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A Review on Recycled Aggregates as an Alternative Building Material

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Abstract - *With the advanced development in the infrastructure area, the usage of natural aggregate is getting more and more severe. In order to reduce the usage of natural aggregate, recycled aggregate can be used as a replacement material. Vast amounts of waste materials are produced by the construction and demolition industry every year. The volume of these materials has reached an unacceptable point for environmental, economic and social reasons. These issues may be addressed by means of more proactive approaches, which include recovery, reuse and recycling techniques. This paper presents a precise and orderly evaluation of previous investigations of recycled aggregate as an alternative building material. Investigations show that the addition of recycled aggregates as a replacement material has a significant effect on the properties of concrete like compressive strength, split tensile strength and flexural strength.*

Key Words: Recycled aggregates, compressive strength, flexural strength, split tensile strength, workability.

1. INTRODUCTION

Industrial development has led to serious problems all over the world such as depletion of natural aggregates and created enormous amount of waste materials from construction and demolition activities. One of the ways to reduce this problem is to utilise recycled aggregates in the production of concrete. Recycled aggregate consists of crushed particles processed from the materials sourced from construction and demolition waste. These materials are generally from buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes. 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. By using recycled aggregate as a replacement to natural 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.

2. LITERATURE REVIEW

R.V. Silva et. al (2015) studied the effect on the carbonation behaviour of concrete by incorporating recycled aggregates, sourced from construction and demolition waste. This paper presents the statistical analysis on the effect of introducing increasing amounts of recycled aggregates on the carbonation depth and coefficient of accelerated carbonation. The incorporation of increasing amounts of Recycled Aggregates (RA) causes greater carbonation depths, assuming all other factors are equal. The use of 100% coarse Recycled Concrete Aggregate (RCA) in concrete may cause up to 2 times the carbonation depths to those of the corresponding Natural Aggregate Concrete (NAC) mixes. The size of the RA also has a clear effect on the carbonation behaviour of concrete. There is a greater probability that concrete mixes made with fine RCA exhibit greater carbonation depths than those of mixes with coarse RCA. It was revealed that irrespective of the age at which a concrete material is processed, the resulting RCA will produce concrete with similar resistance to carbonation. It is possible to produce RAC with similar target strength and carbonation depths to those of a conventional concrete. However, for this to happen, a greater amount of cement would have to be used in the RAC's production to compensate the RA's greater porosity in relation to that of the NA. Another method to compensate for its porosity would be decreasing the w/c ratio while maintaining the cement content. Naturally, this mix would have to be accompanied by super plasticizers in order to maintain similar workability levels. RAC mixes exhibit a similar relationship between the coefficient of accelerated carbonation and compressive strength when compared with NAC. The relationships and methodologies presented in this paper showed that RAC mixes meeting the recommended limiting values for conventional concrete mixes exhibited carbonation resistance satisfactorily to accomplish the target service life and therefore that RAC is a suitable material for reinforced concrete structures subject to carbonation induced corrosion.

