EFFECTS ON PROPERTIES OF CONCRETE DUE TO RECYCLED AGGREGATES

A PROJECT

Submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

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to

DEPARTMENT OF CIVIL ENGINEERING

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HIMACHAL PRADESH, INDIA

May, 2016

Contents

List of Figures

List of Tables

CERTIFICATE

This is to certify that the work which is being presented in the project titled "**Effects on properties of concrete due to recycled aggregates**" in the partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by Avtansh Garg (121698) and Shubham Raj Garg (121702) during a period from July 2015 to May 2016 under the supervision of Mr. Anil Kumar, Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

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ACKNOWLEDGEMENT

We would like to express our gratitude towards the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat, for giving us an opportunity to work on this interesting project as part of our coursework towards the fulfilment of credits in project.

We would like to extend special thanks to Dr. Ashok Kumar Gupta, Professor & Head of Department of Civil Engineering, JUIT, whom constant motivation and support were instrumental in ensuring the fact that the project was completed within time. We got an opportunity to learn a lot under his guidance and without his constant support and enthusiasm the report would not have been possible in this form as today.

Further we would also like to thank Mr. Anil Kumar , Assistant Professor, Department of Civil Engineering, JUIT who spend his precious time and energy in guiding us with the experimental setup and analysis of results.

Finally the acknowledgement would be incomplete without thanking Mr. Itesh Singh, Lab Technician, Department of Civil Engineering, JUIT and spend his precious time to help us with the laboratory works performed during the project.

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ABSTRACT

India is presently generating construction and demolition (C&D) waste close to almost 23.75 million tons annually and these figures are likely to double in the next seven years. Construction and demolition waste has been seen as a resource in developed Countries. The use of recycled aggregates in concrete can be a very useful step in environmental protection. Recycled aggregates are the materials for a sustainable future. This paper reports the basic properties of recycled fine aggregate and recycled coarse aggregate & also compares these properties with natural aggregates. Basic changes in all aggregate properties are determined and their effects on concreting work are discussed at length. Similarly the properties of recycled aggregate concrete are also determined. Basic concrete properties namely compressive strength, flexural strength and tensile strength have been determined by experiments conducted on specimen like cubes, cylinders and beams. Also different combinations of recycled aggregate with natural aggregates have been used for a M20 mix of concrete. It was found through the experiments that the compressive strength of concrete with different amounts of recycled aggregates was comparable to the conventional mix. Also it was found that the tensile and flexural strength of concrete with recycled aggregate was low as compared to conventional mix.

Chapter 1

Introduction

Recycled aggregate is produced by crushing concrete, and sometimes asphalt, to reclaim the aggregate. Aggregate consists of hard, graduated fragments of inert mineral materials, including sand, gravel, crushed stone, slag, rock dust, or powder. Inert solid waste is concrete, asphalt, dirt, brick, and other rubble. Recycled aggregate comes primarily from PCC and AC from road rehabilitation and maintenance, demolition, and leftover batches of AC and PCC.

The AC and PCC generally arrives at the processor in chunks. Heavy crushing equipment is required to break up the chunks into aggregate. Some equipment is portable and can be set up on site for immediate use of product. A crushing plant may include a hopper to receive the material, a jaw to break it into more manageable pieces, a cone or impact crusher to further reduce its size, a vibrating screen to sort to the required specification, and a conveyor belt with a rotating magnet to remove metal contamination such as rebar.

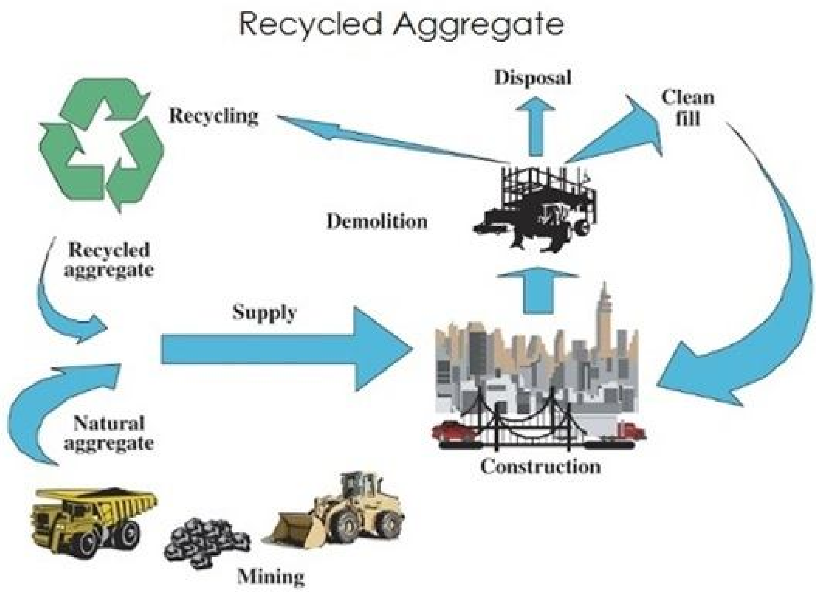

Fig 1.1 Recycling cycle of aggregates

1.1. Need for recycled aggregate

The construction industry in India is booming. Already at 10 per cent of the GDP, it has been growing at an annual rate of 10 per cent over the last 10 years as against the world average of 5.5 per cent per annum. Almost 70 per cent of the building stock in India is yet to come up. The built-up area is expected to swell almost five times from 21 billion sq ft in 2005 to Approximately 104 billion sq ft by 2030. Due to modernization, demolished materials are dumped on land and not used for any purpose. Such situations affect the fertility of land.

