research has shown that aggregate in fact plays a substantial role in determining workability, strength, dimensional stability, and durability of the concrete. Also, aggregates can have a significant effect on the cost of the concrete mixture. So it is the baseline for every construction.

3. Alternative Materials for Concrete

Conventional concrete aggregate consists of sand (fine aggregate) and various sizes and shapes of gravel or stones obtained through rocks that are limited in the environment, so we are discussing about some of the alternatives for aggregate.

3.1 Coconut shell as aggregate

Coconut shell particles are used as reinforcing material for investigation. Shell particles of size between 20 mm – 600 μ are prepared in grinding machine. Coconut shell aggregates are potential candidates for the development of new composites because of their high strength and modulus properties. An approximate value of coconut shell density is 1.60 g/cm3.

Coconut shell being a hard and not easily degrade material if crushed to size of sand can be a potential material to substitute sand. At present, coconut shell has also been burnt to produce charcoal and activated carbon for food and carbonated drink and filtering mineral water use. However, the coconut shell is still under utilized in some places. The chemical composition of the coconut shell is similar to wood. It contains 33.61% cellulose, 36.51% lignin, 29.27% and ash at 0.61%.

3.2 Stone Crusher Waste as Fine Aggregates

Quarry Rock Dust can be defined as residue, tailing or other non-valuable waste material after the extraction and processing of rocks to form fine particles, less than 4.75mm. Quarry dust is made while blasting, crushing, and screening coarse aggregate. Quarry dust has rough, sharp and angular particles, and as such causes a gain in strength due their availability and applicability to better interlocking.

3.3 Waste Plastic as Concrete Composite

Plastic is a material that is being developed for various applications like product packaging, bottling, plastic Bucket, plastic glass, bottles, mugs, plastic furniture's, plastic utensils, plastic auto parts etc. This cheap flexible and strong material is unfortunately non-biodegradable MSW whose disposal is becoming menace. Plastics can be separated into two types. The first type is thermoplastic, which can be melted for recycling in the plastic industry. These plastics are polyethylene, polypropylene, polyamide, polyoxymethylene etc.

The second type is thermosetting plastic. This plastic cannot be melted by heating because the chains are bonded firmly with meshed crosslink's. These plastic types are known as phenolic, melamine, unsaturated polyester, epoxy resin, silicone, and polyurethane. At present, these plastic wastes are disposed by either burning or burying. However, these processes are costly. Rebeiz (1996) [4] investigated the strength properties of un-reinforced and reinforced polymer concrete using an unsaturated polyester resin based on recycle polyethylenerephthalate (PET) plastic waste. The results showed that the resins based on recycled PET can be used to produce a good quality of precast concrete.

3.4 Aggregates by Crushed Rubber from used tyres

When vehicles tires reach the end of their usable life, they can still find some use as a replacement for course aggregate in concrete mixes. Crumb rubber is car or truck tires that are ground up between the sizes of 3 - 10 mm. This mix has very poor compressive strength due to its high air content. It is believed that when this rubber is mixed in with the concrete air becomes trapped in with it. One benefit to the addition of this alternative is the rubber keeps the concrete from shattering in failure.

3.5 *Aggregate from Crushed Concrete*

Concrete and roadways and buildings eventually reach its defined end of life. Today is it common practice for this concrete to get processed into fresh concrete again. Demolished concrete goes through a process that crushes it down to small course sized aggregate so that it can be used again in building projects. For many areas including Michigan, this practice makes more sense than using virgin aggregate for every concrete project.

3.6 Post consumer Glass

Concrete with glass aggregate is a material mixture that has a lot of potential but also a lot keeping it from reaching this potential. Any type of glass when broken down to about #8 to #4 sieve. With compression strengths comparable to that of normal weight concrete and when glass powder has the same gluing effect as cement, Glascrete is the best aggregate alternative of the list. Under ideal conditions this may be the case but there are reasons this material has not seen wide adoption. Glass is well known for having issues with ASR (alkali-silica reaction). When this silica chemically reacts with naturally occurring hydroxyl ions in the cement, silica gel is formed and causes cracks in the cement at it absorbs water. Glass is also very expensive to properly clean. Any residue leftover on glass such as organics or sugar can also negatively affect the strength of concrete. For those who can overcome these obstacles concrete made from glass is the best option.

3.7 Papercrete

Papercrete is a hybrid material made of paper slurry, white lime or sand, and portland cement. To make this type of concrete, add paper pulp, any waste paper will be appropriate, to a basin of water and allow soaking for 24 hours. After this time, mix slurry for ten minutes using a mixer and drain the excess water. The recommended ratio is 1:0.5:4 (portland cement:white lime:paper sludge). Add water as needed to make the mixture workable. This creates a concrete that is not acceptable for structural projects. Walls not used to support have been found to have decreased thermal conductivity and better sound absorption. Because the strain on this type of concrete is so much larger than the stress, walls such as these although being strong will show large amounts of deflection under load.

