The Study of Characteristics of Sub-Base/ Base Course Using Recycled Aggregate, Cement and Pond Ash

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Abstract— **This paper represent the future possibilities of work with recycled aggregate, along the combination of cement & Pond Ash. The bricks, metal and wood items are reused in new construction but the concrete and masonry waste which forms more than 50% of CDW are still not recycled in India. Therefore, there is need to recycle these concrete waste which are creating disposal problem in construction industry. These recycled concrete aggregates (RCA) which are cheaply available from construction and demolition sites can be used in highways construction i.e. in base or sub-base layers of pavement. As the finance and funds are major problem in construction of rural roads, RCA can prove to be best alternative for rural roads which is cheap and sustainable option.**

There are many advantages that lead to the use of RCA materials as pavement material in bases/sub-bases of roads. The main advantages of using RCA in the construction industry are of sustainable values and environmental issues. The wastes from construction and demolition works are of large volume and increasing over time. To overcome this issue, sustainable construction is one of the strategies to be considered by the construction industry. One way of achieving this is to introduce recycled aggregates from these wastes of construction and demolition works into pavements.

Key Words: RCA, Construction and demolition waste (CDW), Cement, Pond Ash
Sub Area: Construction Technology
Broad Area: Transportation Engg.

I. INTRODUCTION

In recent years, the emphasis was given to increase the sustainability of environment and better ways have been explored to manage wastes materials such as coal ash, plastic, rubber, construction and demolition waste, broken glass, scrap tyres, steel furnace slag etc. which are creating a number of problems in handling and disposing.These waste materials are disposed off either in low lying areas or in land fill sites which result in filling of land fill site at a very fast rate. So, reducing, reusing and recycling are the need of hour to save the natural resources as well as to save the land fill site which are otherwise going to create space problems for disposal of waste material. It is estimated that 10-12 million tons of construction and demolition waste (CDW) is generated in India every year which needs a huge space for disposal. It is also surveyed that there is a huge deficit of about 750 million cubic meter aggregates to achieve the targets of road sector in India (www.urbanindia.nic.in). So, CDW can prove to be very useful to meet the demand and supply gap of road sector.

Manuscript received June 30, 2016

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Objectives

A lot of old buildings in India are collapsed or replaced every year. As a result, the demolished debris from the structures is to be disposed either in low lying areas or to landfills or it may be gainfully utilized in the construction of highways as sub-base or base layer after grading it. After crushing the RCA to proper gradation, these can be used in pavement base/sub-base course. The mechanical and durability properties of recycled aggregate can be improved using admixing agents like cement, coal ash, lime etc. and treated material can be used in pavement layers.

In the present work, the effects of addition of admixtures as binary blend on strength characteristics of concrete are investigated. The precise objectives of the study are as follows:-

- The main objective of this research is to understand better the mechanical behavior of recycled mixtures in order to evaluate whether they are gainfully useful as granular material in the base or sub-base layer of road pavement. Moreover, RCA mixtures treated with admixtures are investigated to evaluate the improving range in mechanical performance.
- To analyze the cost of construction of flexible pavement with RCA mixture sub-base and compare the cost with pavement comprises of moorum sub-base course on a rural road where finance and funds are major problems for their development. Moreover, stage construction is done for the design and development of rural roads where these cheap recycled materials can be gainfully used.

Scope of the work

In the present study, an attempt is made to study the gainful use of RCA with admixing agent cement and pond ash. Pond ash which is also a waste material from thermal power plants is used to improve the strength characteristics of RCA mix. The mix of RCA with admixtures cement and pond ash is used in construction of rural road where stage construction is done and is design for presently low traffic volume. The study deals with the strength characteristics of sub-base/base layer of pavement which is improved with addition of cement and pond ash. Analysis of the cost of construction of rural road and comparison of cost of construction of pavement with RCA sub-base course and moorum sub-base course is made. It will increase the environmental sustainability and play an important role in reduction of depletion of natural resources.

II. METHODOLOGY

- Collection of waste material *i.e.* pond ash and recycled concrete aggregates (RCA).
- Crushing, sieving and Laboratory testing of aggregates i.e. RCA
- Evaluation of compaction characteristics by performing Modified Proctor test
- Evaluation of strength characteristics by performing UCS test
- Optimization of cement content for the mixes.
- Evaluations of CBR for the mix at optimum cement contents.
- Cost analysis of rural road with different lead of material availability.

III. LITERATURE REVIEW

Nowadays concrete is the most widely used construction material. Durability is one of the most important considerations in the design of new structures and assessing the condition of existing structures. The last 20 to 30 years have seen a growing awareness amongst engineers of the need to ensure that provisions are made for durability in component of pavement structures. More recently, there has also been a growing awareness of the importance of sustainability in pavement construction and in particular the more effective and efficient use of materials. The review of the existing literature on the use of RCA in base and sub-base layer of pavement is discussed. The most important investigations, related to the current investigation, are summarized and salient facts which seem to emerge from the research discussed. The discussion is generally confined to the strength and durability characteristics of pavement layer with RCA and mineral admixtures such as pond ash (PA).