As per report of Central Pollution Control Board (CPCB) Delhi, in India, 48million tons solid waste is produced out of which 14.5 million ton waste is produced from the construction waste sector, out of which only 3% waste is used for embankment. Out of the total construction demolition waste, 40% is of concrete, 30% ceramic, 5% plastics, 10% wood, 5% metal, and 10% other mixtures. As reported by global insight, growth in global construction sector predicts an increase in construction spending of 4800 billion US dollars in 2013. These figures indicate a tremendous growth in the construction sector, almost 1.5 times in 5 Years. For production of concrete, 70-75% aggregates are required. Out of this 60-67% is of coarse aggregate and 33-40% is of fine aggregate. From environmental point of view, for production of natural aggregates of 1 ton, emissions of 0.0046 million ton of carbon exist where as for 1ton recycled aggregate produced only 0.0024 million ton carbon is produced. Considering the global consumption of 10 billion tons/year of aggregate for concrete production, the carbon footprint can be determined for the natural aggregate as well as for the recycled aggregate. Recycling reduces the cost (LCC) by about 34-41% and CO2 emission (LCCO2) by about 23-28% for dumping at public / private disposal facilities.

1.2. Advantages of recycling of construction materials

- Used for construction of precast and cast in situ gutters andkerbs.
- Also recycled aggregate can be used for many purposes like manufacturing of tiles and in road construction.
- Cost saving - There are no detrimental effects on concrete and it is expected that the increase in the cost of cement could be offset by the lower cost of Recycled Concrete Aggregate (RCA).

- 20% cement replaced by fly ash is found to control alkali silica reaction (ASR).
- Save environment - There is no excavation of natural resources and less transportation. Also less land is required.
- Save time - There is no waiting for material availability.
- Less emission of carbon due to less crushing.
- Up to 20% replacement of natural aggregate with RCA or recycled mixed aggregates (RMA) without a need for additional testing for all concrete up to a characteristic strength of 65 MPa., as per Dutch standard VBT 1995, is permitted.

1.3. Limitations of recycling of construction materials

- Less quality (e.g. compressive strength reduces by 10-30%).
- Duration of procurement of materials may affect life cycle of project.
- Land, special equipments machineries are required (more cost).
- Very high water absorption (up to 6%).
- It has higher drying shrinkage and creep.
- Also as this is a new field so there are less guidelines and specifications for the recycling process.
- Recycling of aggregates causes water pollution.

1.4. Objectives of the study

- To reduce the impact of waste materials on environment
- To find out the ways of cost saving such as transportation, excavation etc.
- To carry out different tests on recycled aggregates and natural aggregates and compare their results

1.5. Methodology

The collection and transportation of C and D waste started on 24 Jul 2009 and processing at the plant commenced on 29 Dec 2009.In the processing facility, IEISL is collecting 500 tonne per day (TPD) of C and D waste from three designated zones of

the Delhi i.e. Karolbagh, Sadar - Paharganj and City. The C andD waste is thereafter being recycled into aggregates at the waste management facility, which is in turn converted to Ready Mix Concrete (RMC), pavement blocks, kerb stones and concrete bricks. The products have been tested in various
laboratories and found to be suitable for the specific purposes. These products are actually being sold in the market.

Chapter 2

Literature Review

A) Scotland – About 63% material has been recycled in 2000, remaining 37% material being disposed in landfill and exempt sites. a) The Government is working out on specifications of recycling and code of practice. b) Attempts are being made for establishing links with the planning system, computerizing transfer note system to facilitate data analysis and facilitating dialogue between agencies for adoption of secondary aggregates by consultants and contractors.

B) Denmark – According to the Danish Environmental Protection Agency (DEPA), in 2003, 30% of the total waste generated was Construction and Demolition waste. a) According to DEPA around 70-75% waste is generated from demolition activity, 20-25% from renovation and the remaining 5-10% from new building developments. b) Because of constraints of landfill site, recycling is a key issue for the country. c) Statutory orders, action plan and voluntary agreements have been carried out, e.g., reuse of asphalt (1985), sorting of Construction and Demolition waste (1995) etc.

C) Netherlands – More than 40 million Construction and Demolition waste is being generated out of which 80% is brick and concrete. a) A number of initiatives taken about recycling material since 1993, such as prevention of waste, stimulate recycling, promoting building materials which have a longer life, products which can be easily disassembled, separation at source and prohibition of Construction and Demolition waste at landfills.

D) USA – Construction and Demolition waste accounts for about 22% of the total waste generated in the USA. a) Reuse and recycling of Construction and Demolition waste is one component of larger holistic practices called sustainable or green building practice. b) Green building construction practices may include salvaging dimensional number, using reclaimed aggregates from crushed concrete, grinding drywall scraps, to use as soil amendment at the site. c) Promoting „„deconstruction"" in place of „demolition". d) Deconstruction means planned breaking of a building with reuse being the main motive.

E) Japan – Much of the R andD in Japan is focused on materials which can withstand earthquake and prefabrication a) 85 million tons of Construction and Demolition waste has been generated in 2000, out of which 95% of concrete is crushed and reused as road bed and backfilling material, 98% of asphalt + concrete and 35% sludge is recycled.

F) Singapore – Construction and Demolition waste is separately collected and recycled. A private company has built an automated facility with 3, 00,000 ton per annum capacity.

G) Hong Kong – Concrete bricks and paving blocks have been successfully produced impregnation of photo catalyst for controlling Nox in ambient air.

