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Techniques to Improve the Performance of Recycled Aggregate Concrete

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Abstract: ***Keeping in view the issue of disposing of the demolished waste and lack of availability of natural aggregates, there has been an increasing demand for recycled aggregates (RA) for construction purposes. Furthermore, incorporation of RA as a fractional or full replacement to natural aggregates (NA) degrades the mechanical and durability properties of the concrete. Hence, globally, studies have been going on using various practices with an objective to improve the performance of concrete made by incorporating RA. By replacing a small proportion of NA with RA there are ample benefits such as savings in the limited landfill spaces, economical construction and less depletion of natural resources. Nevertheless, RA usage is restricted due to its below-par quality and limits its application to only non-important components of structure such as filling material and low-grade concrete. The common cause of bad quality of RA is the huge amount of mortar attached on the exterior surface of the aggregates, which results in higher water absorption, high permeability and a weaker bond between the cement mortar and aggregates that weakens the strength and mechanical performance of concrete made using RA. This paper presents an overview of the different techniques which the construction industry can use to improve the performance of recycled aggregate concrete (RAC). Several techniques including the pre-soaking methods to remove the adhered mortar from the surface of RA, use of superfine pozzolanic material, impregnation of silica fumes, mechanical grinding method and steel fibre reinforced recycled aggregate concrete has been discussed.***

Keywords: Recycled Aggregates, Recycled Aggregate Concrete, Natural Aggregates, Mechanical Properties, Durability Properties

I. INTRODUCTION

Crumpled concrete which is effortlessly available in huge amounts, attained from the demolition of old structures or from left-over concrete from new construction, which creates a huge problem of disposal. That left-over concrete can then be used as RA a substitute for NA for construction. There is a lot of difference between RA and NA in their composition due to attached cement mortar content. This attached cement mortar is the reason for the low performance of RAC leading to high water absorption and high permeability. In the worst-case scenario, the full replacement of RA cause reduction in compressive strength up to 87% **[16] Jishen Qiu.** The cement content attached to the surface of aggregates mainly depends upon its crushing process in production plants. This process of crushing can enhance the superiority of RA by removing the cement mortar attached. But the cost of manufacturing will be increased. Hence it becomes very important to adopt techniques which can help to improve the performance of RA by treating or by using material that enhances the properties. Consequently, improvement of RA needs to be done for the utilization in concrete. This paper represents the different techniques or enhancement methods that have been reviewed from previous studies along with the application and methodology of techniques used. These are the methods that can be used to utilize the RA in concrete. Using RA not only preserves the natural resources and environment but also reduces the waste from landfills which is a major concern of environmentalists nowadays and thus avoid environmental degradation. Thus, to find out the possible techniques, this paper reviews laboratory tests performed and its results and significant research conclusions.

II. PERFORMANCE OF RECYCLED AGGREGATE CONCRETE (RAC)

Performance of RAC depends upon the source of RA, production process of RA and amount of adhered mortar attached to the surface of aggregates. Compressive strength of concrete primarily depends on the RA superiority if on par quality of aggregates is used such as crushing high strength concrete then recycled aggregates have no or very less influence on properties of concrete. Compressive strength of all concrete having RA0, RA50, RA100 shows the slight difference. The similar is for the split tensile strength of concrete. Results showed the same workability of concrete after 30 mints. Moreover, concrete having RA 50% requires 10% more water and for RA 100% requires 20% more water as compared to the control mix. The method which is adopted for RA production also affects the workability [1] Mirjana Malešev. Another study was carried out on RA that 30% replacement does not degrade the quality of concrete but the use of superplasticizers is often considered [2] Nik. D. Oikonomou.

Flexural and splitting tensile strength was lower, the reason for lower strength is due to large coarse aggregates which have large amount adhere mortar attached to the surface of the aggregate. Furthermore, the two-stage mixing approach (TSMA) of RA shows higher strength and compressive strength was 6% higher than the control mix [3] Aliakbar Gholampour. One more study carried out on concrete containing RA in which different water-cement ratios for design mix was considered and results showed lower compressive strength achieved at higher water to cement ratio.