Özgür Çakır et.al (2015) presented the effects of incorporating Silica Fume (SF) in the concrete mix design to improve the quality of recycled aggregates in concrete. Portland cement was replaced with SF at 0%, 5% and 10%. Specimens were manufactured by replacing natural aggregates with recycled aggregates. Two size fractions (4/12 mm and 8/22 mm) as recycled aggregates were used and four series of concrete mixtures were produced. In all concrete mixtures, a constant water/binder ratio at 0.50 was used and concrete mixtures with a target initial slump of S4 class (16–21 cm) were prepared. Concrete properties were evaluated by means of compressive strength, tensile splitting strength, water absorption and ultrasonic pulse velocity and it was found that, using 10% SF as a cement replacement for recycled aggregate concretes enhanced the mechanical and physical properties of concrete. At all the test ages the tensile splitting strength gain of the natural aggregate concrete mixture with and without SF was higher than that of the recycled concrete mixtures. A continuous and significant improvement in the tensile splitting strength of recycled aggregate concretes incorporating SF was observed. Similar to compressive strength test results, concrete incorporating 10% SF and containing 4/12 mm fraction recycled aggregates showed better performance among recycled aggregate concretes. Concretes produced with natural and recycled aggregates incorporating silica fume underwent a reduction in early age compressive strength. The compressive strength decreased with increase in the silica fume content. However, compressive strength loss of concretes containing recycled aggregate was less than the concretes containing natural aggregate at early age due to the SF usage. At 28 and 90 days, the strength of all the concrete mixtures with 5% and 10% of silica fume was increased, in comparison to the strength of the control concrete without silica fume. Usage of SF is more effective on the compressive strength of concrete having 4/12 mm fraction recycled aggregate than 8/22 mm fraction aggregate incorporating the same SF content. Continuous and significant improvement in the tensile splitting strength of recycled aggregate concretes incorporating SF was observed with time. The concrete with 10% SF having 4/12 mm fraction recycled aggregates showed a better performance of compressive and split tensile strength of 124% and 118% that of control mix at 28 days. Water absorption values of concretes containing the recycled aggregates with SF decreased significantly especially at later ages. This effect is more significant in recycled aggregate concretes incorporating 10% SF rather than recycled aggregate concretes incorporating 5% SF.

R.V. Silva et.al (2015) presented the effect of incorporating recycled aggregates, sourced from construction and demolition wastes, on the tensile strength of concrete. It identifies various aspects such as replacement level, size and origin, as well as mixing procedure, chemical admixtures, additions and strength development of recycled aggregates over time. This paper also studied the relationship between the tensile and compressive strengths according to Euro code 2. The results showed that, irrespective of the type, replacement level and quality of the recycled aggregate used, the resulting recycled concrete tends to exhibit a similar relationship to that of the corresponding natural aggregate concrete. It was found that depending on the recycled aggregate's quantity, size, type and quality, there is a higher or lower relative tensile strength loss between the natural aggregate concrete and recycled aggregate concrete. The use of super plasticizers is an effective way of offsetting the strength loss of RAC with increasing replacement levels. The use of RA in concrete appeared to have positive effects on the tensile strength gain over time. When using mineral additions, the expected tensile strength gain or loss when using additions is not generally affected by the increasing RA content in the mix. In other words, the final tensile strength of concrete will result from the overlapping effects of both RA and addition inclusion. The relationship between tensile and compressive strengths appears to have been unaffected by the use of RA. This is very important as many of the existing standards and specifications for conventional concrete use this relationship for estimating the tensile strength by means of a given compressive strength.

Daniel Matias et.al (2014) evaluated the effect of standard and high-performance super plasticizers on the key durability-related properties (shrinkage, water absorption by immersion and by capillarity, carbonation and chloride penetration resistance) of concrete made with different percentages of recycled coarse aggregates from crushed concrete and compare the findings with the corresponding effect on conventional concrete. Results shows that concrete's specific density and the water absorption by immersion or the capillarity properties were not influenced by the super plasticizers in content or type. The porosity of recycled aggregate is the main cause of higher water absorption by immersion in recycled aggregate concrete. Compressive strength tends to decrease with the incorporation of recycled aggregate, but the addition of super plasticizers can enhance the mix compactness, compensating for most of the strength loss. Mixes with recycled aggregates and super plasticizers had better chloride penetration resistance than the natural aggregates. Adding super plasticizers can help to compact the cement paste, hindering the chloride penetration. Recycled aggregates concrete revealed higher shrinkage strains than the natural aggregates however, super plasticizers, especially high performance water reducing ones, can partially prevent the occurrence of this phenomenon in recycled aggregate concrete. It was studied that recycled aggregate concrete is more susceptible to deterioration because of environmental conditions affecting this concrete's durability performance more than that of conventional concrete. However, introducing super plasticizers in recycled aggregate concrete can help to enhance the concrete's performance and offset this higher susceptibility. The concrete's specific density is mostly influenced by the aggregate's density thus higher RA particle density results in higher concrete's specific density. The use of super plasticizers resulted in a decreasing mode of concrete workability. It was found that super plasticizers lose efficiency with increasing RA ratio. Compressive strength tends to decrease with the incorporation of RA, but the addition of super plasticizers can enhance the mix compactness, compensating for most of the strength loss. The use of super plasticizers allowed the carbonation depth of the RA concrete to be lower than that of the RC at early ages.