H) India – Use for embankment purpose in bridges, roads etc. up to 3% to 4% of total production. Akmal, Sami (2011) insist that the available resources should be used appropriately and whenever recycled it should be done at the national level with the help of GULF COOPERATION COUNCIL (GCC) and ENVIRONMENT PROTECTION INDUSTRIAL CO (EPIC). They observe that GCC countries produce more than 120 million tons of waste every year out of which 18.5% is related to solid construction waste. Results from Dubai municipality indicate that out of 75% of 10,000 tons of general waste produced, 70% is of concrete demolition waste.

The author strongly advocates that a strong commitment and investment by government bodies as well as private bodies make this necessary for sustainability. Some materials are reused for recycling such as plastic, glass etc. In the same way concrete can also be used continuously as long as the specification is right. Recycling solid waste materials for construction purposes becomes an increasingly important waste management option, as it can lead to environmental and economic benefits. Conservation of natural resources, saving of energy in production and transportation, and reduction of pollution are also the advantages of recycling. In particular, concrete is a perfect construction material for recycling.

In gulf countries natural resources are imported from different locations for fulfilling the need of construction. Small sources available in gulf countries in Arabian Peninsula are limited. For construction work, demand of desalinated water and sand locally available exits. Conservation of natural sources, saving natural resources, energy transportation and reduction of pollution are advantage.

Guide for Cement and Concrete Association of New Zealand (CCANZ) 8 has show that the charges applying $10/ton on land fill dumping often make recycling concrete aggregate (RCA) a preferred option. The use of RCA to conserves natural aggregate and the associated environmental cost of exploration and transportation waste minimization and reducing the burden on landfills is a global issue. Extensive research has been carried out worldwide on the use of recycled aggregate in concrete. It also shows that globally the concrete construction industry has taken a responsible attitude to ensure that its natural resources are not over exploited. Due to issues relating to sustainability and limited natural resources, it is clear that the use of recycled and secondary aggregates (RSA), for example, crushed concrete and asphalt and industrial by products such as fly ash and blast furnace slag, will grow. However, currently, it is only in the USA, Japan, parts of Western regulations have been sufficiently put in the place that the use of RSA exceeds 10% of the total aggregate usage. Consequently, worldwide the use of RSA stands at approximately 750 million tonnes, it is less 3% out of total aggregates use in world. They also insist that sustainability is generally recognized as a foundation for resource and energy – saving technological developments in many fields including that of construction.

Parekh, Modhera5 (2011) discuss the issues relating to sustainability and limited natural resources. They also suggest use of recycled and secondary aggregates (RSA), for example crushed concrete and asphalt and industrial by products such as fly ash and blast furnace slag. Then products now reused in different material production.

There are many studies that prove that concrete made with this type of coarse aggregates can have mechanical properties similar to those of conventional concretes and even high-strength concrete is nowadays a possible goal for this environmentally sound practice.

Mirjana Malešev4 et al insiste that the quantity of recycled aggregate varies with river aggregate by % of 0,50,100 respectively. The properties of workability (slump test) immediately after mixing and 30 minutes after mixing, bulk density of fresh concrete, air content, bulk density of hardened concrete, water absorption (at age of 28 days), wear resistance (at age of 28 days), compressive strength (at age of 2, 7 and 28 days), splitting tensile strength (at age of 28 days), flexural strength (at age of 28 days), modulus of elasticity (at age of 28 days), drying shrinkage (at age of 3, 4, 7, 14, 21 and

28 days), bond between ribbed and mild reinforcement and concrete are tested. Ninety nine specimens were made for testing of the listed properties of hardened concrete.

It has been found that workability of concrete with natural and recycled aggregate is almost the same if water saturated surface dry recycled aggregate is used. Also, if dried recycled aggregate is used and additional water quantity is added during mixing, the same workability can be achieved after a prescribed time. Bulk density of fresh concrete is slightly decreased with increase in the quantity of recycled aggregate.

The authors also insist that for concrete, compressive strength mainly depends on the quality of recycled aggregate. If good quality aggregate is used for the production of new concrete, the recycled aggregate has no influence on the compressive strength, regardless of the replacement ratio of natural coarse aggregate with recycled aggregate. The same findings are found for concrete tensile strength (splitting and flexural). The modulus of elasticity of concrete also decreases with increasing recycled aggregate content as a consequence of lower modulus of elasticity of recycled aggregate compared to natural aggregate. Shrinkage of concrete depends on the amount of recycled concrete aggregate. Concrete with more than 50% of recycled coarse aggregate has significantly more shrinkage compared to concrete with natural aggregate. Increased shrinkage is a result of the attached mortar and cement paste in the recycled aggregate grains.

Brett et (2010) insist that the use of recycled aggregates in concrete is both economically viable and technically feasible. In addition to demolition waste sources, RA can also be composed of excess Concrete materials returned to the plant.

Mirza and Saif have studied the effect of silica fume on recycled aggregate concrete characteristics. The percentages of recycled aggregate replacements of natural aggregate used by weight were 0, 50, and 100%, whereas the percentages of silica fume replacements of cement used by weight were 5, 10, and 15%. The results show that the compressive and tensile strengths values of the recycled concrete aggregate increase as the recycled aggregate and the silica fume contents increase. The study also indicates that in order to accommodate 50% of recycled aggregate in structural concrete, the mix needs to incorporate 5% of silica fume.

Gupta discusses that normally coarse aggregate is the fractured stone obtained from rocks in hills or pebbles from river bed, and because of depletion of good conventional aggregate in certain regions, the need for development of Recycled Aggregate technology should be taken up commercially. It is similar to fly ash, which is available from electrostatic precipitators of various super thermal power stations which is an industrial waste material. It is chemically reactive when, mixed with cement for use in concrete. This is also useful as partial replacement of cement, as it gives concrete having better impermeability. Thus, it has a wider use in construction industry. He also notifies large scale recycling of demolished waste will offer, not only the solution of growing waste disposal problem and energy requirement, but will also help construction industry in getting aggregates locally. Such demolition waste can be crushed to required size, depending upon the place of its application and crushed material is screened in order to produce recycled aggregate of appropriate sizes. An aggregate produced by demolished buildings will be called Recycled Aggregates.

