Fly Ash and Recycled Coarse Aggregate in Concrete: New Era for Construction Industries - A Literature Review

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ABSTRACT: Use of recycled coarse aggregate in concrete can be useful for environmental protection and economical terms. Recycled aggregates are the materials for the future. Same as fly ash is also a by-product from various industries. Fly ash is a group of materials that can vary significantly in composition. It is residue left from burning coal, which is collected on an electrostatic precipitator or in a bag house. It mixes with flue gases that result when powdered coal is used to produce electric power. The advantages of using fly ash far outweigh the disadvantages. The most important benefit is reduced permeability to water and aggressive chemicals. Properly cured concrete made with fly ash creates a denser product because the sizes of the pores are reduced. This increases strength and reduces permeability. Globally, the concrete industry consumes large quantities of natural resources, which are becoming insufficient to meet the increasing demands. At the same time, large number of old buildings and other structures have reached the end of their service life and are being demolished, resulting in generation of demolished concrete. Some of this concrete waste is used as backfill material, and much being sent to landfills. Recycling concrete by using it as replacement to new aggregate in concrete could reduce concrete waste and conserve natural sources of aggregate. In the last two decades, varieties of recycling methods for construction and demolition wastes have been explored and are in well-developed stage. Fly ash is known to be a good pozzolanic material and has been used to increase the ultimate compressive strength and workability of fresh concrete.

KEYWORDS: Fly ash, Recycled Coarse Aggregate, Concrete

INTRODUCTION OF RECYCLED COARSE AGGREGATE

Recycling is the act of processing the used material for use in creating new product. The usage of natural aggregate is getting more and more intense with the advanced development in the infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. Recycled aggregate is comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. These materials are generally from buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes.

The aim for this on-going project is to determine the utilization of recycled coarse aggregates for application in high strength structural concrete, which will give a better understanding on the uses of concrete with recycled coarse aggregates, as an alternative material to natural coarse aggregate in structural concrete.

CLASSIFICATION OF AGGREGATES

NATURAL AGGREGATE

Construction aggregates produced from natural sources such as gravel and sand, and extractive products such as crushed rock.

- Crushed rock
- Sand and gravel
- Crushed river gravel

MANUFACTURED AGREGATE

Aggregates manufactured from selected naturally occurring materials, by-products of industrial processes or a combination of these.

- Foamed Blast Furnace Slag (FBS)
- Fly Ash Aggregate
- Manufactured Sand
- Polystyrene Aggregate (PSA)
- Expanded Clays, Shales and Slates

RECYCLED AGGREGATE

Aggregates derived from the processing of materials previously used in a product and/or in construction.

- Recycled Concrete Aggregate (RCA)
- Recycled Concrete and Masonry (RCM)
- Reclaimed Aggregates (RA)
- Reclaimed Asphalt Pavement (RAP)
- Reclaimed Asphalt Aggregate (RAA)
- Scrap Tyres
- Polystyrene Aggregate (PSA)
- Used Foundry Sand

REUSED BY-PRODUCT

Aggregates produced from by-products of industrial processes.

- Air-cooled BF Slag (BFS)
- Granulated BF Slag (GBS)
- Electric Arc Furnace Slag (EAF)
- -Steel Furnace Slag (BOS)
- Fly Ash (FA)
- Furnace Bottom Ash (FBA)
- Incinerator Bottom Ash (IBA)
- Coal Washery Reject (CWR)
- Organic Materials
- Crusher fines
- Mine tailings

COMPARISON OF RECYCLED COARSE AGGREGATES AND NATURAL AGGREGATES

STRENGTH

The strength of recycled coarse aggregate is lower than natural aggregate. The weight of recycled coarse aggregate is lighter than natural aggregate. This is the general effect that will reduce the strength of reinforced concrete.

TEXTURE

Recycled Coarse Aggregate has the rough – textured, angular and elongated particles where natural aggregate is smooth and rounded compact aggregate. The properties of the freshly mixed concrete will be affected by the particle shape and surface texture of the aggregate. The rough – textured, angular and elongated particles require much water than the smooth and rounded compact aggregate when producing the workable concrete. The void content will increase with the angular aggregate where the larger sizes of well and improved grading aggregate will decrease the void content.

