International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 03 | Mar-2018 www.irjet.net p-ISSN: 2395-0072

INNOVATION IN STRENGTH PROPERTIES OF RIGID PAVEMENT CONCRETE BY PARTIAL MIXING OF SILICA FUME AND RECYCLED COARSE AGGREGATE: A REVIEW

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***Abstract* -** In this paper a review aims to find the possibility of the structural usage of recycled coarse aggregate in lieu or mixed with natural aggregates, based on better understanding of behaviour of recycled aggregate in concrete structures experimenting fresh and hardened concrete, mixtures containing recycled aggregates. The literature review provides an overview of sustainability and key performance indicators, the material properties of recycled aggregate concrete both as an aggregate and in concrete, concrete mixture and proportioning designs with recycled aggregate concrete, performance of existing recycled aggregate concrete pavements, and the implementation of recycled aggregate concrete highlighting some examples where recycled aggregate concrete has been used successfully. Use of recycled aggregate in pavement concrete can be useful for environmental protection and economical terms. Recycled aggregates are the materials for the future. It is well known fact that it is giving little lower strength than natural aggregate concrete. Though, if it is used up to 20% of replacement, than it can give almost similar strength to that of natural aggregate concrete. Hence it was necessary to improve strength of recycled aggregate concrete for higher recycled aggregate content. Silica fume is very popular material used for strength improvement. Hence popular mix of M20 was checked with different % of silica fume combination. 5%, 10% and 15% of silica fume were replaced with cement and 20%, 30% and 40% of recycled aggregates were replaced with natural aggregate and results were analyzed.

Key Words: Recycled Coarse Aggregate, Silica fume.

1. INTRODUCTION

Concrete is the premier construction material across the world and the most widely used in all types of civil engineering works, including infrastructure, highway pavements, low and high-rise buildings, defence installations, environmental protection facilities . The use of recycled aggregates in concrete opens a whole new range of possibilities in the reuse of materials in the building industry. The utilization of recycled aggregates in pavement concrete is a good solution to the problem of an excess of waste material, provided that the desired final product will fit the standards. The studies on the use of recycled aggregates have been going on for 50 years. In fact, none of the results showed that recycled aggregates are unsuitable for structural use. Recently the use of recycled concrete as a structural fill material, in lieu of natural aggregate, has recently been increasing. In some regions, recycled concrete aggregate may cost 20 % to 30 % less than natural aggregate.

The construction of infrastructures related to bridges, highway pavements, water systems, and buildings has been increasing from the beginning of the past century, especially in areas where population density is high. Infrastructures need to be repaired with the pass of the time. In some cases, constructions need to be replaced, because their service life is reached or their original design no longer satisfies the new requirements (population, traffic, or weather). These facts have generated two important issues: first, a growing demand for construction aggregates, and second an increasing production of construction material waste. The construction waste only, on the other hand, produced from building demolition is estimated to be 123 million tons per year. Historically, the most common method of managing this material has been through disposal in landfills. It is estimated that 50 percent of concrete debris and 20 percent of all asphalt pavements end up in landfills. As cost, environmental regulations, and land policies of landfill arise, the concern to seek alternative uses of the waste material also increases. This situation has led the aggregate industry to begin reclaiming construction waste as an alternative aggregate especially for pavement uses. Additionally, government entities have started promoting this recycling process as an option to natural aggregate, helping extend the life of natural resources, reducing the environmental disturbance around construction Site, and reducing the volume of waste to landfill areas.

2. SILICA FUME

Silica fume was first discovered in Norway in 1947 when the environmental controls started the filtering of the exhaust gases from furnaces. The main portion of these fumes was a finely composed of a high percentage of silicon dioxide. Silica fume consists of the fine particles with specific surface about six times of cement because its particles are very finer than cement particles. Hence, it has been found that when silica fume mixes with concrete the minute pore spaces decreases. Silica fume is pozzolanic, because it is reactive, like volcanic ash. Its effects are related to the strength, modulus, ductility, sound absorption, vibration damping capacity, abrasion resistance, air void content, bonding strength with reinforcing steel, shrinkage, permeability, chemical attack resistance, alkali-silica reactivity reduction, creep rate, corrosion resistance of embedded steel reinforcement, freeze-thaw durability, coefficient of thermal expansion, specific heat, defect dynamics, thermal conductivity, dielectric constant, and degree of fiber dispersion in mixes containing short microfibers.