Sankarnarayanan find out the scenario in India presence of Construction and Demolition waste and other inert material (e.g. drain silt, dust and grit from road sweeping) and observes the following

i) The potential to save natural resources (stone, river sand, soil etc.) and energy, exits in these wastes

ii) Its occupying significant space at landfill sites. iii) Its presence spoils processing of bio-degradable as well recyclable waste, Construction and Demolition waste has potential use after processing and grading, Utilization of Construction and Demolition waste is quite common in industrialized countries but in India so far no organized effort has been made. The author suggests the following -

Working Sub-Group on construction and demolition waste

Presence of Construction and Demolition waste and other inert material (e.g. drain silt, dust and grit from road sweeping) is significant about a third of the total municipal solid waste generated. Construction and Demolition waste needs to be focused upon in view of

(i) The potential to save natural resources (stone, river sand, soil etc.) and energy.

(ii) Its bulk which is carried over long distances for just dumping.

(iii) It is occupying significant space at landfill sites.

(iv) Its presence spoiling processing of bio-degradable as well recyclable waste.

Construction and Demolition waste has potential use after processing and grading. Utilization of Construction and Demolition waste is quite common in industrialized countries but in India so far no organized effort has been made.

Government and ULB (Urban Services Ltd.) Initiatives

1. The Solid Waste Management (SWM) Cell of the Govt. of Maharashtra has given a prominent place to C andD waste in their action plan. Action point 1 state that „„Separate collection of debris and bulk waste. Each city needs to have its own mechanism for collection and disposal of waste from bulk waste producers and construction debris‟‟ (prescribed time – 30th November, 2006).

2. Municipal Corporation of Mumbai has notified „„Construction and Demolition and Desilting Waste (Management and Handling) Rules, 2006‟‟.Construction and Demolition waste along with silt was used as cover material in the closure project of old dump-site at Gorai in Mumbai. The bulk of Construction and Demolition waste generated in Delhi does not get into the municipal solid waste stream as Management of construction and demolition waste (MCD) has certain intermediate points for Construction and Demolition waste but proper disposal is a problem because the debris is dumped in the existing landfills, eating into their space.MCD was instrumental in getting a feasibility study done in collaboration with IL andFS. The study "Feasibility study on use of Construction and Demolition waste in road works" was carried out by CRRI. The study found potential feasibility for application in (a) embankment and sub-grade construction, (b) sub-base construction, (c) stabilized base course construction and (d) rigid pavement construction. MCD has allocated a DBOT project for proper storage and collection of 500 TPD Construction and Demolition waste from 3 MCD zones, transportation to an identified site where the material would be processed and utilized. The rejects would be land filled at the same site. The DBOT partner – IL and FS Waste Management and Urban Services Ltd. would also build a „test‟ road using processed C and D waste with technical assistance of CRRI which would then be monitored for more than a year.

3. Municipal Corporation of Delhi (MCD) is responsible for the transportation and disposal of

unclaimed waste (Delhi Municipal Corporation Act,1957). The total quantity of C andD waste collected and disposed by MCD is significantly less than the quantity of C andD waste generated in the city. In collaboration with MCD, a pilot project has been developed by IL and FS Environmental Infrastructure andS ervices Ltd (IEISL) to demonstrate the potential of a scientifically managed process in relation to the collection and recycling of CandD waste in Delhi. The project has been set up on a PPP basis at Burarion approximately seven acres of land provided bythe MCD for a period of 10 years. The collection and transportation of C andD waste started on 24 Jul 2009 and processing at the plant commenced on 29 Dec 2009.In the processing facility, IEISL is collecting 500 tonne per day (TPD) of C and D waste from three designated zones of the Delhi i.e. Karolbagh, Sadar - Paharganj and City. The C and D waste is thereafter being recycled into aggregates at the waste management facility,

which is in turn converted to Ready Mix Concrete (RMC), pavement blocks, kerb stones and concrete bricks.

4.. Efforts would be made for market development of processed C and D waste.

Relevant rules and guidelines C and D is briefly included in the Municipal Solid Waste (Management and Handling) Rules, 2000 but there is no detail information, except a brief mention in Schedule II of the rule for its separate collection. This brief mention does not appear to be sufficient in view of its growing quantum and the way it affects the overall management of municipal solid waste. Greater details and more teeth are required for (a) controlling the situation and (b) management of C and D waste in a comprehensive manner which is likely to have significantly positive impact on the overall scenario of waste management and cleanliness.

Chapter 3
Steps to be Taken in India

3.1 Fast track formation of BIS code on recycled material

There is a need to have a paid code for recycled material. The precedent has already been set by induction of exception clauses for fly ash use into the manufacturing of building materials. There is a lot of research going on in this area; this research should be leveraged quickly to formulate standards and hasten the process.

3.2 Promote alternative material in buildings

Devise innovative schemes that allows new products, systems or techniques related to housing/building not covered so far by BIS, to be certified after detailed evaluation. Construction agencies or authorities may include a material in their schedule of rates if backed by a test study based on BIS criteria. Promote alternative material for non-structural use as an interim measure till the time standards are in place.

3.3 Revise CPWD SOR to include products made out of recycled construction material Using publicly available scientific studies done by institutes like the National Council for Cement and Building Material, the CPWD should revise its SOR to allow use of products like paver blocks and flooring tiles made out of recycled C andD waste. This will ensure market development for the recycled products making them economically viable for recyclers and reduce subsidy burden on civic bodies.