QUALITY

The quality is different between recycled coarse aggregate and recycled coarse aggregate. The quality of natural aggregate is based on the physical and chemical properties of sources sites, where the recycled coarse aggregate is depended on contamination of debris sources. It also stated that natural resources have suitable for multiple product and higher product larger marketing area, but recycled aggregate have limited product mixes and the lower product mixes may restrain the market.

DENSITY

The density of the recycled coarse aggregate is lower than natural aggregate. When compared with natural aggregate, recycled coarse aggregates have lower density because of the porous and less dense residual mortar lumps that is adhering to the surfaces. When the particle size is increased, the volume percentage of residual mortar will increase too.

LOCATION

Natural aggregate is derived from a variety of rock sources. The processing plant for natural aggregate depends on the resource. It usually occurs at the mining site and outside the city.

Recycled coarse aggregate is derived from debris of building constructions and roads. The locations of recycling plants are depending on where the structures are demolished. The recycling process is often located in the urban area.

PROPERTIES OF RECYCLED COARSE AGGREGATE (RCA)

- Recycled coarse aggregate (RCA) is produced by crushing sound concrete, clean demolition waste. Other materials that may be present in RCA are gravel, crushed stone, hydraulic-cement concrete or a combination thereof deemed suitable for premix concrete production.
- RCA should not have greater than 0.5% brick content.
- Applications include partial replacement (up to 30% of coarse RCA) for virgin material in concrete production for non-structural work such as kerbs and gutters. Current field experience with the use of recycled concrete aggregates for structural applications is scarce.
- RCA has a lower specific gravity and higher water absorption than most natural aggregates.
- Adjustments of the mix design would be necessary to offset the effect of RCA on workability, absorption, strength and shrinkage.

ADVANTAGES OF RECYCLED COARSE AGGREGATE

- There are many advantages through using the recycled coarse aggregate. The advantages that occur through the usage of recycled coarse aggregate are listed below.

ENVIRONMENTAL GAIN

The major advantage is based on the environmental gain. Construction and demolition waste in general going to landfill. Through recycling these materials, it can keep diminishing the resources of urban aggregated. Therefore, natural aggregate can be used in high grade applications.

SAVE ENERGY

The recycling process can be done on site. According to Kajima Technical Research Institute (2002), Kajima is developing a method of recycling crushed concrete that used in the construction, known as the Within-Site Recycling System. Everything can be done on the construction site through this system, from the process of recycled aggregate, manufacture and use them. This can save energy to transport the recycled materials to the recycling plants.

COST

Secondly is based on the cost. The cost of recycled aggregate is cheaper than virgin aggregate. It depends on the aggregate size limitation and local availability. This is just around one and half of the cost for natural aggregate that used in the construction works. The transportation cost for the recycled aggregate is reduced due to the weight of recycled aggregate is lighter than virgin aggregate.

Concrete Network stated that recycling concrete from the demolition projects can save the costs of transporting the concrete to the land fill and the cost of disposal . Beside that, Aggregate Advisory Service, also state that the recycling site may accept the segregates materials at lower cost than landfill without tax levy and recycled aggregate can be used at a lower price than primary aggregate in the construction works.

SUSTAINABILITY

The amount of waste materials used for landfill will be reduced through the usage of recycled aggregate. This will reduce the amount of quarrying. Therefore this will extend the lives of natural resources and also extend the lives of sites that using for landfill.

WIDE MARKET

The markets for recycled concrete aggregate are wide. According to Environmental Council of Concrete Organization, recycled concrete aggregate can be used for sidewalk, curbs, bridge substructures and superstructures, concrete shoulders, residential driveways, general and structural fills. It also mentioned that recycled concrete aggregate can be used in sub bases and support layers such as un-stabilized base and permeable bases.

DISADVANTAGES RECYCLED COARSE AGGREGATE

LACK OF SPECIFICATION AND GUIDELINES

There is no specification or any guideline when using recycled concrete aggregate in the constructions. In many cases, the strength characteristic will not meet the requirement when using recycled concrete aggregate. Therefore, more testing should be considered when using recycled concrete aggregate.

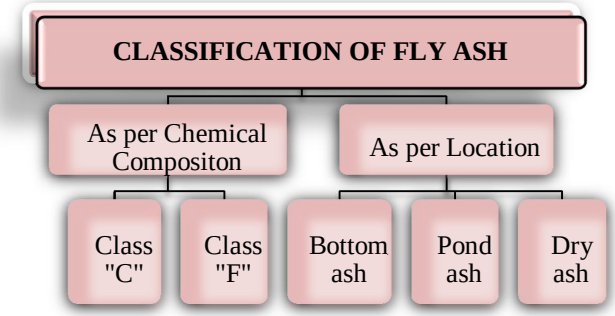
WATER POLLUTION

The recycled process will cause water pollution. Morris of National Ready Mix Concrete Association had mentioned that they wash out water with the high pH is a serious environmental issue. According to Building Green (1993), the alkalinity level of wash water from the recycling plants is pH12. This water is toxic to the fish and other aquatic life.