Also, addition of silica fume decreases the workability of the mix. Silica fume can solve problems, because of its very loose bulk density and fine particles. However, it causes other problem such as stickiness, bridging in storage silos, and clogging of the pneumatic transport equipment.

Vibration reduction is useful for structural stability, hazard mitigation, and structural performance improvement. Effective vibration reduction requires both stiffness and damping capacity. Silica fume is effective for increasing both damping capacity and stiffness. Sound or noise absorption is helpful for numerous structures, such as noise barriers and pavement overlays. The addition of silica fume to the concrete increases the sound absorption ability.

The use of crushed aggregate from either demolition concrete or from hardened leftover concrete can be regarded as an alternative coarse aggregate, typically blended with natural coarse aggregate for use in new concrete. The use of 100% recycled coarse aggregate in concrete, unless carefully managed and controlled, is likely to have a negative influence on most concrete properties – compressive strength, modulus of elasticity, shrinkage and creep, particularly for higher strength concrete. Also the use of fine recycled aggregate below 2 mm is uncommon in recycled aggregate concrete because of the high water demand of the fine material smaller than 150 μm, which lowers the strength and increases the concrete shrinkage significantly.

Many overseas guidelines or specifications limit the percentage replacement of natural aggregate by recycled aggregate. In general leftover concrete aggregate can be used at higher replacement rates than demolition concrete aggregate. With leftover concrete aggregate, information will generally be known about the parent concrete – strength range and aggregate source etc., whereas for demolition concrete very little information may be known about the parent concrete, and the resulting aggregate may be contaminated with chlorides or sulphates and contain small quantities of brick, masonry or timber which may adversely affect the recycled aggregate concrete. Often the sources of material from which a recycled aggregate came (and there could be more than one source), are unknown and the variability and strength of the recycled aggregate concrete could be adversely affected in comparison with a recycled aggregate concrete where the recycled aggregate came from one source with a known history of use and known strength. It is therefore necessary to distinguish between the properties of recycled aggregate concrete made using demolition concrete aggregate and that using leftover concrete aggregate.

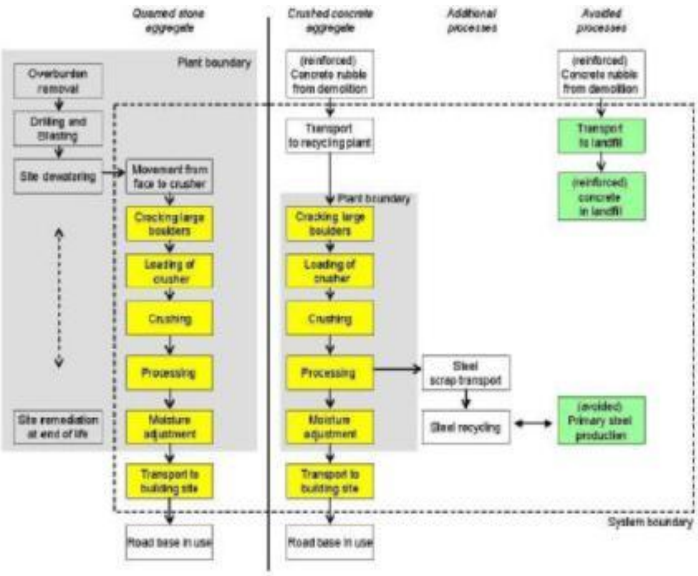
3. PRODUCTION OF RCA

Recycled aggregates to be produced from aged concrete that has been demolished and removed from foundations, pavements, bridges or buildings, is crushed and processed into various size fractions. Reinforcing steel and other embedded items, if any, are removed and care is taken to prevent contamination by dirt or other waste building materials such as plaster or gypsum. It is prudent to store old concrete separately to other demolition materials to help avoid contamination. Records of the history of the demolition concrete – strength, mix designs etc. –would seldom be available, but if available these are useful in determining the potential of the recycled aggregate concrete.