3.4 Include explicit provision on collection, disposal, and reuse recycled construction material Also, set up a system and infrastructure for collection and disposal of C andD waste and recycling centres with appropriate technologies.

3.5 Promote efficient construction management practices to minimise waste National regulations and municipal rules need to push for optimal use of building space and materials, waste prevention, use of recycled content, on-site segregation, and collection and disposal system. The BIS is currently developing the Indian Standard Guidelines for Construction Project Management.

3.6 Promote use of alternative material in other infrastructure

Experiments by the Central Road Research Institute, Delhi have shown that it is possible to use C and D waste for building road, embankments and pavements. This must be included in the roadmap of all infrastructure construction agencies.

3.7 Introduce tax policies To minimise waste generation and prevent unsafe disposal. Introduce taxation to create incentive for waste minimisation.

Chapter 4
Production of Recycled Aggregate

4.1 Evaluation of Source Concrete

The first step in producing RCA from a concrete pavement is to determine the quality and overall properties of the source concrete. Records of the original concrete components, strength and durability can be useful in determining the potential applications for the RCA produced.

4.2 Pavement Preparation

If the RCA being produced is to be considered for use in a new concrete mixture, e-orts must be made to minimize the potential for introducing contaminants throughout the production process. Contaminants are generally of much less concern for RCA intended for use in sub-base aggregate and other applications. Potential contaminants in concrete pavement recycling typically include joint sealants, asphalt concrete shoulders and patching materials, reinforcing steel and dowel bars, and soils and foundation materials (NHI 1998). If possible, contaminants should be removed by an accepted method prior to the recycling process. Concrete pavements with asphalt concrete patches and overlays can be processed to produce RCA, but it generally is recommended that the two materials be recycled separately.

4.3 Pavement Breaking and Removal

The main purpose of pavement breaking is to size the material for ease of handling and transporting to the crushing plant. The slabs are broken into pieces small enough to be lifted and transported easily. Although other breaking technologies are available, the most readily available equipment for this operation are “impact breakers”, which break the pavement by dropping or hurling a heavy mass onto the pavement (Figure 1).

Figure 4.1. Trailer-mounted diesel hammer, one of the most common types of impact breakers

Front-end loaders and dump trucks can easily handle removal and transport of the broken pavement fragments to the crushing site (Figure 2).

Figure 4.2 - Front End loader

4.4 Removal of Embedded Steel

The removal of reinforcing steel, tie bars and dowel bars can occur during several phases of the recycling process, but typically is accomplished during the breaking and removal operation or following the primary and secondary crushing operations, where electromagnets often are used to pick steel from the conveyor belts (Figure 3).

Figure 4.3 Conveyor belts with electromagnets

4.5 Beneciation

Beneciation is the treatment of any raw material to improve its physical or chemical properties prior to further processing or use. This can be a necessary step in some aggregate processing operations to prevent the inadvertent inclusion of organic material, excessive dust, and other contaminants that would cause problems in the intended application of the aggregate. The degree of beneciation required depends upon the condition and composition of the crushed concrete, as well as the intended use of the RCA.

4.6 Stockpiling

Coarse RCA can be stockpiled using the same techniques and equipment as are used with virgin coarse aggregate materials. Fine RCA stockpiles generally need to be protected from precipitation to reduce the potential for secondary cementing due to hydration of exposed and previously unhydrated (or partially hydrated) cement grains. As with virgin ne and coarse aggregates, more than two separate stockpiles may be necessary to allow the production of aggregate blends that meet project specifications.

4.7 In-Place Concrete Recycling

When RCA is to be used in a sub-base layer of the roadway and/or shoulders, production can be accomplished using an in-place concrete recycling train. Such systems are capable of separating coarse and ne RCA during recycling operations and typically utilize crushers
(mounted on crawler tracks) that have been specially adapted for in-place recycling.

4.8 Crushing and Sizing

The same basic equipment used to process virgin aggregates also can be used to crush, size and stockpile the RCA (ECCO 1999), although some equipment modifications may permit more e-cient processing of most salvaged concrete pavements. The three main types of crushers used in concrete recycling feature “jaw”, “cone” and “impact” designs, which depends on how they crush the concrete. While most concrete crushing plants are designed for high-production use by large contractors, “mini concrete crushers” (capable of being towed behind a pick-up truck) also are available for small, local projects (Figure 4).With appropriate adjustments, concrete crushing plants can be set up to produce almost any desired gradation, although there often is an excess of ne RCA prod

Figure 4.4 Aggregate Crushing Plant

4.9 Quality control

The flow of quality control is from investigation of the original concrete to application of the recycled coarse aggregate concrete. Quality control is carried out according to the construction specification and manufacturing guidelines for recycled coarse aggregate concrete

- Material must be free of Contamination
- Material must pass OPSS and CSA Quality Test for Aggregate
- Material must be free of Chemical reactants and products•
- The origin of the material must be known (i.e. what was it before? Where did it come from?)
- The onus is on the Suppliers to manage their piles properly
- The Supplier must insure that the material meets the guidelines for proper use in Roads and Structures

Chapter 5

Tests on Recycled Aggregates

5.1 Particle Size Distribution

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS 2386 (Part I) – 1963. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves.

5.1.1 Significance

Sieve analyses are performed on aggregates used in roadway bases and in portland cement and asphalt cement concretes. Sieve analyses reveal the size makeup of aggregate particles – from the largest to the smallest. A gradation curve or chart showing how evenly or unevenly the sizes are distributed between largest and smallest is created in this test. How an aggregate is graded has a major impact on the strength of the base or on the properties and performance of concrete.

