INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)

www.ijprems.com
editor@ijprems.com

Vol. 04, Issue 05, May 2024, pp: 1388-1394

e-ISSN : 2583-1062

Impact Factor: 5.725

STUDY USING DEMOLISHED CONCRETE FOR PAVEMENT CONSTRUCTION

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DOI: https://www.doi.org/10.58257/IJPREMS34509

ABSTRACT

Recycled aggregates consist of crushed, graded inorganic particles processed from the material that have been used in the constructions and demolition debris. The aim of the present study is to determine the strength characteristic of recycled aggregates for the application in concrete pavement construction. The scope of the thesis is to determine and compare the compressive strength, flexural strength and sulphate resistance of concrete by using different proportions of recycled aggregates. The investigations were carried out for workability test, compressive strength test, flexural strength test and sulphate resistance test. A total of five mixes of M-40 grade concrete with replacement of coarse aggregates with 0%, 10%, 20%, 30% and 40% recycled coarse aggregates were studied. The water cement ratio was kept constant at 0.38. The workability of concrete in general was decreased with the increase in recycled aggregates in concrete. For the strength characteristics, the results showed that the strengths of recycled aggregate concrete were comparable to the strengths of natural aggregate concrete.

Keywords:- inorganic particles, recycled aggregate , demolition debris, workability test, compressive strength

1. INTRODUCTION

In the era of construction, concrete has been the leading building material since it was discovered and found viable for future due to its durability, casy maintenance, wide range of properties and adaptability to any shape and size. Concrete is the composite mix of cement, aggregates, sand and water. Concrete gets hardened like stone on mixing water with cement and aggregates. Concrete has two types of ingredients namely active and inactive. The active group consists of water and cement. The inactive part consists of sand and coarse aggregates. Concrete has high compressive strength and low tensile strength. To overcome this shortcoming, steel reinforcements are used along with the concrete. This type of concrete is called reinforced cement concrete (RCC).

Concrete structures that are designed to have service lives of at least 50 years have to be demolished after 20 or 30 years because of deterioration caused by many agents. Old buildings require maintenance for better and higher economic gains. The rate of demolition has increased and there is a shortage of dumping space and also increase in cost of dumping. Instead of dumping this demolished concrete, use of demolished concrete as recycled concrete would not only reduce the cost but also conserve the non- renewable energy sources. The use of demolished concrete will further result in reduction in use of natural aggregates. The usage of natural aggregates is causing damage to natural resources resulting in imbalance in environment. Recycled aggregates consist of crushed, graded inorganic particles obtained from the materials that have been used in constructions. Recycled aggregates are generally obtained from buildings, roads and bridges which are demolished due to completion of life, wars and earthquake.

Background

Developments

Earthquakes and bombarding in wars causes a lot of destruction of buildings and roads causing generation of lot of concrete waste. In Second World War, bombardment caused demolition of buildings and roads. Transportations and reconstruction were the restrains in economy. At the same time, disposal of concrete waste was also a big problem. The idea of reusing demolished concrete as aggregates gave a solution to this problem and hence was justified as alternative material source in 1976.

Worldwide aggregate use is estimated to be ten to eleven billion tons each year. Of this, approximately eight billion tons of aggregate (sand, gravel, and crushed rock) is being used in Portland cement concrete (PCC) every year [Naik 2005, Mehta 2001]. Also there is a critical reduction of natural aggregate and an increasing amount of demolished concrete [Hansen 1984]. It is estimated that 150 million ton of concrete waste is produced in the United States annually [Salem 2003]. In 2005, the American Society of Civil Engineers reported US infrastructure in poor condition with an estimated repair cost of $1.6 trillion over five years.

Prospects in India

Indian economy is of developing nature. So the problem of demolished waste is not huge as in developed countries. But it is not far off when India may have to face this problem. In the down town areas of the metropolitan cities concrete towers are replacing the old buildings causing generation of demolished waste which needs to be transported and dumped. It is estimated that the construction industry in India generates about 10-12 million tons of waste annually. Projections for building material requirement of the housing sector indicate a shortage of aggregates to the extent of about 55,000million m3. An additional 750 million m3 aggregates would be required for achieving the targets of the road sector. Recycling of aggregate material from construction and demolition waste may reduce the demand-supply gap in both these sectors. Thus in a developing country like India, effective use of demolished concrete could be of great help in reduction of concrete waste and maintaining a pollution free environment

2. ENVIRONMENTAL IMPACT

Waste concrete has an adverse impact on environment. Transportation of waste concrete from site has bad impact on environment and the waste concrete filled valuable space in landfills. Construction and demolition waste makes up a large portion of all generated solid waste [Meyer 2008]. In 1980 the Environmental Resources Limited in the East European Communities (EEC) estimated that 80 million tons of demolition waste, mostly concrete, was produced each year. This number was expected to double by 2000, and triple by 2020 [Bairagi 1990]. Due to concerns with space and cost, traditional disposal of concrete waste in landfills was no longer an acceptable option [Meyer 2008).