Cement content in the concrete mix also a major factor leading different results [4] Rahal K. The fresh properties of RCA have been studied and significant methods have been used to improve the performance of RCA by [13] Modhera and Parekh, [14] Ishtiyaq Gull study revealed that addition of RA in concrete has lower the workability. The lower workability may be due to more water absorption of RA than the NA.

It was revealed that the addition of certain minerals and admixtures enhance workability. [15] M. Etxeberria carried out the microstructural study of RAC showing the difference in the interfacial transition zone between cement and aggregate. The concluded results show inferior strength of RAC as compared with NAC.

III. TECHNIQUES TO IMPROVE THE PERFORMANCE OF RAC

Different techniques are used for the treatment of RA for the effective application in fresh concrete, to increase engineering properties and durability. This treatment helps in modifying all the complications of RA in hardened or fresh concrete.

A. Acid Treatment

Cement hydration materials in the hardened paste can be eliminated in an acid solution. Thus, acids can remove the adhere mortar efficiently and improve the quality of RA. [5] Saravanakumar. P in his study treated RA in sulphuric acid (H_2So_4) in which RA were soaked in acid with 0.1 M for 24 hr at room temperature. With a wooden stick, the acid container was periodically stirred so that proper reaction takes place which further results in the removal of adhered mortar from RA. Then RA were taken out and washed properly with water and sundried. The results show the increased performance of RAC with improved compressive strength by 12.5% than untreated aggregates. Moreover, the split tensile strength of the concrete also demonstrated improved performance. [6] Vivian W.Y. Tam conducted the study on acids of three different classes namely HCL, H_2So_4 and H_3So_4. Pre-treatment has revealed that water absorption of RA has significantly decreased but shows increment in chloride and sulphate content which are in permissible limits. Whereas, mechanical performance has shown enhancements after pre-treatment. Results display 21.84% improvement of compressive strength with 20% replacement of RA after 7 days of curing, improvement of flexural strength by 22.90% was recorded after curing of 14 days. Likewise, 30% RA shows 20.48% refinement for modulus of elasticity when using HCL (Hydrochloric acid) for pre-treatment. The various reaction takes place under different acids such as HCL, $H2SO_4$ and H_3PO_4 and the unusual reaction takes place under H_3PO_4 which restricts the advantage made from this method with slight performance improvement of RA.

B. Use of Pozzolanic Slurry

Pozzolana are the by-product of industries such as coal, iron, industries etc which can be used to improve the performance of RA. The use of mineral admixtures in design mix can enhance the mechanical properties of concrete [7] Abhijit Mistri. Silica fume can be used that is intended to cover RA with thin layer silica fume particles. Silica fume is supposed to react with calcium hydroxide from the hydration of the cement to create a thick layer coating the top of the aggregate, which will improve its strength by [8] Katz. In his study concrete were prepared of three different w/c ratios two different methods were used for the treatment of RA one is silica fume impregnation and ultrasonic cleaning.

The results showed that the impregnation of silica fumes was effective and shows more significant results at an early stage. The results show the improvement of 23% ~33% and 15% after the curing days of 7 and 28 days. [9] Wafaa Mohamed Shaban used the approach of coating RA with slurry of fly ash, silica fumes and nano-silica fumes by the soaking method. The use of slurry for coating helps in enhancing the performance of RA by strengthening the weak mortar. Combination of fly ash and silica slurry soaking of RA is an effective method.

Extensive perfection in the RCA microstructure was detected through surface treatment.[10] Jozef Junak also follows the approach of coating RA with geopolymer slurry prior to mixing. The thickness of 0.25mm for the coating of RA was done in a rotating mixer. Long term strength of treated RA with geopolymer slurry cause concrete to have similar strength as compared to the control mix. With the increase in time coated RA water absorption significantly reduced and the value was closer to that of the control sample.

C. Mechanical Grinding

Mechanical grinding is a technique in which adhere mortar is removed due to scrubbing of concrete debris. [11] Revathi Purushothaman in the study has performed rubbing treatment on RA to remove the cement content with Los Angles Abrasion machine. The abrasion value of RA was more due to attached mortar and from trials, the conclusion was made to scrub RA only for 5 mints. Outcomes obtained from this approach prove that mechanical treatments are effective in achieving on par strength of RAC.[12] Dimitriou suggested another approach, a method in which RA are grinded in the mixer for about five hours at 10 rpm and water is added to remove smaller particles, weaker mortar and dust. The result shows less expensive concrete with nearly the same superiority as normal concrete

D. Heating and Grinding

Heating and grinding process in which RA are heated at a very high temperature of 200°~500° C and then the grinding process is done. Experiment results show that heating of aggregates takes place in an electric furnace for about 1hr and after that sample is grinded with steel ball. Moreover, the amount of cement mortar removed, specific gravity and abrasion value were investigated. The results depict that increase in temperature cause more removal of adhere mortar content.