5.1.2 The Apparatus used are

i) A set of IS Sieves of sizes – 80mm, 63mm, 50mm, 40mm,31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm,4.75mm, 3.35mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm and 75µm.

ii) Balance or scale with an accuracy to measure 0.1 percent of the weight of the test sample.

5.1.3 The Procedure

i) The test sample is dried to a constant weight at a temperature of 110 + 5^{o}C and weighed.

ii) The sample is sieved by using a set of IS Sieves.

iii) On completion of sieving, the material on each sieve is weighed.

iv) Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight.

v) Fineness modulus is obtained by adding cumulative percentage of aggregates retained on each sieve and dividing the sum by 100.

5.1.4 The Result

Sieve analysis is carried out as per IS 2386 for crushed recycled concrete aggregate and natural aggregates. It is found that recycled coarse aggregate are reduced to various sizes during the process of crushing and sieving, which gives the best particle size distribution. The amounts of fine particles less than 4.75mm after recycling of demolished waste were in the order of 5-20% depending upon the original grade of demolished concrete. The best quality natural aggregate can be obtained by primary, secondary and tertiary crushing, whereas the same can be obtained after primary and secondary crushing incase of recycled aggregate. The single crushing process is also effective in the case of recycled aggregate. The particle shape analysis of recycled aggregate indicates similar particle shape of natural aggregate obtained from crushed rock. The recycled aggregate generally meets all the standard requirements of aggregate used in concrete.

5.2 Water Absorption

This test helps to determine the water absorption of coarse aggregates as per IS 2386 (Part III) – 1963. For this test a sample not less than 2000g should be used.

5.2.1 Significance

The measured water absorption rate and specific gravity of aggregates is routinely used in design and construction of pavement materials and structures worldwide. The ability to measure the water absorption and specific gravity of aggregate materials with high degree of accuracy and repeatability in a short time is critical for engineers and practitioners interested in the properties of soils and aggregates. The apparatus used for this test are Wire basket – perforated, electroplated or plastic coated with wire hangers for suspending it from the balance, Water-tight container for suspending the basket, Dry soft absorbent cloth – 75cm x 45cm (2 nos.), Shallow tray of minimum 650 cm^2 area, Air-tight container of a capacity similar to the basket and Oven.

5.2.2 The Procedure

i) The sample should be thoroughly washed to remove finer particles and dust, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22 and 32^{o}C.

ii) After immersion, the entrapped air should be removed by lifting the basket and allowing it to drop 25 times in 25 seconds. The basket and sample should remain immersed for a period of 24 + ½ hrs afterwards.

iii) The basket and aggregates should then be removed from the water, allowed to drain for a few minutes, after which the aggregates should be gently emptied from the basket on to one of the dry clothes and gently surface-dried with the cloth, transferring it to a second dry cloth when the first would remove no further moisture. The aggregates should be spread on the second cloth and exposed to the atmosphere away from direct sunlight till it appears to be completely surface-dry. The aggregates should be weighed (Weight ‘A’).

iv) The aggregates should then be placed in an oven at a temperature of 100 to 110^{o}C for 24hrs. It should then be removed from the oven, cooled and weighed (Weight ‘B’).

Formula used is Water absorption = [(A – B)/B] × 100%. Two such tests should be done and the individual and mean results should be reported.

5.2.3 Results

The RCA from demolished concrete consist of crushed stone aggregate with old mortar adhering to it, the water absorption ranges from 1.5% to 7.0%, which is relatively higher than that of the natural aggregates. Thus the water absorption results are satisfactory.

5.3 Bulk Density

This method of test covers the procedure for determining
unit weight or bulk density and void of aggregates. The bulk density is the weight of material in a given volume, and for the purpose of this standard it is measured in kilograms per litre. The bulk density of an aggregate is affected by several factors,

including the amount of moisture present and the amount of effort introduced in filling the measures.

5.3.1 The apparatus shall consist of the following

Balance - A balance sensitive to 0-5% of the weight of the sample to be weighed.

Cylindrical Metal Measure-The measure shall preferably be machined to accurate internal dimensions and shall be provided with handles. It shall also be watertight, and of sufficient rigidity to retain its form under rough usage, and should be protected against corrosion.

The measure shall be of 15 or 30 litres capacity according to the maximum nominal size of the coarsest particles of aggregate and shall comply with the requirements given in Table I.

Tamping Rod- A straight metal tamping rod of cylindrical cross section
16 mm in diameter and 60 cm long, rounded at one end.

5.3.2 The Procedure

i) Condition of Specimen-The test shall normally be carried out on dry material when determining the voids, but when bulking tests are required material with a given percentage of moisture may be used.

ii) Rodded or Compacted Weight - The measure shall be filled about one-third full with thoroughly mixed aggregate and tamped with 25 strokes of the rounded end of the tamping rod.

iii) A further similar quantity of aggregate shall be added and a further tamping of 25 strokes given.

iv) The measure shall finally be filled to over-flowing, tamped 25 times and the surplus aggregate struck off, using the tamping rod as a straightedge.

v) The net weight of the aggregate in the measure shall be determined and the bulk density calculated in kilograms per litre.

vi) Loose Weight - The measure shill be filled to overflowing by means of a shovel or scoop, the aggregate being discharged from a height not exceeding 5 cm above the top of the measure.

vii) Care shall be taken to prevent, as far as possible, segregation of the particle sizes of which the sample is composed. The surface of the aggregate shall then be levelled with a straightedge.
viii)The net weight of the aggregate in the measure shall then be determined and the bulk density calculated in kilogram per litre.