Achieving Sustainability with Recycled Aggregate Concrete

Sustainability is defined as "Meeting the needs of the present without compromising the ability of the future generations to meet their own needs" [Naik 2005). The current usage of aggregate is not sustainable as demonstrated by the growing shortage of natural aggregates in urban area. Recycling concrete, from deteriorated concrete structures, would reduce the negative impact on the environment and increase sustainability of aggregate resources [Oikonomou 2005, Hansen 1985]. Use of RCA conserves virgin aggregate, decreases the impact on landfills and energy consumption, increases cost savings in the transportation of aggregate and waste products.

3. BARRIERS TO RECYCLED CONCRETE AGGREGATE USE

There are several barriers in use of RCA in concrete. Cost of concrete crushers is very high which increases the initial cost for plant. In addition, maintenance cost of concrete crushers is also significant. Other barrier is related to quality of RCA. Highways require quality material that meets engineering, economic and environmental considerations [Turley 2003]. However, where high performance concrete is not required, RCA can be used and thus, virgin aggregate can be conserved [Meyer 2008]. A lot of fine demolished concrete aggregate is created during the crushing process. This excess fine aggregate requires disposal or an alternate use. The absorption, strength, and impurities varies with the sources and type of RCA used. This means that it is unusable or that it might adversely impact the new pavement structure. "Durability performance of RCA is not well understood because of the limited and contradictory research results" [Salem 2003]. Concrete that contains RCA has lower compressive strength, flexural strength and sulphate resistance. It is also not known how RCA affects durability, since most studies focus only on the properties of RCA concrete [Olorunsogo 2002]. Government agencies also do not show any interest in quality assurance and are also slow to embrace the use of RCA due to concerns about quality and a reluctance to change what has worked in the past [Turley 2003]. The use of material specifications are barrier to the use of RCA in concrete. A performance- based or end result specification would allow more RCA use [Turley 2003]. However, specific standards on how to use RCA in new concrete are not currently available.

4. OBJECTIVES OF THE STUDY

The study on use of demolished concrete in pavement construction consists of conducting laboratory investigations on cement concrete prepared by using demolished concrete to estimate its suitability for pavement construction. The main objectives of the study are:

1. To prepare mix design for M40 concrete with varying proportions of recycled aggregates.
2. To determine the compressive strength of the samples at the end of 7, 28, 56 and 90 days.
3. To determine the flexural strength of the samples at the end of 7, 28, and 90 days
4. To determine the sulphate resistance strength of samples at the end of 7, 28 and 56 days.

The purpose of this research was to study the behavior of recycled coarse aggregates when it was included in Plain Cement Concrete. Slump tests were performed on freshly mixed concrete, and compression tests were performed on hardened concrete. Samples of concrete were prepared with RCA and natural aggregate, changing their mixture design parameters, including coarse aggregate proportion.

5. LITERATURE REVIEW

In road construction recycled aggregates are used as granular base course. They have proved better than the natural aggregates when used as granular base course. In case of wet sub grade areas, recycled aggregates stabilize the base and provide an improved working surface for pavement structure construction. Recycled aggregates are used as base, sub base course and sometimes for foundation purpose also. In USA, the use of recycling technology in a number of full scale pavement rehabilitation projects has been accomplished since 1976 [Kumar, Satish,2002).

In Lowa [Kumar, Satish,2002] recycled concrete was first used in 1976 for the production of new concrete where a 41 years old pavement was crushed and demolished concrete was used for the construction of 1 mile long and 22.5 cm thick highway pavement. In other construction of 17 mile long and 20 cm thick highway pavement, crushed concrete was used in Lowa in 1978. The Minnesota department of transportation recycled 16 mile long plain concrete pavement into a new concrete pavement on trunk highway in 1980. In Netherland, recycled aggregates are used for partition walls in apartments. After the damage caused in Second World War, countries like Germany, England, Netherland and other European countries have tried to use recycled concrete in new construction and made a lot of investigations over it. Some countries have developed code of practice for the use of recycled aggregates. In India recycled aggregates are not much used, but its future seems bright and one can predict remarkable contribution of recycled aggregates.

