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A Review onProperties of Self Compacting Concrete Using Recycled Coarse Aggregate

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Abstract- Recycling of construction and demolition waste is a promising way towards sustainable construction. Coarse recycled concrete aggregates have been widely studied in recent years, and reported as a suitable alternative for natural coarse aggregates. However an extensive study of use of recycled aggregate in a new generation concretes is a relatively scarce field. Hence this study is a step forward which justifies and encourages the use of recycled aggregate in self compacting concrete to create a sustainable solution to warrant the problem of environment protection. In this paper the effect of coarse recycled concrete aggregates on the fresh and mechanical properties of self compacting concrete are investigated.

Keywords- Recycled aggregates, sustainable, self compacting concrete, fresh, mechanical).

I. INTRODUCTION

Concrete is the most widely used construction material in the world with annual consumption estimated between 21 and 31 billion tonnes (Sabnis, 2012). Concrete is used more than any other man-made material (Lomborg, 2001) and is the second largest material consumed by mankind after food and water (Adegbola and Dada, 2012). Mehwish et al., 2013 have inferred that about 7.5 billion cubic meters of concrete is produced each year, more than one cubic meter for every person on the Earth. Production of concrete requires a host of material resources in terms of cement, sand and aggregates.

Most of these materials used in concrete are naturally occurring and due to their extensive use are becoming scarce. River sand sources are fast depleting and the quantity of sand required is falling short of demand. To overcome this deficit, alternative material to river sand, namely manufactured stone crushed sand is being used in the industry in making concrete. It is well known fact that even aggregates are depleting and an alternative resource needs to be recognized and tried.

The Countries who have faced with issues pertaining to shortage of supply of raw materials have already switched on to recycling for meeting their requirement. As a large proportion of this requirement can be supplemented by using the demolished material, nevertheless this secondary material needs to be assessed before being used in making of second generation concrete. This work tests such demolished material as an alternative material to be used in concrete by recycling thus saving onto the natural resources and also satisfying the social and environmental objective.

II. BACKGROUND

International Scenario

The recycling industry had its existence in European countries way back during the Second World War. During this period a large quantity of rubble left behind was required to be disposed off. With the economy of these countries dismally shattered, acute transportation problem and shortage of equipment to work in aggregate quarries, the problem of reconstruction in these countries posed a major challenge. This paved a way in reusing of demolished concrete and building rubble as an alternate raw material.

In addition to this, number of European countries notably, Germany, England, and Netherlands made systematic attempts to harness the use demolition material in the pavements. Around the year 1973, fresh upsurge in research interest was seen in Western Europe and U.S.A. The objective of research this time was different: heavy urbanization and expansion had depleted the natural resources. Growth was seen consistently in the construction sector which resulted in heavy demand for these natural resources that was expected to grow further in future. As reported by Van, 2006 the construction spending has increased from 3500 billion US Dollars in 2003 to 4800 billion US Dollars in 2008 and 6200 billion US Dollars in 2013. These figures indicate an enormous growth worldwide in construction market that is predicted to almost double in 10 years time.

A large demand for the natural resources must be met with to sustain the growth. KeunHyeok Yang et al., (2008) have reported that the global requirement of normal aggregates will be around 8 - 10 billion tons annually beyond 2010. Thus globally enormous need for natural non-renewal resources is required to satisfy this growth in the construction sector. On account of the non-replenishing material the cost of construction is also considerably rising, thus paving way for a search of an alternative resource. Furthermore, major repair and renovation works have generated large amounts of waste adding to the burden for need of alternative method of disposal. Lauritzen (2004) has reported that the quantity of construction and demolition waste discarded every year in the USA is about 250-300 million tonnes per year, 200 to 300 million tonnes in the European economic communities, 4.5 million tons annually in Egypt (AlAnsary et al., 2004) 30 million tonnes in Japan and in the United Kingdom, and 24 million tonnes in France (Alaejos et al., 2004).