5.3.3 The result

The bulk density of recycled aggregate at 1456.4 kN/m^3 is lower than that of natural aggregate, thus results are not satisfactory; due to less Bulk Density the mix proportion gets affected.

5.4 Aggregate Crushing Value

This test helps to determine the aggregate crushing value of coarse aggregates as per IS 2386 (Part IV) – 1963.

5.4.1 Significance

Aggregates used in road construction should be strong enough to resist crushing under traffic wheel loads. If the aggregates are weak, the stability of the pavement structure is likely to be adversely affected. The strength of coarse aggregates is assessed by the aggregate crushing test. The aggregate crushing test value provides a relative measure of resistance to crushing under a gradually applied compressive load. To achieve a high quality of pavement, aggregate possessing low aggregate crushing value should be preferred.

5.4.2 The apparatus used is

Cylindrical measure and plunger

Compression testing machine,

IS Sieves of sizes – 12.5mm, 10mm and 2.36mm

5.4.3 Procedure

Procedure to determine Aggregate Crushing Value

i) The aggregates passing through 12.5mm and retained on 10mm IS Sieve are oven-dried at a temperature of 100 to 110^{o}C for 3 to 4hrs.

ii) The cylinder of the apparatus is filled in 3 layers, each layer tamped with 25 strokes of a tamping rod.
iii) The weight of aggregates is measured (Weight ‘A’).
iv) The surface of the aggregates is then levelled and the plunger inserted. The apparatus is then placed in the compression testing machine and loaded at a uniform rate so as to achieve 40t load in 10 minutes. After this, the load is released.
v) The sample is then sieved through a 2.36mm IS Sieve and the fraction passing through the sieve is weighed (Weight ‘B’).
vi) Two tests should be conducted.

Aggregate crushing value = (B/A) x 100%.

5.4.4 The Result

Through test the crushing value was found to be 34.6%

Chapter 6

Mix Design Calculations for M20

For mix design the IS 10262: 2009 code has been used. The calculations performed are given in this chapter.

6.1 Mix Design Computations

1. TARGET MEAN STRENGTH (TMS)

a) Statistical constant K = 1.65

b) Standard deviation S = 4.6

Thus, TMS = 27.59 N/mm^2

2. SELECTION OF W/C RATIO

a) As required for TMS = 0.5

b2) As required for 'Moderate' Exposure = 0.55

Assume W/c ratio of 0.5

3. DETERMINATION OF WATER and SAND CONTENT

For W/C = 0.6

C.F. = 0.8

Max. Agg. Size of 20 mm

a) Water content = 186 g/cum

b) Sand as percentage of total aggregate by absolute volume = 35 %

Thus,

Net water content = 180.42 kg/cum

Net sand percentage = 33 %

4. DETERMINATION OF CEMENT CONTENT

W/c ratio = 0.5

Water content = 180.42 kg/cum

Thus, Cement content = 360.84 kg/cum Adequate for moderate exposure Say 360 kg/cum

5. DETERMINATION OF COARSE AND FINE AGGREGATE CONTENT

Assume entrapped air as 2 %

Thus,

0.98 cum = [180.42+360/3.05 + {1/0.33}×{fa/2.6}]/1000

and 0.98 cum = [180.42+360/3.05 + {1/0.67}×{Ca/2.68}]/1000

Hence,

fa = 584 kg/cum

Ca = 1223.8 kg/cum

The final mix proportions of M20 grade of concrete become

Table 6.1 Mix Design ratio

Water	Cement	FA	CA
180.42	360	584	1223.8
0.50	1.00	1.62	3.40

Table 6.2 Recycled Aggregate used

Water (kg)	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Recycled Aggregate (kg)	% of Recycled aggregate
5	10	16.2	27.2	6.8	20
5	10	16.2	23.8	10.2	30
5	1	16.2	20.4	13.6	40

Chapter 7

Tests on Concrete Specimen

7.1 Compressive strength of Concrete Cubes

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. For cube test two types of specimens either cubes of 15 cm×15 cm×15 or 10cm×10 cm×10 cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15 cm × 15cm ×15 cm are commonly used. This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimens should be made even and smooth.

Fig 7.1 - Cube Mould

These specimens are tested by compression testing machine after 28 days curing. Load should be applied gradually at the rate of 4 KN per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

7.1.2 Procedure

7.1.2.1 Apparatus

Compression testing machine

7.1.2.2 Preparation of concrete samples

The proportion and material for making these test specimens are from the same concrete used in the field.

7.1.2.3 Specimen

6 cubes of 15 cm size Mix. M20

Mixing

Mix the concrete either by hand or in a laboratory batch mixer

Hand Mixing

(i)Mix the cement and fine aggregate on a water tight none-absorbent platform until the mixture is thoroughly blended and is of uniform colour

(ii)Add the coarse aggregate and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch

(iii)Add water and mix it until the concrete appears to be homogeneous and of the desired consistency

Sampling

(i) Clean the mounds and apply oil

(ii) Fill the concrete in the molds in layers approximately 5cm thick

(iii) Compact each layer with not less than 35strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet pointed at lower end)

(iv) Level the top surface and smoothen it with a trowel

Curing

The test specimens are stored in moist air for 24hours and after this period the specimens are marked and removed from the molds and kept submerged in clear fresh water until taken out prior to test.

Procedure:

(I) Remove the specimen from water after specified curing time and wipe out excess water from the surface.

(II) Take the dimension of the specimen to the nearest 0.2m

(III) Clean the bearing surface of the testing machine

(IV) Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.

(V) Align the specimen centrally on the base plate of the machine.

(VI) Rotate the movable portion gently by hand so that it touches the top surface of the specimen.