3.8 *Plastic*

High-density polyethylene can be added to concrete and sand as a feasible replacement for course aggregate. Research has shown that plastic bags that are tightly packed and then heated shrink to a size that can easily be used in concrete. But as the name implies, the material is too ductile at full strength to support structural loads at 2500psi. One benefit to this material is its measurable qualities in holding heat within buildings

3.9 *Fly Ash*

Several lightweight concrete aggregates can be produced from fly ash. In addition to the use of furnace bottom ash in concrete masonry, pellets of fly ash can be bound by thermal fusion or chemically, using cement or lime. Such materials have many desirable properties some other material that can be used are **china clay waste, slate waste and pulverized fuel ash***.*

4. Suitability of Green Concrete in Structures

Several factors which enhance the suitability of green concrete in structures include:

- *Aggregate composed of recycled concrete generally has a lower specific gravity and a higher absorption than conventional gravel aggregate.*
- *New concrete made with recycled concrete aggregate typically has good workability, durability and resistance to saturated freeze-thaw action.*
- *The compressive strength varies with the compressive strength of the original concrete and the water-cement ratio of the new concrete. It has been found that concrete made with recycled concrete aggregate has at least two-thirds the compressive strength and modulus of elasticity of natural aggregate concrete.*
- *Reduce the dead weight of a structure and reduce crane age load; allow handling, lifting flexibility with lighter weight.*
- *Good thermal and fire resistance, sound insulation than the traditional granite rock.*
- *Good thermal resistant and fire resistant.*
- *Improve damping resistance of building.*
- *Speed of construction, shorten overall construction period.*
- *Reduction of the concrete industry's CO_2 emission by 30 %.*
- *Increased concrete industry's use of waste products by 20%.*
- *No environmental pollution and sustainable development.*
- *Green concrete requires less maintenance and repairs.*
- *Green concrete sometimes give better workability than conventional concrete.*
- *Compressive strength behaviour of concrete with water cement ratio is more than that of conventional concrete.*

5. Barriers in Implementing "Green" Concrete

Despite the potential benefits from using "green" raw materials in concrete production, there are barriers to the wide application of potential AAs. Generally speaking, the barriers exist in concrete properties, cost effectiveness, and industry perception as explained below

5.1 Concrete properties:

- *Using waste streams as concrete ingredients could improve certain types of concrete properties while undermining some others. For example,*
- *Glass aggregate in concrete can be problematic due to the alkali silica reaction between the cement paste and the glass aggregate, which over time can lead to weakened concrete and decreased long-term durability.*
- *It is found from research that using crushed oyster shell maintained or improved the compressive strength but decreased the workability.*
- *The chemical reaction between silica-rich glass and the alkali was a major concern when using glass in concrete (Batayneh et al., 2007).*
- *Concrete containing plastic aggregate decreased compressive and tensile strengths (Siddique et al., 2008).*

5.2 Cost effectiveness:

Cost effectiveness would be the driving force for the industry to implement "green" concrete. But it has its own drawbacks:

- *Recycling and reuse of wastes requires extra labour and energy input.*
- *Batayneh et al. (2007) suggested that the cost between crushing wastes (e.g., glass, plastic and RCA) and supplying prime aggregate (gravel) should be compared in project management.*
- *Similarly, Meyer (2009) recommended comparing the transportation cost between RCA (recycled concrete aggregate) from construction & demolition debris and virgin aggregate.*

5.3 Industry perception/practice:

- *The construction and building product industry is conservative in nature due to the fear of product failure, which becomes a barrier to the utilization of waste materials as pointed out by Duxson et al. (2007).*
- *They also indicated the existing negative perceptions of the industry on non-conventional practice in concrete production, which may not be always true. For example, fly ash-contained cement was perceived to have the poor freeze-thawresistance. Also, the industry tends to follow existing building codes and standards and is resistant to new technologies (Duxson et al.,2007).*

6. CONCLUSIONS

The high cost of conventional construction material affects economy of structure. With increasing concern over the excessive exploitation of natural aggregates, synthetic lightweight aggregate produced from environmental waste is a viable new source of structural aggregate material.

The uses of structural grade lightweight concrete reduce considerably the self-load of a structure and permit larger precast units to be handled. Recently in the environmental issues, restrictions of local and natural access or sources and disposal of waste material are gaining great importance. Today, it becomes more difficult to find a natural resource. Use of the waste materials not only helps in getting them utilized in cement, concrete and other construction materials, but also has numerous indirect benefits such as reduction in land fill cost, saving in energy, and protecting environment from possible pollution effect. It also helps in reducing the cost of concrete manufacturing

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