Madan Mohan Reddy K et.al (2012) studied the use of local construction and demolition waste as coarse aggregate in concrete. The performance of compressive strength produced by recycled aggregate concrete and results are compared with the natural coarse aggregate concrete. The slump of reference specimen with 100% of Coarse Aggregate (CA), mix specimen with 100% replacement of RCA and mix specimen with 100% replacement of the Saturated Surface Dry of RCA (SSD RCA) were studied. The results reveal that slump of reference specimen is higher while the concrete mix specimen (100% replacement of RCA) has no slump. The slump of RAC is low and that can be improved by using SSD RCA to improve the workability of fresh concrete. Dry density of concrete with RCA is low because it contains saturated surface and it absorbs moisture. Result shows the compressive strength of recycled aggregate concrete is on average 87% of the natural aggregate concrete at an age of

28 days. This study reveals that concrete can be successfully produced using RCA that have been produced from demolition and construction waste. Concrete produced by RCA does not perform as good as concretes produced by CA in terms of strength. However, the concrete still has a strength that would make it suitable for some applications.

Yong et.al (2009) presented a study on the effect of utilisation of recycled aggregate as coarse aggregate in concrete. Recycled concrete aggregates from site-tested concrete specimens was used in this research. These consist of 28-days concrete cubes after compression test obtained from a local construction site. These concrete cubes are crushed to suitable size and reused as recycled coarse aggregate. Concrete is produced with replacement of 0%, 50% and 100% of RCA as well as 100% replacement of SSD RCA with the same mix proportion. The w/c used in all mixes is 0.41. The proportion of cement: sand: gravel is 1: 1:11: 2.07. The workability of fresh concrete is not satisfied since the slump of recycled concrete made with 100% Recycled Coarse Aggregate is 0mm. It was recommended to saturate the RCA to SSD condition before casting. Recycled aggregate concrete can achieve high compressive strength, split tensile strength as well as flexural strength. RAC has higher 28-day compressive strength and higher 28-day split tensile strength compared to control concrete. However, the 28-day flexural strengths of RCA was found to be lower than that of natural concrete.

Salomon M. Levy et.al (2004) conducted a study on the effect of fine and coarse recycled aggregates recovered from demolished masonry and concrete structures utilized in the manufacture of new concrete mixtures. Three properties of concretes were analyzed: water absorption, total pores volume, and carbonation. The recycled concrete mixtures were created by replacing parts of the natural aggregates of concrete with 0%, 20%, 50%, and 100% of aggregates from recycled sources. The results reveal that concrete made with recycled aggregates (20%, 50%, and 100% replacement) from old concrete or from old masonry can have the same compressive strength and workability to that made with natural aggregates in the range of 20 – 40 MPa at 28 days. In the recycled aggregates concrete performed in this study, the carbonation depth decreased when the replacement was 20% or 50%.The coarse recycled concrete aggregate exhibited almost 57% carbonation depth at 50% replacement of natural aggregate at 30 MPa. The properties of water absorption and pores volume was found to be lowest at 20% replacement with 95% and 92% that of natural aggregate at 30 MPa. When the natural aggregate is replaced by 20% of the recycled aggregates from old concrete or old masonry, the resulting recycled concrete will likely present same, and sometimes better, behaviour than the reference concrete made with natural aggregates in terms of the properties studied in this investigation.

3. CONCLUSIONS

An evaluation of previous investigations on recycled aggregate concrete is done. Recycled concrete exhibited almost the same strength characteristics like compressive strength, split tensile strength as well as flexural strength, like reference concrete made with natural aggregates. The use of recycled aggregate in concrete appeared to have positive effects on the tensile strength gain over time.The study also shows that RCA exhibits carbonation resistance adequate enough to accomplish the target service life. Thus recycled aggregate has a significant role in achieving sustainable construction by reusing the concrete debris saving landfill space and reducing gravel mining simultaneously achieving concrete with similar strength properties that of normal concrete.

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