It is estimated that these figures will increase nearly threefold by the turn of this century. Evidently, these countries for the above reasons took up ―Recycling Technology‖ very seriously. Significant research progress in the United States of America, the United Kingdom, Germany, France, Japan and Netherlands indicated positive and encouraging conclusions advocating utilization of recycled aggregate for construction purposes, especially for pavements of all types. Owing to the extensive studies, developed countries like the Netherlands, Belgium and Denmark presently recycle more than 80 percent of its construction and demolition waste. In recent years many countries have considered the reutilization of construction and demolition waste as a new construction material as being one of the main objectives with respect to sustainable construction activities. From the mid 70‘s many researchers have dedicated their work to describe the properties of these aggregates, the minimum requirement for their utilisation in concrete and the properties of concrete made with recycled aggregates. Many of the aforementioned countries have also started formulating their codes of practice/standards as guidelines for use of recycled aggregate for construction purpose.

2.Indian Perspective

Indian construction industry today is amongst the fifth largest in the world and at the current rate of growth, it is slated to be amongst the top two by the next century. It makes a significant contribution to the gross domestic product (GDP) growth and to national economy. The construction sector alone contributes around 8 percent of GDP and is the second largest economic activity after agriculture. The contribution of construction to India‘s GDP is likely to increase in the coming years with huge infrastructure projects taken up by the government in the Power and Highway sectors. As per the UN 1995 report it is believed that India will have more than 40 percent of its populace living in cities in the next 30 years. The Planning Commission of India has proposed an investment of around US$ 1 trillion in the Twelfth five-year plan (2012-2017), which is double of that in the Eleventh five-year plan. Growth in the current scenario is indispensable for a developing country like India.

Construction materials in general and aggregates in particular, are important components of infrastructure requirements. Projections for building requirement in the housing sector indicate a shortage of about 55000 million cum of aggregates and another 750 million cum is required to fulfill the target of the road sector. With the shortage as likely seen today, the future seems to be in dark for the construction sector. The projected requirements of natural raw materials are not only required to fulfill the demand for the upcoming projects, but also are the needs of the extensive repairs or replacements required for the existing infrastructure and structures built few decades back.

Fulfilling the demand of resources at present is one part but presently the construction industry is facing with the massive waste disposal problem. Estimated waste generated during construction is 40 to 60 kg/m2 and during renovation another 40 to 50 kg/m 2 Technology Information, Forecasting and Assessment Council TIFAC, 2002. The management of construction and demolition waste is a major concern due to increase in quantity of demolition rubble, continuing shortage of dumping sites, increase in cost of disposal and transportation and above all, the concern about environment degradation. In developing countries the amount of construction and demolition waste is constantly increasing owing to the rise in living standards, change in consumption pattern and normal growth of population. According to a survey conducted by Central Pollution Control Board, the estimated quantity of solid waste generated in India in 2007 was around 48 million tons per annum of which 25 percent was the waste from construction. The Energy and Resources Institute (TERI) has estimated that by 2047, waste generation in Indian cities will increase five-fold to touch 260 million tonne per year, implying that the current solid waste generation is over 50 million tonne per year (Kala and Kumar, 2013). They estimated the annual increase in the quantity of solid waste in Indian cities to be at the rate of 5 per cent per annum.

Presently in India this waste is disposed off in the landfill or used as an infill material. The poor management of solid waste has led to contamination of groundwater and surface water through leachate. Unscientific practices in processing and disposal in reclaimed areas or river banks compound the environmental hazards posed by solid waste. With landfill spaces decrease and environment being destroyed, this inert waste needs a better strategy to manage. Thus with huge demand seen in construction industry and strategies present to fulfill the demand, an integrated and holistic approach involving design and construction engineering is required which respects the construction and economic environment of the country. Rapid strides are being made towards advancement of research in the field of construction material and technology. Recycle options have been tried to fulfill the growing demand which has led to the reuse of demolished waste in countries outside India.

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Research work on recycling of aggregates has also been carried out at Central Building Research Institute.

(CBRI), Roorkee, and Central Road Research Institute (CRRI), New Delhi, but as per the study commissioned by (TIFAC), 70 percent of the construction industry is not aware of recycling techniques. Hence creating awareness as well as promoting the use of recycled product is the need of the day to achieve the necessary goal. Thus it is seen that the problems in India are also alarming as in the west, considering the quantum of construction and demolishing waste generated. It is not far off when India may also have to seriously think of reusing demolished rubble and concrete for production of recycled construction material. Work on recycled concrete has been carried out at few places in India but waste and quality of raw material produced being site specific, tremendous inputs are necessary if India has to use the material in construction for producing concrete.