Review of past works

Unbound recycled concrete aggregate

Scientific knowledge on the potential for the use of recycled concrete aggregates in unbound road applications has advanced considerably. In India and many countries and regions, however, the production of recycled concrete aggregate is much lower than the generation of mixed recycled aggregate obtained from the treatment of mixed rubble. This is made up of materials of various types, such as concrete, ceramics, asphalt, natural stone, as well as organic impurities (such as wood, plastic, and paper-cardboard), and inorganic impurities (metal and gypsum). Vegas et al. (2011) constituted a scientific working document for regulating the use of recycled aggregates obtained from the treatment of mixed rubble in unbound structural road applications. In the short term, the intention was to continue this work by investigating the conditions of use of recycled aggregates of this type in bound applications with cement and lime, applying stricter criteria with regard to mechanical performance and durability.

Arulrajah et al. (2012) considered a comprehensive laboratory evaluation of the geotechnical properties of five predominant types of construction and demolitions (C&D) waste materials. The C&D materials tested were recycled concrete aggregate (RCA), crushed brick (CB), Waste Rock (WR), Reclaimed asphalt pavement (RAP), and Fine Recycled Glass (FRG). The geotechnical assessment included particle size distribution, particle density, water absorption, compaction, Los Angeles abrasion, post-compaction sieve analysis, flakiness index, hydraulic conductivity, and California bearing ratio (CBR) tests. Shear strength properties of the materials were studied through a series of tri-axial tests. In terms of usage in pavement sub-bases, RCA and WR were found to have geotechnical engineering properties equivalent or superior to that of typical natural granular sub-base materials. CB at the lower target moisture contents of 70% of the OMC was also found to meet the requirements of typical quarry granular sub-base materials. The properties of CB, RAP, and FRG, however, may be further enhanced with additives or mixed in blends with high quality aggregates to enable their usage in pavement sub-bases

Cerni et al. (2012)provided a practical and innovative method for ranking granular material for pavement design on the basis of a performance-related approach such as permanent deformation analysis; on the other, they supported the use of construction and demolition materials as a sustainable and cost effective alternative to traditional aggregates. Arulrajah et al. (2012) investigated the recycled crushed brick when blended with recycled concrete aggregate and crushed rock for pavement sub-base applications. The research indicates that up to 25%, crushed brick could be safely added to recycled concrete aggregate and crushed rock blends in pavement sub-base applications. The repeated load tri-axial test results on the blends indicate that the effects of crushed brick content on the mechanical properties in terms of permanent deformation and resilient modulus of both the recycled concrete aggregate and the crushed rock blends were marginal compared to the effects on dry density and moisture content.

Park (2003)tested the physical and compaction properties of two different recycled aggregates obtained from a housing redevelopment site (RCA1) and a concrete pavement rehabilitation project (RCA2). The bulk specific gravity and water absorption values were 2.53% and 2.54% and 1.43% and 1.77% for RCA1 and RCA2, respectively. The optimum moisture contents were found to be 9% and 12.8%, and the corresponding dry densities were 2.21 and 1.81 mg/m^3 for RCA1 and RCA2, respectively. It was apparent that the optimum moisture content increased with an increase in water absorption of the aggregates. Arulrajah et al. (2012) achieved a laboratory investigation into the geotechnical properties of recycled concrete aggregate (RCA). The Los Angeles abrasion loss tests indicated that the RCA is durable. CBR values were found to satisfy the local state road authority requirements for sub-base material. Repeated load triaxial tests established that the RCA would perform satisfactorily as a pavement sub-base material in the field. The results of the laboratory testing undertaken in this research indicated that RCA satisfied the criteria for use in pavement sub-base applications. Arulrajah et al. (2012) indicated that, at a density ratio of 98% compared to maximum dry density obtained in the modified proctor test and with moisture contents in the range of 65–90% of the optimum moisture content, most of the recycled C&D materials produce comparatively smaller permanent strain and greater resilient modulus than natural commonly used granular sub-base materials in pavement sub-base applications.

According to Fabiana et al. (2011)the possibility of using crushed concrete and demolition debris as sub-base coarse

aggregate was investigated. CBR experiments were conducted, and the behavior of the recycled materials was compared with the behavior of limestone. The results showed that CBR of crushed concrete was similar to that of natural aggregate. Conversely, demolition debris presented a fairly decrease in its CBR.

Jimenez et al. (2012)in this article evaluates the behavior and environmental impact of two recycled aggregates from selected construction and demolition waste (CDW) in field conditions. For this purpose, one experimental unpaved rural road with two sections: the first using a mixed recycled aggregate and a recycled concrete aggregate and the second section consisted of crushed limestone aggregate as a reference. The results show that recycled aggregates from selected CDW can be used as an alternative to natural aggregates in unpaved rural road construction without risk of environmental impact. This study is important for increasing recycling rates and creating a market for mixed recycled aggregates in countries such as India, which has one of the lowest recycling rates.