The processes for the production of recycled aggregates are carried out in plants of treatment which are similar to the plants of crushing of natural aggregates. These include mainly five stages in the recycling process of construction and demolition waste and they are done in the following order

1. Coarse separation
2. Crushing
3. Separation of ferrous elements
4. Screening
5. Removal of impurities by air separation

During the coarse separation the debris is chopped smaller so as to go smoothly into the crusher inlet. The crushing can be also performed by squeezing, impacting and grinding. To obtain a decreasingly sized product three different crushing stages, take place primary crushing, secondary crushing and milling. Particle size distribution classes are determined during the screening operation. If necessary, impurities like wood, plastic and paper can be removed. Air separation technique is more convenient than the washing separation which is more expensive. The process ends with the storage of the products



4. ACHIEVING SUSTAINABILITY WITH RECYCLED CONCRETE AGGREGATE

Sustainability is defined as "Meeting the needs of the present without compromising the ability of the future generations to meet their own needs". The current usage of aggregate is not sustainable as demonstrated by the growing shortage of natural aggregates in urban area. Recycling concrete, from deteriorated concrete structures, would reduce the negative impact on the environment and increase sustainability of aggregate resources. Using recycled aggregate concrete conserves virgin aggregate, reduces the impact on landfills and decreases energy consumption. Using recycled aggregate concrete creates cost savings in the transportation of aggregate and waste products, and in waste disposal. It is estimated that using recycled aggregate concrete can save up to \$4.80 m^2. Finding ways to reuse C&D waste and minimize things that are not suitable for reuse will increase sustainability.

5. UTILIZATION OF RCA AND SILICA FUME ON RIGID CONCRETE

Jianzhuanget al., (2005) said, the compressive strength is the peak value of the stress–strain curve, and the area under the ascending portion of the curve provides a measure of the toughness of concrete, meanwhile the descending portion of the curve indicates its ductility. The descending part is essential when the concrete structures could be subjected to dynamic loading such as impact, earthquakes, or fatigue loading.

Poon et al. (2004) studied Influence of moisture states of natural and recycled aggregateson the compressive strength of concrete, and concluded that the concrete mixtures prepared with the incorporation of recycled aggregates, the air dried (AD) aggregate concretes exhibited the highest compressive strength. The surface dried density (SSD) recycled aggregates seemed to impose the largest negative effect on the concrete strength, which might be attributed to ''bleeding'' of excess water in the pre-wetted aggregates in the fresh concrete. Based on the results of his study, aggregates in the AD state and contain not more than 50%recycled aggregate should be optimum for normal strength recycled aggregate concrete production.

Nelso and Chai (2004) stated the following in their work on high-strength structural concrete with recycled aggregates. The workability was good and can be satisfactorily handled for 0% recycled aggregate to 80% recycled aggregate. The slumps from 0% recycled aggregate to 80% recycled aggregate were considered moderate due to the drop in the range of 5mm to 0 mm.

Gilpinet al. (2004) their research was made on testing of the properties of aggregates, particularly the recycled aggregate. The aim is to assess the materials‟ suitability for purpose; the production of RCA, and to obtain the required mix design parameters. Physical and mechanical properties of the aggregates need to be investigated as these in turn will affect the properties of fresh and hardened concrete. The main aggregate properties to be considered when recycled aggregates are used in new concrete are: specific gravity, absorption, angularity, gradation, compressive, flexural, and tensile strength, susceptibility to alkali-aggregate reactivity and freeze-thaw distress.