III. AIMS AND OBJECTIVE

The objective of this work is to analyse and propose technical guidelines on compressive strength, performance criteria and behaviour of concrete made with recycled aggregates. For recycled aggregates to be used in structural concrete, it is necessary to carry out an in depth study of their material properties and analyse how these properties in turn affect the quality of the second-generation concrete. There is already very rich experience in some European countries, Japan and in the USA on quality control standards of recycled aggregates and guidance on using them in construction. Japan and other developed countries have even laid down specifications for use of recycled aggregate in concrete. Therefore it is necessary to prepare specifications for the use of this material in construction having regards to local conditions in India.

Recycled aggregates are obtained from the demolished waste crushed concrete. From a quality point of view, these aggregates are heterogeneous in composition being derived from different minerals and adhered mortar. The properties of these aggregates must be determinedif they are to be used in concrete, therefore an attempt is made to study the aggregate characteristics to be employed in concrete mixes. Thus the objective of present work is.

- To characterize the recycled aggregates in terms of physical and chemical properties and also to study the properties of concrete made with recycled aggregates, to study the durability properties and lay standard guidelines for using recycled aggregate in concrete.
- To analyze the structural behaviour of concrete made with different percentages of recycled coarse aggregates.
- To analyze the option for the use of recycled aggregate in concrete in main stream construction rather than using it as an infill material.
- To ameliorate the reservations if any, for the use of recycled aggregates in concretes and make the industry aware of the option available on recycling and reuse.

IV. HYPOTHESIS

Hypothesis 1: Research works signify that the concrete made using recycled aggregates does not provide the desired compressive strength. A reduction in compressive strength of around 15 to 25 percent is observed when recycled aggregates are used in making concrete. This work will assess such recycled aggregates and determine whether M25 grade concrete could be prepared. The work will also try to propose a mix design procedure to be adopted if recycled aggregates are to be used in producing concrete.

Hypothesis 2: Recycled aggregates are poor in their characteristics on account of the adhered mortar content which is porous. This attached adhered mortar is the cause of higher water absorption and lower specific gravity in case of recycled aggregates. It is observed from various research reports that it is on account of this adhered mortar that concrete made with recycled aggregates compromises on compressive strength. Thus this work would try to testthe material and find out possible alternatives to improve the quality of recycled aggregates so as to prevent its detrimental effect on concrete without imposing huge capital expenditure and be feasible to be applied on site for mass production.

Hypothesis 3: Any grade of concrete not only needs to provide the desired compressive strength but also to satisfy the criteria of performance during its serviceable life. Performance is generally understood by the ability of the material to resist strain and permeation of water and other aggressive agents. Since concrete prepared with recycled aggregate is porous on account of the adhered mortar content it would be essential to evaluate whether such concrete is also durable though it may provide the necessary compressive strength. Durability in the present context will be evaluated in terms of water permeability, chloride permeation, drying shrinkage, modulus of elasticity and creep strain in concrete prepared with recycled aggregates.

V. LITERATURE REVIEW

VíctorRevilla-Cuesta, Porosity-based models for estimating the mechanical properties of self-compacting concrete with coarse and fine recycled concrete aggregate: Predicting the mechanical properties of Self-Compacting Concrete (SCC) containing Recycled Concrete Aggregate (RCA) generally depends, in great part, on the RCA fraction in use. In this study, predictive equations for estimating SCC mechanical properties are developed through SCC porosity indices, so they are applicable to any RCA fraction and amount that may be used. A total of ten SCC mixes were prepared, nine of which containing different proportions of coarse and/or fine RCA (0%, 50% or 100% for both fractions), and the tenth mixed with 100% coarse and fine RCA, and RCA powder 0–1 mm. The following properties were evaluated: compressive strength, modulus of elasticity, splitting tensile strength, flexural strength, and effective porosity as measured with the capillary-water-absorption test. Negative effects on the above properties were recorded for increasing contents of both RCA fractions. The application of simple regression models yielded porosity-based estimations of the mechanical properties of the SCC with an accuracy margin of ±20%, regardless of the RCA fraction and amount. The results of the multiple regression models with compressive strength as a secondary predictive variable presented even greater robustness with accuracy margins of ±10% and almost no significant effect of accidental porosity variations on prediction accuracy. Furthermore, porosity predictions using the 24-h effective water also yielded accurate estimations of all the above mechanical properties. Finally, comparisons with the results of other studies validated the reliability of the models and their accuracy, especially the minimum expected values at a 95% confidence level, at all times lower than the experimental results.