INTRODUCTION OF FLY ASH (FA)

- When coal is burnt in a modern pulverised fuel furnace, two types of ash are produced. The fine ash, which is recovered from the flue gas, is fly ash (FA).
- This material accounts for up to 90% of the total ash produced.
- The remainder consists of similar particles that have fused together into an aggregate - size-lumps.
- They fall to the bottom of the furnace and are known as furnace bottom ash (FBA).
- Historically, the addition of fly ash to concrete had been considered to be part of fine aggregate replacement. Modern mix design treats fly ash exclusively as part of the binder system with the use of higher amount of fly ash in high volume fly ash (HVFA) concrete.

CLASSIFICATION OF FLY ASH



DIFFERENCE BETWEEN CLASS-F FLY ASH AND CLASS-C FLY ASH

Class F Fly Ash	Class C Fly Ash
It is achieved by burning anthracite and Bituminous coal.	It is achieved by burning of younger lignite and sub bituminous coal.
Fly ash contains less than 20% lime.	Fly ash contains More than 20% lime.
It requires an activator for making cementatious products.	It does not require an activator for making cementatious products.
	
Source:http://www.caer.uky.edu/kyasheducation/flyash.shtml	Source:http://www.caer.uky.edu/kyasheducation/flyash.shtml

BOTTOM ASH

- Ash collected at the bottom of boiler furnace characterized by better geo- technical properties is termed as bottom ash. It is a good material for fill, road and embankment construction.

POND ASH

- Fly ash and bottom ash are mixed together with water to form slurry, which is pumped to the ash pond area.In ash pond area, ash gets settled and excess water is decanted. This deposited ash is called pond ash. This is used as a filling material including in the construction of roads & embankments.

DRY ASH

- Ash collected from different rows of Electro-static precipitators in dry form is termed as dry ash. It is used in the manufacture of PPC, Concrete & Cement mortar, Lime fly ash bricks, Building blocks, Aerated concrete block.

ADVANTAGES OF FLY ASH

ECONOMY

- Fly ash costs less than cement, however fly ash does not substitute cement and gain strength when mixed with water; it compliments cement in that it uses by-products of the cement hydration process to build strength. As a result fly ash can be blended with cement in order to achieve a more cost effective cement solution.

DURABILITY

- Fly ash particles being far smaller than cement and spherical in shape fill the voids between cement particles in the concrete matrix, which results in less water being required to get concrete into a workable/placeable state. The lower water content increases the concrete density which in turn improves the concrete durability, in addition, the lower water content also contributes to other factors like less shrinkage/cracking.

LONG TERM STRENGTH DEVELOPMENT

- Fly ash is a synthetic pozzolan and will, in the presence of Calcium Hydroxide (from cement hydration process) and water, form C-S-H (Calcium Silicate Hydrate) which gives fly ash based concrete the ability to develop strength over prolonged periods of time.

ENVIRONMENTAL GAIN

- Firstly, beneficiation of a waste product from coal fired power stations into useable building materials and thereby ensuring waste materials do not end up on landfill sites. The second significant environmental benefit is that considerably less clinker is required to produce one ton of finished cement product which therefore means a cement producer will reduce its CO^2 emissions.

DISADVANTAGES OF FLY ASH

SLOWER STRENGTH GAIN

- Concrete changes from a liquid to a solid a few hours after pouring, but the curing process may take much longer. It continues to gain strength for weeks after its initial setting period. The addition of fly ash can increase the length of time concrete takes to reach its full strength. This can cause problems when slow strength gain means delays in construction.

LONGER SETTING TIMES

- Fly ash admixtures can lengthen the time it takes for concrete to set. Sometimes this is desirable, particularly in hot weather which speeds up concrete set times, but at other times it is an inconvenience and can cause delays in construction. Other admixtures may be necessary to adjust the set time of the concrete, depending on the percent fly ash in the mixture and the outside temperature.