Compressive Strength

The ability to resist compression loads is called Compressive strength. It was found that the use of RCA in the concrete mix decreased compressive strength compared to natural aggregate. But it was also found that, at 28 days, all mix designs usually exceeded 50MPa compressive strength [Shayan 2003]. In one study, it was found that the compressive strength of natural concrete was 58.6 MPa, and the RCA concrete ranged from 50.9 to 62.1 MPa. The compressive strength for 50% RCA concrete was higher than 100% RCA concrete [Poon 2002]. In other study, it was found that the loss of compressive strength was in the range of 30-40% for the concrete made with RCA at 28- days [Katz 2003]. There was very less reduction in 28- and 56-day compressive strength when natural aggregate was partially replaced with RCA and a much greater reduction when RCA was used in full [Abou-Zeid].

In 2002, Buyle-bodin, et. al. showed a comparison between the behavior of RAC and natural aggregates. The affect of both the composition and the curing conditions was discussed. It was observed that durability of RAC was controlled by flow properties of high total W/C ratio and air permeability. The diffusion of CO2 was faster, that lead to a weaker resistance of RAC to environmental attacks.

In 2003, Hendricks, et.al developed the approach called design for recycling that could be used to optimize design of constructions for later use and the design for disassembly that could be used for demolition. For the technical aspects two models were developed concerning degradation processes and the high graded applications. These models were based on life cycle assessment method.

A lot of investigations have been done for use of demolished concrete and it was found that the use of recycled aggregate is an appropriate solution to the problem dumping and transportation of demolished concrete. It was found that the recycled aggregates are valuable building material in environmental, economical and technical aspects. Initially, recycled aggregates were used as landfills but now a day they are used for construction for buildings and roads. Recycled aggregates have been used in concrete kerb and gutter mix in Australia [Shing Chai NGO,2004]. In the project of Lenthall Street in Sydney, 10 mm recycled aggregates and blended recycled sand are used for concrete kerb and gutter mix.

Market development study for recycled aggregates products [Shing Chai NGO,2004] stated that recycled aggregates can be used in embankment fill. The embankment site is on the wet sub grade areas, recycled aggregates can stabilize the base and provide an improved working surface for the remaining work. In Hongkong they are used as paving blocks. Norwegian Building Research Institute mentioned that RCA can be used as backfill materials in pipe zones.

The compressive strength is most affected by the w/c ratio [Lin 2004]. Other influential parameters include fine recycled aggregate content, cleanness of aggregate, interaction between fine recycled aggregate content and crushed brick content, and interaction between w/c ratio and coarse RCA content [Lin 2004]. At a constant w/c ratio, air-dried RCA containing concrete had the highest compressive strength compared to oven-dried and saturated surface dry RCA [Poon 2003]. Particularly at lower w/c ratios. unwashed RCA reduces compressive strength. Compressive strength is 60% of virgin concrete at 0.38 w/c and 75% at 0.6 w/c.

In 2006, Poon et.al studied the environmental effects of using recycled aggregates. Concrete mixes were prepared with varying proportions of recycled aggregates. The proportion of recycled aggregates was kept varying from 0% to 100%. Target strength was kept 35 MPa. The investigations were made on affect of recycled aggregates on slump value and bleeding. The effects of delaying the bleeding tests and using fly ash on the bleeding of concrete have been examined. From this study, it was found that the use of recycled aggregates caused higher rate of bleeding. The slump of concrete mixes or without recycled aggregates was increased due to replacement of cement by 25% fly ash. It reduced bleeding rate and bleeding capacity with only minor negative effects on concrete strength at or before 28 days, but it gave positive effects on strength at age of 90 days.

6. METHODOLOGY

The methodology of the present study follows Indian Standard code IS: 516- 1959. Testing of strengths of concrete was carried out as per this code. Concrete mix design guidelines were as per IS: 10262-2009.

Scope Of Methodology

This chapter covers the methods used for compressive strength, flexural strength and sulphate resistance tests of concrete with Recycled aggregates

Preparation Of Samples For Compression Test

Preparation of Material

Proportioning

Weighing

Mixing of Concrete

All the materials should be taken at room temperature before going for batching and mixing. Materials are taken separately to ensure the avoiding the mixing of foreign material in them. Materials should be taken in such a way as to produce a mix of desired grading. Sieves should be used to separate the fine aggregates and coarse aggregates.