HosseinSasanipour, Durability properties evaluation of self-compacting concrete prepared with waste fine and coarse recycled concrete aggregates: Using recycled aggregates obtained from construction and demolition waste in concrete is a promising and appropriate solution to control the excessive consumption of natural resources in construction. In this study, the effect of fine and coarse recycled concrete aggregates (RCA) was evaluated by replacing 25%, 50%, 75% and 100% in self-compacting concretes (SCC) on mechanical properties such as compressive and tensile strength, ultrasonic pulse velocity in hardened concrete and durability properties including water absorption, volume of permeable voids, electrical resistivity and resistance to chloride ion penetration. The fresh properties of the SCC were determined using slump flow and J-ring tests. Three series of mixes were made; in the first series, coarse recycled aggregates were replaced by natural coarse aggregates.

In the second series, fine recycled aggregates replaced fine natural ones. In the third series, the combination of the coarse and fine recycled aggregates was used in the mixes. In all mixes, the cement content and water-cement ratio were constant equal to 420 kg/m^3 and 0.4, respectively. Replacement of recycled aggregates causes a decrease in compressive strength of all mixes and their effect on tensile strength was insignificant. The measured durability properties such as water absorption and volume of permeable voids of recycled aggregate concretes were also adversely affected by the incorporation of RCAs and these properties increase with an increase in RCAs contents. The results indicate that replacement of 25% coarse RCAs had no significant effect on the durability properties of self-compacting concrete including electrical resistivity and chloride ion resistance, while with the increasing fine and coarse RCAs the electrical resistivity and resistance to chloride ion penetration decreased. Results indicate that the resistance to chloride ion penetration was greatly reduced by increasing replacement of fine recycled aggregates. Very strong correlations of electrical resistivity with water absorption, and total charge passed with permeable voids of mixes containing RCA were also observed.

Hossein Sasanipour, Effect of specimen shape, silica fume, and curing age on durability properties of self-compacting concrete incorporating coarse recycled concrete aggregates: The usage of recycled concrete aggregates (RCAs) can be effected as a replacement of natural aggregates in the assurance of the environment. Utilizing these products of construction and demolition wastes in self-compacting concrete (SCC) has positive advantages such as reducing the extravagant consumption of natural supplies and decreasing carbon dioxide emissions. However, using RCAs may be affected on the properties of concrete such as reduction in compressive strength, electrical resistivity (ER), increasing in water absorption (WA) and porosity.

In this study, the durability performance of SCCs containing coarse RCAs as a partial or total replacement of natural aggregates, and silica fume (SF) as a partial replacement of cement is investigated. The replacement level of SF was considered 8% by weight of cement. Replacement level of RCAs with natural aggregates is selected at 0, 25%, 50%, 75% and 100%. Fresh properties of SCC were evaluated by measuring slump flow and J-ring tests. Durability performance of hardened concrete was investigated using WA, ER and rapid chloride penetration tests. Cube and cylindrical specimens were used to recognize the effect of shape and size specimen on ER and ultrasonic pulse velocity (UPV). Results showed that replacing RCAs decreased durability performance, but using SF in mixes significantly enhanced the ER and chloride ion penetration resistance of SCC. Results illustrated that cylindrical specimens have more consistent results than cube ones. Likewise, assessing durability performance at 91 days concluded reliable results than that in 28 days.

