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Strength and durability studies on recycled aggregate concrete

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1. INTRODUCTION

1.1 GENERAL

Concrete is one of the most widely used construction material causing a high demand for it.As a result of this, there is an increase in the demand for its constituents like the coarse aggregates, sand, cement and water. This increase in demand is causing extensive quarrying of natural aggregates as it is required as coarse aggregates in concrete production and also it forms the major constituent by mass in concrete.

In order to have sustainability in construction there has been lot of substitution for various constituents of concrete by secondary building materials. Alternatively, artificial aggregates such as manufactured sand furnace slag, fly ash, expanded clay, broken bricks and steel may also be used where suitably. It has many advantages like low cost, general availability of raw material, adaptability, low energy requirement and utilization under different environmental conditions.

The aim of any sustainable construction is to decrease the impact on environment of any construction over its lifetime. Concrete is the main material used in construction all over the world. Due to increase in Construction and Demolition activities worldwide, the concrete wastes generated due to demolition also increases. But this waste is not used for any purpose which is totally loss in the economy of the country because natural resources are depleting at a quick pace. Further the generated concrete wastes pose serious disposal problems as the municipalities are not able to find the best solution for it without affecting the environment. We know that the most common practice all over the world in case of most of the materials (paper, plastic, rubber, wood, concrete, etc.) is recycling to save the natural resources and environment. Concrete is such an expensive and energy

consuming material but it is shocking that concrete waste is seldom used by recycling the concrete as a recycled concrete aggregate (RCA) to use for the construction purposes. Instead it is just disposed of in landfills.

LITERATURE REVIEW

Ismail Abdul Rahman et al: The effect of size of the recycled aggregates on the strength and workability of the concrete is discussed in this paper. The aggregate properties are analyzed according to BS 882:1992.From the aggregate testing properties the authors conclude that, RA are flakier and more elongated than the corresponding NA. Specific gravity of RA and NA are almost similar. Water absorption is more in RA than NA and it is found to increase with increase in size of RA. But still the % of water absorption for aggregate size of 20mm is 3.48% which is still less than the maximum specified in code i.e. 10%. Hence the author concludes that RA can be used in any construction.

Mirjana Maleševet al: A comparative analysis of the experimental results of the properties of fresh and hardened concrete with different replacement ratios of natural with recycled coarse aggregate is presented in the paper. Three concrete types were tested within the research program. The type and quantity of coarse aggregate: - (R0), control mixture, - (R50), - (R100) and recycled concrete aggregate grain sizes were 4/8, 8/16 and 16/31.5 mm. Recycled concrete aggregate was produced by crushing of old concrete cubes used for compressive strength testing and one precast reinforced concrete column whose initial compressive strengths were known. Based on the tests on aggregates as per Serbian standards, the authors conclude that the RA in the range 8-16 and 16-32 did not satisfy the impact and crushing requirements.

ADVANTAGES OF RECYCLED AGGREGATES

- **Environmental Gain:** The major advantage is based on the environmental gain. According to CSIRO, demolition waste makes up to around 40% of the total waste each year (estimate around 14 million tons) going to land fill.
- **Saves 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 is used in the construction, known as "within site recycling system". Everything can be done in the construction site through this system, from the processing of recycled aggregates to manufacturing and using them. This can save energy required to transport materials to recycling plants.

 Cost: The cost of recycled aggregate is cheaper than virgin natural aggregate. According to PATH Technology Inventory, the costs of recycled concrete aggregate are around $3.50 to $7.00 per cubic yard. It depends on the aggregate size limitation and local availability. This is just around half the cost for natural aggregate that used in the construction works.

 Job opportunities: There will be many people involved in the development and application of this new technology, such as specialized and skilled persons, general workers, drivers and etc. According to Scottish Executive (2004), a Scottish Market Development Program has been developed. The purpose of this program is to recycle the materials that are arising in Scotland. This program has provided many jobs in the Scottish industry.

 Sustainability: The amount of waste materials finding their way into landfills will be

Reduced through usage of recycled aggregate. This will therefore reduce the amount of quarrying thereby extending the lives of natural resources and also the lives of sites that are used for landfill.

 Wider market available: The markets for recycled concrete aggregate are wide. According to Environmental Council of Concrete Organization, recycled concrete aggregate can be used for sidewalks, curbs, bridge substructures and superstructures, concrete shoulders, residential driveways, and structural fills. It also mentioned that recycled concrete aggregate can be used in sub bases and support layers such as unsterilized bases and permeable bases.

NEED FOR THE CURRENT STUDY

With tremendous advancements in the field of construction, it has become a necessity to maintain sustainability in construction. Most of the governments across the world have made it compulsory nowadays to assess the impact on the environment of any construction. It is very essential that any construction does not have any negative impact on the environment. Hence it becomes our responsibility as civil engineers to not only ensure that it is safe and satisfies all the required design criteria but also has no negative effect on environment. One of the best ways to do so would be to use alternative building materials in the place of the conventional materials. This has 2 advantages, one it reduces the depletion of natural aggregates and the other, and it seems to be the most suitable solution for getting rid of demolition wastes.