Butler et al. (2011) found strong relationship between aggregate crushing value (ACV) and splitting tensile strength. As the ACV increase, the splitting tensile these recycled concretes was 4% higher. In the case of a substitution level of 50%, the shrinkage increase was 12% greater than that of the conventional concrete after 6 months strengths become more sensitive. Comparison based on ACV can be made between a particular recycled coarse aggregate source and a natural aggregate source. This comparison could be used as an early indicator of how concrete produced with recycled coarse aggregate will perform, with respect to its splitting tensile strength, compared to concrete produced with natural coarse aggregate and the results shows that the production of the concrete at a plant installed onsite is more costly than other production methods, even for the large-scale construction, and thus is not feasible.

Bołtryk et al. (2001) Concrete compressive strength was tested according to the standard PN-EN 12390-3. The results show not significant difference of compressive strength of concretes in which coarse aggregate was partially or totally replaced by recycled aggregate in relation to NAC. Results presented in Figure (2.2). Show that the highest compressive strength after 28 days was achieved by specimens with 25% and 75% of recycled coarse aggregate. The difference is however insignificant and equals about 4% in relation to NAC. After 90 days of hardening the highest compressive strength achieved NAC and the lowest RAC1 (25% of recycled coarse aggregate). The difference reached 8.3%. The 90-day compressive strength of RAC3 (75% of recycled coarse aggregate) is the closest to compressive strength of NAC. Rinsing the dust fractions from recycled aggregate improved cohesion between aggregate grains and cement paste and in this way improved strength of the interfacial zone.

Limbachiya and Leelawat (2000) found that recycled concrete aggregate had 7 to 9% lower relative density and 2 times higher water absorption than natural aggregate. According to their test results, it shown that there was no effect with the replacement of 30% coarse recycled concrete aggregate used on the ceiling strength of concrete. It also mentioned that recycled concrete aggregate could be used in high strength concrete mixes with the recycled concrete aggregate content in the concrete.

Yamato et al. (1988) investigated the freezing and thawing resistance of the concretes made with the recycled coarse aggregate produced in a recycling plant. The authors concluded that the resistance of recycled aggregate concrete was lower than that of the control concrete. For the replacement by the recycled aggregate of less than 30%, the reduction in the freezing and thawing resistance was small.

6. CONCLUSION

While studies have shown that recycled concrete aggregate can be used as aggregate for new concrete, there is a need to obtain long-term in-service performance and life cycle cost data for concrete made with recycled aggregate concrete to assess its durability and performance. If additional research supports the use of concrete buildings then existing specification should be revised to permit and encourage the use of recycled concrete as aggregate. Using recycled aggregate in concrete mixes leads to conserve existing supplies of natural aggregates and to reduce the amount of solid waste that must be disposed of in landfills. Further testing and studies on the recycled aggregate concrete is highly recommended to indicate the strength characteristics of recycled aggregates for application in high strength concrete as rigid pavement concrete. Below are some of the recommendations for further studies:

ACKNOWLEDGEMENT

- An important step in maintaining and encouraging the recyclability of concrete is the ability to separate other building materials like wood, bricks, polyethylene products, minerals etc. from the concrete construction that would either be incompatible in a common preparation process, or would at least restrict the recycling.
- Although by decreasing the water/cement ratio, recycled aggregate can achieve higher compressive strength concrete. But the workability will be very low. Therefore, it is recommended that adding admixtures such as super plasticizer and silica fume into the mixing so that the workability will be improved.
- More investigations and laboratory tests should be done on the strength characteristics of recycled aggregate. It is recommended that testing can be done on concrete slabs, beams and walls. Some mechanical properties such as creeping and abrasion were also recommended.
- More trials with different particle sizes of recycled aggregate and percentage of replacement of recycled aggregate are recommended to get higher strength characteristics in the recycled aggregate concrete.
- More investigations and laboratory tests should be done on the durability of recycled aggregate concrete in new concrete, and its creep and shrinkage characteristics.
- Further studies on the long-term feasibility of recycling.
- The fire-resistant property of recycled aggregates should be carefully studied.
- More studies on the economic aspect of concrete processing and recycling.
- More investigations and laboratory tests should be done on the use of fine recycled aggregates.

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