Overall, physical properties RA may improve by heating but also increases cost due to heating at a high temperature in an electric furnace. [18] Ji-Whan Ahn. [19] Bru also performed study on heating of RA in the microwave oven and then adhere concrete was removed using an impact crusher with 290 rpm.

The result shows that microwave heating of aggregates before crushing proved to be an effective approach. [20] A. Akbarnezhad microwave-assisted recycled aggregates can be used for removal of mortar from aggregates. The visual examination showed that removal of the mortar layer makes moderately loud noise at the initial heating of 10s for saturated aggregates and 30s for air-dried samples.

Furthermore, results showed aggregates which are saturated before heating shows better yield and on par RA production. Compressive and flexural strength of concrete was also improved after heating aggregates in the oven.

E. Bacterial Treatment of Recycled Aggregates

In an effort to enhance the performance of RAC, a novel approach of surface modification of RA by microbial carbonate precipitation (MCP) was considered **[16]**. Factors manipulating MCP on RAC was explored. S. pasteurii bacterial was used for the treatment of recycled aggregates. Growth media of different level of pH was prepared with sodium hydroxide and hydrochloric acid. The results showed that amount of MCP shows the highest value at 9.5 pH and upsurges with the increase in temperature and bacteria concentration. As the weight increases of RCA due to MCP, water absorption decreases. In another research, bacteria (Sporosarcina Pasteurii) was incorporated for the surface modification of RCA using bio deposition method **[17]**. Calcium carbonate bio deposition was used for the surface modification and for precipitation calcium chloride was utilized. Results exhibited minor water absorption fall off by bio deposition of aggregates. Better results were detected in the case of fine-grain aggregates. Besides, the bacteria (Sporosarcina Pasteurii) shows a positive effect by reducing water absorption of aggregates **[17]**.

F. Steel Fibres

Steel fibre is material which is used for reinforcing the concrete for better performance. These are short discrete length material with different cross-sections and aspect ratio from about 20 to 100. Steel fibres are sufficiently small which can be randomly mixed in unharden concrete mixture using the normal mixing procedure. **Sryh and Forth [21]** incorporated steel fibres in concrete having RA and investigated dry shrinkage and creep of concrete. Where the researcher developed nine concrete mixes divided into groups where the percentage of RA, using three ratios (0, 50 and 100 per cent) as replacements for normal aggregates. Three proportions of steel fibre (0, 0.5 and 1%) were also used.

The results presented that the addition of steel fibres to RAC reduces the drying shrinkage and tensile creep whereas compressive creep deformation was very less. It can be concluded that steel fibres with RA improves the mechanical properties and reduces long term effect on concrete. **Chandar et al. [22]** investigated the effect of adding steel fibres with the existence of RA in concrete, where they casted samples containing neither recycled aggregate nor steel fibre as control specimen and also casted other combinations containing recycled aggregate with proportion (100%) as a substitute to the NA with the accumulation of steel fibres by five ratios (0, 0.5, 1, 1.5, 2%).

The result showed improvement of compressive strength with the addition of steel fibres and enhanced tensile strength of the RA concrete and the increase is obvious at the addition ratios (1 and 1.5%).

IV. CONCLUSION

A. From the review of several studies, it has been discovered that treated recycled aggregates can be used as a building material. But if utilized with the appropriate method and amount it can give effective results.

B. Recycled aggregates quality is lower than natural aggregates due to adhere mortar attached to its surface. Moreover, water absorption of RA is much more than natural aggregates.

C. Reviewing the ample of treatment methods and considering the sustainable construction and environment, strengthening the adhere mortar using pozzolanic slurry is an excellent approach.