With increase in urbanization, land availability is continuously reducing and hence dumping of wastes in landfills is becoming increasingly difficult. Hence some alternative has to be found to effectively manage the demolished wastes generated. Further with increased development in standard of living and urbanization, the demand for new and better infrastructure increases making way for demolition of old buildings to be replaced by new ones. Further natural and man caused disasters cause demolition of buildings. Continuous demolition activities generate tons of demolition wastes which have to be taken care of. As the availability of land for their disposal is very less and also the natural aggregates required for concrete production is also depleting, we can use the demolished concrete wastes as aggregates in new concrete. Nowadays a wide range and variety of materials are being used to produce conventional concrete as the demand on natural Aggregates is increasing. Also it is important for us to conduct this study as there is no standard procedure of mix design for recycled aggregate concrete and the right mix has to be arrived by trial and error method to obtain the mix of required strength and workability. Because of large number of parameters and their variability, different approaches have to be used to arrive at the right mix.

The conventional mix design cannot be directly applied for mix proportioning and design based on the experiments seems to be the best option. The effect of variability and interaction of different materials can be properly taken care of in the mix design by experimental investigations.

In view of the above listed factors there is a need to develop a rational mix design method based on experimental methods such that it meets all the required design requirements .in this study Perumal's method of mix design is adopted for high strength concrete design.

Comparison of test results of coarse aggregates

PROPERTIES	NA	RA
FINENESS MODULUS	6.25	5.45
SPECIFIC GRAVITY	2.657	2.469
BULK DENSITY	COMPACT STATE-1.55kg/l LOOSE STATE-1.404kg/l	COMPACT STATE-1.44kg/l LOOSE STATE-1.31 kg/l
CRUSHING VALUE	27.56%	28.1%
IMPACT VALUE	21.176%	29.66%
WATER ABSORPTION	0.311%	2.24%

CONCLUSIONS

The experimental investigation was done to understand the nature, properties and the usability of construction and demolished wastes as aggregates in new concrete. Although many investigations have been done on this topic, up to now these wastes were majorly used in nonstructural constructions like kerbs, sub base course and base course etc. Further these demolished wastes were used in normal strength concrete of grade M25 and M30 etc. recently. This experimental program mainly deals with the next big step which we can take in this research. That is trying to make use of demolished wastes as coarse aggregates in high strength concrete – M60 which are used in bridge construction. Based on the experiments conducted on this subject many observations were recorded and the following conclusions were made:

- The different materials used in the production of high strength concrete have been evaluated for their strength and properties and have been characterized respectively to determine if they are suitable for being used in the production of high strength concrete.
- The constituents' mainly coarse aggregates, fine aggregates and cement have been tested for their basic properties and it is found that all the results in most cases lie within the expected range.
- The specific gravity of the aggregates must lie in the range of 2.5 to 3.
- The specific gravity of natural coarse aggregates lie within the range and is 2.657
- On the other hand the specific gravity of recycled aggregate concrete is slightly lesser than the range and is 2.469.
- Again the bulk density of the natural aggregates lies in the required range and is 1.55kg/L in compact state and 1.404kg/L in loose state.
- Whereas the bulk density of recycled aggregates is lower than that of natural aggregates similar to specific gravity and is 1.44kg/L in compact state and 1.31kg/L in loose state.
- From the above it can be concluded that both the specific gravity and bulk density of recycled aggregates is lower than that of the natural aggregates and this can be attributed to the attached mortar present in the recycled aggregates.
- The attached mortar in the aggregates make the aggregate lighter hence reducing the Specific gravity and bulk density of it.

SCOPE FOR FUTURE INVESTIGATION

From the investigations conducted and conclusions drawn, we can say that there is still lot of scope of research and improvement and modifications which, when incorporated may yield better and different results, further improving our knowledge and understanding in this topic.

Some of them are:

- In this experimental program, the demolished aggregates were crushed manually which creates non uniform aggregate sizes and aggregates of lower quality. Hence mechanized crushing methods can be adopted to obtain more uniform and superior quality aggregates.
- The method of removing attached mortar in aggregates was by manually washing them. Here again mechanized processes like grinding in ball mills can be used to remove the attached mortar to a greater extent.
- Perumal's method of mix design was adopted to make the high strength concrete grade M60 as per Indian codal provisions. Mix designs conforming to different codes can be done and the results can be compared.
- The water cement ratio was kept constant for all replacement ratios and it was observed that with increase in % replacement the strength developed reduces. In order to obtain better strength for higher replacement ratio mixes, suitable modifications in w/c ratio and mix design can be done and investigated.
- The possible use of various chemical and mineral admixtures can be investigated to further improve the strength and properties of concrete.
- Further on knowing the properties of the aggregates and mortar, the properties like compressive strength, split tensile strength, modulus of elasticity, etc. of concrete can be analytically analyzed and compared to experimental values.
- Further RC members like beams and columns can be cast using RAC and various parameters like stress, strain, deflection , flexure, shear ,crack width and spacing, etc. can be analyzed and compared to that of NAC.
- Other than the conventional tests of durability and strength which have been performed, other newer and advanced tests can be performed to understand the nature of the concrete better. Also, Shrinkage and creep effects on specimens can be studied. Modulus of elasticity can be tested.
- The strength and durability tests can be performed for a larger period of time like 56 days, 90 days, etc. and the effect and behavior of the specimens can be studied.

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