L.A.Pereira-de-Oliveira, Permeability properties of self-compacting concrete with coarse recycled aggregates: This article addresses to the issue of durability related properties of self-compacting concrete (SCC) with the use of coarse recycled aggregates obtained from demolition of concrete structures. The objective was to verify the influence of recycled aggregates on SCC permeability properties. For this purpose four different types of concrete mixes were produced, one of them used as reference with natural coarse aggregates and the others prepared with 20%, 40% and 100% of recycled coarse aggregates. The properties related to the durability of SCC, as air and water permeability and capillary absorption were determined on concrete specimens with and without preconditioning. The results from fresh and hardened concrete properties lead to the conclusion that it is viable to replace natural coarse aggregates by recycled coarse aggregates since the present research does not show any detrimental to the SCC permeability properties.

K.C.Panda, Properties of Self Compacting Concrete Using Recycled Coarse Aggregate: This paper presents the influence of different amounts of recycled coarse aggregate (RCA) obtained from a demolished Town Club building of Banki, N.A.C of Cuttack region, about 25 years old on the properties of self compacting concrete (SCC) and compared the results with normal vibrated concrete (NVC) containing 100% natural coarse aggregate (NCA). Important properties such as physical and mechanical properties of natural and recycled aggregates are carried out. NCA is partially replaced with RCA by an amount 10%, 20%, 30% and 40%. The effect of RCA on the properties of SCC in green state (e.g. Slump flow test, V-Funnel test and L-Box Test) and properties of concrete in hardened state (e.g. compressive strength, flexural strength, and Split tensile Strength) are studied. The mix design was carried out for M25 grade of concrete. The experimental results indicate that the compressive strength, flexural strength and split tensile strength of the SCC with 100% natural aggregate is less than the normal vibrated concrete (NVC) with 100% natural aggregate and the strength of SCC decreases with an increase in recycled aggregate (RA) replacement ratios. The present study recommends SCC marginally achieves required compressive strength up to 30% replacement of RCA.

Zoran JureGrdic, Properties of self-compacting concrete prepared with coarse recycled concrete aggregate: Self-compacting concrete has significant environmental advantages in comparison to the vibrated concrete: absence of noise and vibrations during installing provides a healthier working environment. In the paper the potential for usage of coarse recycled aggregate obtained from crushed concrete for making of self-compacting concrete was researched, additionally emphasizing its ecological value. On the other hand the issue of the waste disposal sites created by the demolition of old structures is solved. In the experiment, three types of concrete mixtures were made, where the percentage of substitution of coarse aggregate by the recycled aggregated was 0%, 50% and 100%. In the process of mixing, equal consistence of all concrete mixtures was achieved. The obtained results indicate that the properties of these concretes have only a slight difference, and that the recycled coarse aggregate can successfully be used for making of self-compacting concrete.

S.C.Kou, Properties of self-compacting concrete prepared with coarse and fine recycled concrete aggregates: In this study, the fresh and hardened properties of self-compacting concrete (SCC) using recycled concrete aggregate as both coarse and fine aggregates were evaluated. Three series of SCC mixtures were prepared with 100% coarse recycled aggregates, and different levels of fine recycled aggregates were used to replace river sand. The cement content was kept constant for all concrete mixtures. The SCC mixtures were prepared with 0, 25, 50, 75 and 100% fine recycled aggregates, the corresponding water-to-binder ratios (W/B) were 0.53 and 0.44 for the SCC mixtures in Series I and II, respectively. The SCC mixtures in Series III were prepared with 100% recycled concrete aggregates (both coarse and fine) but three different W/B ratios of 0.44, 0.40 and 0.35 were used. Different tests covering fresh, hardened and durability properties of these SCC mixtures were executed. The results indicate that the properties of the SCCs made from river sand and crushed fine recycled aggregates showed only slight differences. The feasibility of utilizing fine and coarse recycled aggregates with rejected fly ash and Class F fly ash for self-compacting concrete has been demonstrated.