Proportioning

Proportioning of the material should be done as per design mix. Proportions of the materials were decided as per weight used in test cubes and unit weight of materials.

Weighing

The quantity of cement, each size aggregate and water was decided as per weights.

Mixing of Concrete

Mixing of concrete should be done either by hand mixing or by machine mixing. In the present study, machine mixing was used for mixing of concrete. Power driven mixer was used for mixing the materials. All the mixing water was added to mixing drum before introducing the solid materials. Half of the coarse aggregate was added to drum, then fine aggregate was added following the addition of cement and in the last remaining coarse aggregate was added to drum. Mixing time was not taken more than 2 minutes after adding the materials to drum and mixing is continued till uniform concrete was appeared.

Workability

Workability of concrete was checked by using slump test and compaction factor test.

Size of the Test Specimens

Moulds of cast iron were used to cast test samples, in shape of cube. Dimensions of cube were 150mm×150mm×150mm.

Casting of Specimens

Cubic moulds were well cleaned before pouring concrete in them. Mould oil was applied to inner sides of mould to avoid the sticking of concrete to sides of mould. Side plates were tightly assembled after application of mould oil between the joints. Concrete was poured in them and vibrated till compaction.

Compacting of Concrete Samples

Compacting of concrete was done by table vibrator. Vibrating was done till desired compaction was reached.

Capping of Samples

Even after vibrating the samples, the top of the cubes were not plain. Capping was done to make this side plain. The plainness of top side was checked by means of straight edge and filler gauge. Caps were made thin as practicable they could be. It was taken into consideration that capping did not cause fracture while testing the samples.

Method Used For Capping (Neat Cement Method)

Test cubes were capped with a thin layer of stiff, neat Portland cement paste' after the concrete had ceased settling in the moulds, generally for two to four hours or more after moulding. The thickness of cap layer was not kept less than 13mm. The cement for capping should be mixed to a stiff paste for about two to four hours before it was to be used in order to avoid the tendency of the cap to shrink. Adhesion of paste to the capping plate may be avoided by coating the plate with a thin coat of oil.

Opening of Moulds and Curing of Samples

Test specimens were stored in a place, free from vibration, humidity and organic materials. After 24 hours moulds were removed and test sample were taken out of moulds. Cubes were kept in water for curing, free from impurities. The water was renewed after 7 days. The temperature of water was kept at 27°C 2° C. Cubes were kept submerged in water till the testing.

7. TESTING FOR COMPRESSION STRENGTH

Testing Machine

Compressive strength testing machine was used to test the samples for compressive strength. The test samples were tested at the age of 7, 28, 56 and 90 days The ages of samples were considered from the time water was added to dry materials. Three samples for each batch were prepared and their average value was taken for final compressive strength.

Procedure

Specimens submerged in water were tested immediately after removing from the water and while they were still in the wet condition. Surface water and grit was wiped off the specimens. Wiped off specimens were kept in open for 24 hours before testing so that they could get dry completely. The dimensions of the specimens to the nearest 0-2 mm and their weight were noted before testing.

Placing the Cubes in the Machine

The bearing surfaces of the testing machine were cleaned and any other material removed from the surfaces of the specimen. Cubes were placed in the machine in such a way that the load was applied to other side than the casting side. Nothing was placed between the faces of the test specimen and the steel platen of the testing machine The load was applied without shock and increased continuously until the resistance of the specimen to the increasing load broke down and no greater load could sustain. The maximum load applied to the specimen was then recorded and the appearance of the concrete checked for any unusual features.

8. PREPARATION OF SAMPLES FOR FLEXURAL STRENGTH

Preparation of material, proportioning, weighing, mixing of material and workability for the flexural strength should be same as in section 3.2.

Size of Specimen

Cast iron mould of beams used to cast sample for flexural strength were of dimensions 100mm×100mm×500mm.

Casting of Beams

Moulds were cleaned and oiled same as the cubic mould. Fresh concrete was poured into beam moulds. Compacting, curing and opening of moulds should be done in same manner as done in case of cubic moulds.