Cement treated recycled concrete aggregate

Cement treated materials, which are a family of compacted mixtures with granular materials, Portland cement and water, have been widely applied as road base/sub-base pavements. Since 1915, when a pavement was constructed and compacted by using a mixture of shells, sand, and Portland cement, the materials treated by cement vary from coarse-grained aggregates, recycled aggregates to very fine-grained soils. In practice, note that there are also other stabilizing agents to stabilize road materials. They are lime, granulated blast furnace slag, pozzolanas, bitumen, and chemical stabilizers. The literature review of previous researches has indicated that coarse-grained materials with low plasticity index are the most appropriate granulates for cement treatment where the cement treated granular materials have been used as semi-rigid base course.

Cement treated aggregate material (CTAM) is described as a mixture in which a relatively small amount of cement is used as a binder of coarse aggregates, and which needs a proper water content for both compaction and cement hydration. Generally, CTAM as a road base material is produced by using coarse natural or crushed aggregates and designed as a heavy traffic base or a heavy traffic wearing course. Recently, in order to protect the natural resource and reduce the environmental pollution of solid waste, recycling aggregates, such as crushed concrete and crushed masonry, have been considered to be used in road bases. Hilmi et al. utilized a traditional base material in road pavements treated with cement content of 2%, 4%, 8%, and 10% by total weight. They reported that the cement content was the most important parameter controlling the design life (fatigue performance) of stabilized layers. It should be stressed that layer thickness was also important on design life. Mixes having cement content less than 8% might be used as sub-base materials instead of being used in pavement base.

Agrela et al. investigated the use of mixed recycled cement treated aggregates to build the sub-base and base layers of roads. They reported that compared with natural aggregates, mixed recycled aggregates had a low optimal density in the modified proctor test because of the increasing percentage of masonry particles. A greater amount of water was necessary to enable optimal compaction of cement treated mixed recycled aggregates in road sub-bases. Cement treated mixed recycled aggregates had a lower workability time, and thus, it might be useful to apply a setting retardant additive. Cement treated mixed recycled aggregates exhibited good mechanical performance in terms of adequate compressive strength, low deflections under impact load, and appropriate roughness values.

Ahmed Ebrahim Abu El-Maaty Behirystudy the feasibility of using recycled concrete aggregate (RCA) mixed with traditional limestone aggregate (LSA) which is currently being used in base or sub-base applications in Egypt. Moreover, the influence of mixture variables on the mechanical properties of cement treated recycled aggregate (CTRA) is investigated. Models to predict the compressive and tensile strengths based on mixture parameters are established. It was concluded that with increasing the concrete recycled aggregate to natural limestone aggregate, the maximum density and CBR values of untreated mixtures decrease and the optimum moisture content increases and a linear relationship can be given to approximate the relationship between the UCS and the cement content where the UCS of concrete recycled aggregate is obviously higher than it for limestone aggregate especially with increasing cement content. It was also concluded that with the increase in fine material amount, the strength ratio (FS/UCS) increases within limits from 10% to 20%. The LSA obtains strength ratio higher than it for RCA where the recycled aggregate shows about 75–80% of the flexural strength for natural aggregates and about 70% of the indirect tensile strength for natural aggregates. The curing period has no obvious effect on the strength ratio.

The only limitation in the article published by Ahmed Ebrahim Abu El-Maaty Behiry is that the fly ash which is produced approximately 112 million tons each year from thermal power plants in India, is not used and its percentage utilization is less than 10%. Rafat Siddique (2003) studied the effect of replacement of fine sand with Class F type fly ash in mix and the test results indicate significant improvement in the strength properties of plain concrete by the inclusion of fly ash as partial replacement of fine aggregate.

CONCLUSIONS

RCA is a demolition waste which could be utilized with admixtures pond ash and cement in sub-base course of rural road pavements.The present study has shown quite encouraging results and following important conclusions and recommendations can be drawn from the study:The optimum moisture content (OMC) of RCA-pond ash-cement mix increases with increase in cement content of the mix and the increase is linear with increase in cement content.

1. The Unconfined Compression Strength increases with increase in Pond ash from 10% to 20% (i.e. from PA_{10} to PA_{20} mix) in mix for same cement content.
2. The mix with 50% RCA-I (retained on 4.75 mm IS sieve), 30% RCA-II (passing through 4.75 mm IS sieve), 20% Pond ash and 5.25% cement content which gives maximum 26.16% soaked CBR strength.
3. It can be concluded from the analysis of cost of Rural Road that there is decrease in cost of pavement upto 50kms lead for 3% CBR sub-grade and upto 50 kms lead for 5% CBR sub-grade by replacing Moorum

with a mix of 50% RCA-I, 30% RCA-II, 20% Pond ash and 5.25% cement. Hence, this proportion may be economically used in road.

4. The cost analysis shows that the difference cost of construction on RCA sub-base and moorum sub-base is marginal up to a lead to 100kms and beyond 100 kms the increase is not so significant that the indirect benefits of using RCA sub-base can be ignored. So, having the indirect advantages of using RCA sub-base which can't be measured in terms of cost, the RCA sub-base can be used with marginal increase in direct cost.

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