ErhanGüneyisi, Rheological and fresh properties of self-compacting concretes containing coarse and fine recycled concrete aggregates: In this study, the rheological and fresh properties of self-compacting concrete (SCC) using recycled concrete aggregate (RCA) as both coarse and fine aggregates have been investigated. SCC mixtures were prepared containing natural aggregate replacements at the levels of 0, 50 and 100% for coarse recycled concrete aggregates (CRCA) and in each series of mixtures fine recycled concrete aggregate (FRCA) replacements were varied at the levels of 0, 25, 50, 75 and 100%. In all concrete mixtures, 20% of cement content was replaced with fly ash (FA) and water-to-binder ratio (w/b) was used as 0.32.

SunitaKotwal, Experimental investigation of Steel Fibre reinforced Self Compacting Concrete (SCC) using recycled aggregates as partial replacement of coarse aggregates: The Present Study focuses to gauge the performance of Steel fibre reinforced Self compacting concrete designed with target strength of 30 N/mm^2. The specimen were prepared by using recycled aggregates as a partial replacement of coarse aggregates with varying percentage of 10, 30 and 50 percent. Thereafter, casted samples were tested for fresh concrete properties such as V-funnel, L-box and U-box. The compressive strength test and Split Tensile tests were performed to determine the effect of hardened concrete using recycled aggregates and steel fibre.

VíctorRevilla-Cuesta, Simultaneous addition of slag binder, recycled concrete aggregate and sustainable powders to self-compacting concrete: a synergistic mechanical-property approach: The behavior of Self-Compacting Concrete (SCC) is very sensitive to the use of by-products in replacement of conventional cement or finer aggregate fractions. The high proportions of these raw materials in SCC can in great part explain this performance. 18 SCC mixes of slump-flow class SF3 were prepared for a thorough evaluation of different sustainable materials and for the prediction of their effects as binder or fine/powder aggregate on the mechanical properties of SCC. The mixes incorporated 100% coarse Recycled Concrete Aggregate (RCA); different amounts (0%, 50% or 100%) of fine RCA; CEM I ordinary Portland cement and CEM III/A (with 45% ground granulated blast furnace slag); and more sustainable powders compared to conventional limestone filler <0.063 mm (such as limestone powder 0/0.5 mm and RCA powder 0/0.5 mm).

Jesúsde-Prado-Gil, To predict the compressive strength of self compacting concrete with recycled aggregates utilizing ensemble machine learning models: This study aims to apply machine learning methods to predict the compression strength of self-compacting recycled aggregate concrete. To obtain this goal, the ensemble methods: Random Forest (RF), K-Nearest Neighbor (KNN), Extremely Randomized Trees (ERT), Extreme Gradient Boosting (XGB), Gradient Boosting (GB), Light Gradient Boosting Machine (LGBM), Category Boosting (CB) and the

Generalized Additive Models: Inverse Gaussian (GAM1) and Poisson (GAM2) were applied. For the development of the models, 515 research article samples were collected and divided into three subsets: training (360), validation (77), and testing (78). The SCC components: cement, water, mineral admixture, fine aggregates, coarse aggregates, and superplasticizers were taken as input variables and compression strength as output variables. To determine the ability of the models to project compressive strength, the following metrics were used: R^2, RMSE, MAE, and MAPE. The results indicate that the RF ($R^2 = 0.7128$, RMSE = 0.0807, MAE = 0.06) and GB ($R^2 = 0.6948$, RMSE = 0.0832, MAE = 0.0569) models have a strong potential to predict the compressive strength of SCC with recycled aggregates. The sensitivity analysis of the RF model indicates that cement and water are the variables that have the highest impact in predicting the compressive strength, while coarse aggregate has the lowest impact.

VI. CONCLUSION

It is desirable to use SCC because of its advantages like faster rate of construction and superior level of finish and also it can be used in congested reinforcement very well. Since the strength is not much reduced with recycled aggregates and flow properties were good recycled aggregatecan be effectively used in SCC. Early age strength was less in SCC compared to traditional concrete. While comparing the Split tensile strength SCC gave highest result. But with coarse aggregate replacement gives a less value. When Flexural strength was studied all concrete mixes gave similar to that of traditional concrete. The water absorption increased in SCC with recycledaggregate was due to the higher water absorption in RCA. But it is within satisfactory limits. So RCA is a good alternative of CA in SCC. SCC with morepercentage of RCA is to be studied.

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