9. TESTING OF SAMPLES FOR FLEXURAL STRENGTH

Flexural testing machine was used to determine the flexural strength. The bed of the testing machine should be provided with two steel rollers, on which the specimens were to be placed or supported The load should be applied through two similar roller, mounted at the third points of the supporting span, the rollers were at the distance of 1/3 of the length of beam from either side. The load should be divided equally between the two loading roller, and all rollers should be mounted in such a manner that the load applied axially and without subjecting the specimen to any torsional stresses or restraints.

Procedure

Test specimens submerged in water should be taken out and wiped off to remove the water and any impurities on surface.

Placing the Beams in the Machine

The bearing surfaces of the supporting and loading rollers should be wiped, and any loose sand or other material removed from the surfaces of the specimen where they were to make contact with the rollers. The specimen should then be placed in the machine in such a manner that the load should be applied to the uppermost surface. The axis of the specimen should be carefully aligned with the axis of the loading device. Nothing should be used between the bearing surfaces of the specimen and the rollers, the load should be applied without shock and increased continuously. The load should be increased until the specimen fails, and the maximum load applied to the specimen during the test should be recorded.

Calculation

The flexural strength of the specimen should be expressed as the modulus of rupture o calculated as below

$\sigma = FL / bd^2$

Where

F is the load (force) at the fracture point in MPa

L is the length of the support (outer) span in mm

b is width in mm

d is thickness in mm

10. SULPHATE RESISTANCE OF CONCRETE

Procedure of test should be same as of compressive strength except curing of samples. Curing of samples should be done in MgSO4 solution for desired time

period after keeping the cubes in water for 28 days.

Methodology of the present study includes the procedure of study. As discussed in chapter 1, the main objectives of the study were to find out the compressive strength, flexural strength and sulfate resistance of the concrete made with demolished concrete. It was estimated that whether RCA concrete was usable in pavement construction. Methodology of this study has following parts:

1. Literature review of the available studies in various journals, conferences etc.
2. Collection of RCA and natural aggregate.
3. Investigation of physical and mechanical properties of concrete with of RCA and natural aggregate which includes sieve analysis, bulk density of aggregates (coarse + fine), water absorption of aggregates(coarse + fine) and specific gravity of aggregates(coarse + fine).
4. Mix design of concrete (M40).
5. Casting of test samples. (Cube for compressive strength and sulfate resistance, beams for flexural strength)
6. Curing of samples in water tank for specified time period (Curing in MgSO, solution for sulfate resistance).
7. Samples testing for compressive strength, flexural strength and sulfate resistance at specified time periods.
8. Analysis and discussions of test results.
9. Conclusions and recommendations.

11. CONCLUSION

The present study of air entrained concrete has given a number of conclusions. Whilst some results remain fruitful for future aspects, other makes the use of AEA's to be a troublesome issue.

While enumerating the advantages, the noticeable change in workability has been noticed and shortened time and vibrations for proper consolidation. Decreased strength of concrete is the major concern towards the usage of AEA's. Hence, the practical implication towards the usage of AEA's can be attributed to the fact that how much strength of a structure can be sacrificed so as to optimise the usage of AEA's However, after the series of test results being achieved, à consolidated conclusion re- garding the parameters being considered in the present study can be summarised as follows:-

Since workability depends upon the slurnp value and the compaction factor as well; a gradual increase can be observed in the workability of the concrete as the quantity of air entraining agent is being increased, in general, the slump value increased with increase in the proportion of air entraining agent. Compressive strength has been noticed to increase with age while obtaining the test results of the study. Whilst considering the compressive strength for a particular mix at specified ages, an increasing trend is being seen.

For M0, compressive strength of 38.13 MPa at 7 days rises to 52.37 MPa at 90 days. For M1, compressive strength of 31.56 MPa at 7 days rises to 38.89 MPa at 90 days. For M2, compressive strength of 31.03 MPa at 7 days rises to 39.40 MPa at 90 days. For M3, compressive strength of 30.86 MPa at 7 days rises to 31.80 MPa at 90 days. For M4. compressive strength of 29.70 MPa at 7 days rises to 31.71 MPa at 90 days.

At a particular age, MO has the highest compressive strength while M4 having the lowest; a decremented pattern can be seen. At 7 days, compressive strength of MO is 38.13 MPa which further decreases to 29.70 MPa for M4. At 28 days, compressive strength of MO is 48.29 MPa which further decreases to 30.24 MPa for M4. At 56 days, compressive strength of MO is 51,76 MPa which further decreases to 31.10 MPa for M4. At 90 days, compressive strength of M0 is 52.37 MPa which further decreases to 31.21 MPa for M4.

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