D. The next novel conceivable treatment could be bacterial treatment (biodeposition) in which bacteria heals the micro-cracks of adhere mortar which results in the strengthening of RA. But in this method bacteria need controlled temperature and food for survival.

E. Recycled aggregates pre-soaking treatment is the best method for removing the adhere mortar water absorption reduced and mechanical performance improved. Consequently, pre-treating RA is decided to be a productive technique for higher grade utilization in construction activities.

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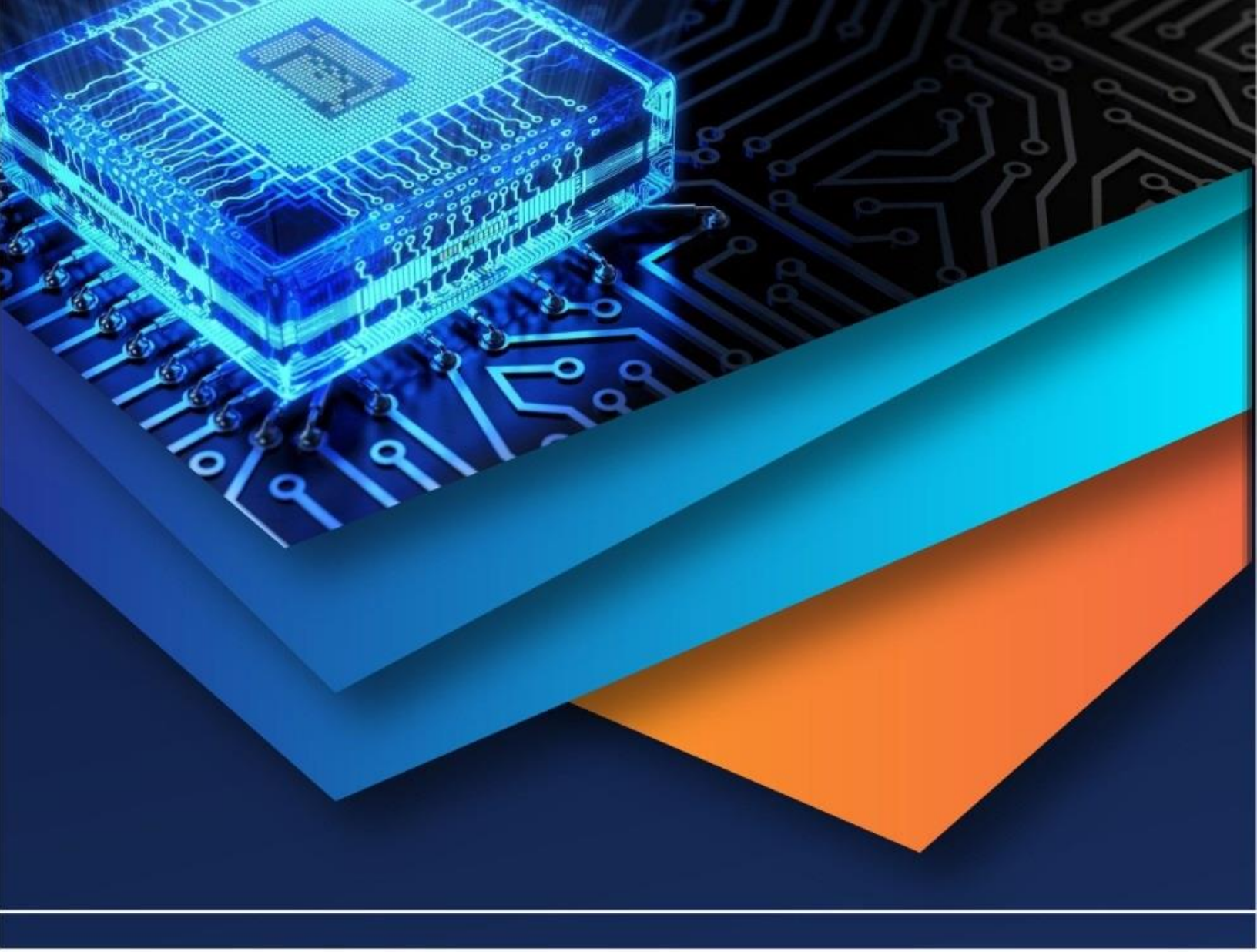

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