COLOR VARIABILITY

- The structural effects of fly ash may be more critical, but cosmetic concerns also affect its use in concrete. It is more difficult to control the color of concrete containing fly ash than mixtures with Portland cement only. Fly ash also may cause visual inconsistencies in the finished surface, such as dark streaks from carbon particles.

AIR CONTEXT CONTROL

- Concrete is susceptible to damage from freeze/thaw cycles if it does not contain air. Tiny air bubbles can be created in concrete by using air-entraining admixtures that cause the concrete to foam in the mixing and pouring stage. Fly ash reduces the amount of air entrainment, and concrete mixtures high in fly ash often require more air-entraining admixture.

SEASONAL LIMITATIONS

- The winter season is problematic for concrete pouring, and mixtures high in fly ash are even more susceptible to low temperatures. Low temperatures lengthen setting times and cause slow strength gain even in concrete mixtures without fly ash. When fly ash is added, low temperatures exaggerate these problems. Some regions have bans or restrictions on using fly ash in the winter months.

AIR POLLUTION

- Fly ash escaping through chimneys contains particulate matters along with various harmful gases like So_2, NO_2, CO_2 and CO. Fly ash from ponds flies in summer and winter during excavation. in association with moisture in the atmosphere, fine particles of fly ash often from aerosols which affect visibility around power stations, through to varying extent.

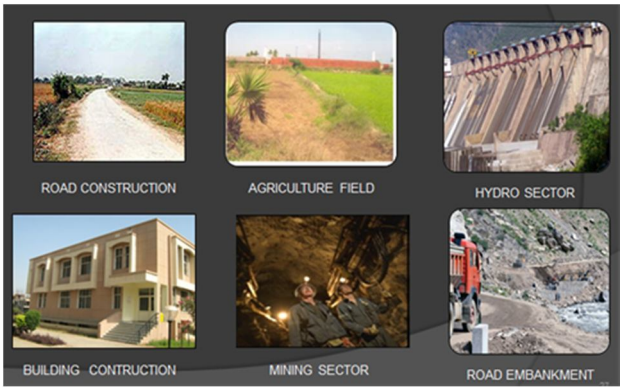
WATER POLLUTION

- Substantial quantities of fly ash are carried over to river system in the wet form. Heavy metal like Cd, Cr, Fe, Zn and Pb flow into the rivera along with fly ash carrying various types of diseases. If fly ash disposed with water in ponds then the settlement of ash in ground and due to capillary action the fly ash particles percolates into ground and mixed with underground water. The mix of ash with water will change the pH of water and also change electric conductivity.

LAND POLLUTION

- In addition to the requirement of large tracts of land and the high cost of disposal, dumping of fly ash on land can lead to erosion of soil and damage to crops. In cases, where fly ash collection systems are not very efficient. It also changes in soil characteristics.

APPLICATION OF FLY ASH IN CONSTRUCTION INDUSTRIES



REVIEW OF USE OF RECYCLED COARSE AGGREGATE & FLY AH IN CONCRETE

- The applications of recycled coarse aggregate in the construction area are very wide. There are many testing based on the recycled coarse aggregate have been carried out all around the world.
- The main aim of using recycled coarse aggregate is to reduce the use of natural resources.
- From the literature review shown, the results of different properties are all mainly reducing when the replacement of recycled coarse aggregate used in the concrete increased.
- Another improving method is using the Fly ash in the recycled coarse aggregate mixing.
- Application of fly ash in the recycled coarse aggregate concrete can improve the durability of the recycled coarse aggregate concrete.
- The use of fly ash could improve the strength characteristic of recycled coarse aggregate concrete.

RECOMMENDATIONS FOR FURTHER STUDIES

- Further testing and studies on the recycled coarse aggregate concrete is highly recommended to indicate the strength characteristics of recycled coarse aggregate for application in high strength concrete.
- Due to more water absorption of recycled coarse aggregate it may have less workability.
- Therefore, it is recommended that adding admixtures such as super plasticizer, fly ash, silica fume. etc into the mixing so that the workability can be improved.
- More investigations and laboratory tests should be done on the strength characteristics of recycled coarse aggregate. It is recommended that testing can be done on concrete slabs, beams and walls.
- More trials with different particle sizes of recycled coarse aggregate and percentage of replacement of recycled coarse aggregate with fly ash as cementitious material with % replacement of cement are recommended to get different outcomes and higher strength characteristics in the recycled coarse aggregate concrete with fly ash.

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