(VII) Apply the load gradually without shock and continuously at the rate of 140kg/cm2/minute till the specimen fails

(VIII) Record the maximum load and note any unusual features in the type of failure.

Calculations

Size of the cube =10cm×10cm×10cm

Area of the specimen (calculated from the mean size of the specimen)=100cm^2

Similar calculation should be done for 28 day compressive strength

Maximum load applied = …… tones =……. kN

Compressive strength = (Load in N/ Area in mm$^{2)}$ = …………N/mm^2

=……………………….N/mm^2

Results:

Average compressive strength of the concrete cube =………. N/mm^2 (at 28 days)

Fig 7.1 Strength of Cube at different % of recycled aggregate

M20	20% recycled Aggregate	18.5 N/ mm^2
M20	30%	16.75N/ mm^2
M20	40%	14 N/mm^2

Fig 7.2 - Compressive Testing of Cube

Fig 7.3 – Failed Cube after compression

Percentage strength of concrete at various ages

The strength of concrete increases with age. Table shows the strength of concrete at different ages in comparison with the strength at 28 days after casting.

Table 7.2 - % Strength of Concrete during Different Periods

Age	Strength per cent
1 day	16%
3 days	40%
7 days	65%
14 days	90%
28 days	99%

Table 7.3 - Compressive strength of different grades of concrete at 7 and 28 days

Grade of Concrete	Minimum compressive strength N/mm^2 at 7 days	Specified characteristic compressive strength (N/mm^2) at 28 days
M15	10	15
M20	13.5	20
M25	17	25
M30	20	30
M35	23.5	35
M40	27	40
M45	30	45

7.2 Split Tensile Test

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete.

The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

To determine the splitting tensile of concrete.

7.2.1Equipment

Compression testing machine

7.2.2 Sampling of Concrete Cylinders

The cylinder mould shall is of metal, 3mm thick. Each mould is capable of being opened longitudinally to facilitate the removal of the specimen and is provided with a means of keeping it closed while in use. The mean internal diameter of the mould is 10 cm ± 0.2 mm and the height is 20 +/- 0.1 cm. Each mould is provided with a metal base plate mould and base plate should be coated with a thin film of mould oil before use, in order to prevent adhesion of concrete.

7.2.3 Tamping Bar

The tamping bar is a steel bar of 16 mm diameter, 60 cm long and bullet pointed at the lower end

7.2.4 Compacting of Concrete

The test specimen should be made as soon as practicable after the concrete is filled into the mould in layers approximately 5 cm deep. Each layer is compacted either by hand or by vibration.

7.2.5 Compacting by Hand

When compacting by hand, the standard tamping bar is used and the stroke of the bar should be distributed in a uniform manner. The number of strokes for each layer should not less than 30. The stroke should penetrate in to the underlying layer and the bottom layer should be rodded throughout its depth. After top layer has been compacted, the surface of the concrete should be finished level with the top of the mould, using a trowel and covered with a glass or metal plate to prevent evaporation.

7.2.6 Curing of Specimen

The test specimens are stored in moist air for 24 hours and after this period the specimens are marked and removed from the moulds and kept submerged in clear fresh water until taken out prior to test.

Concrete cylinder 20 cm diameter and 20cm long.

Procedure of Splitting Tensile Test

1. Take the wet specimen from water after 7 days of curing
2. Wipe out water from the surface of specimen
3. Draw diametrical lines on the two ends of the specimen to ensure that they are on the same axial place.
4. Note the weight and dimension of the specimen.
5. Set the compression testing machine for the required range.
6. Keep are plywood strip on the lower plate and place the specimen.

7. Align the specimen so that the lines marked on the ends are vertical and centered over the bottom plate.
8. Place the other plywood strip above the specimen.
9. Bring down the upper plate to touch the plywood strip.
10. Apply the load continuously without shock at a rate of approximately 14-21 $kg/cm^2/min$ (Which corresponds to a total load of 9900 kg/min to 14850kg/min)
11. Note down the breaking load(P)

7.2.6 Calculations

As per IS 456: 2000, split tensile strength of concrete = $0.7f_{ck}$

The splitting tensile strength is calculated using the formula

SPLIT TENSILE STRENGTH

$T = 2P/ \pi DL$

Results

Splitting tensile strength of given concrete =……………….N/mm^2

Table 7.4 Tensile Strength at different recycled aggregates

M 20	20%	3.1 N/mm^2
M 20	30%	2.8 N/mm^2
M 20	40%	2.4 N/mm^2

Splitting tensile strength of given concrete for conventional aggregate should be 8.4 N/mm²

Fig. 7.4 – Cylinder in Split Tensile Test

Fig. 7.5 – Failed Cylinder Specimen

7.3 Flexural Strength of concrete

7.3.1 Objective

To determine the Flexural Strength of Concrete, which comes into play when a road slab with inadequate sub-grade support is subjected to wheel loads and / or there are volume changes due to temperature / shrinking.

7.3.2 Equipment and Apparatus

Beam mould of size 10×10×50 cm

- Tamping bar (40 cm long, weighing 2 kg and tamping section having size of 25 mm x 25 mm)

- Flexural test machine– The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60 cm for 15.0 cm specimens or 40 cm for 10.0 cm specimens. The load shall be applied through two similar rollers mounted at the third points of the supporting span that is, spaced at 20 or 13.3 cm centre to centre. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints.

Flexural Strength Test Arrangement

Procedure:

1. Prepare the test specimen by filling the concrete into the mould in 3 layers of approximately equal thickness. Tamp each layer 35 times using the tamping bar as specified above. Tamping should be distributed uniformly over the entire cross-section of the beam mould and throughout the depth of each layer.
2. Clean the bearing surfaces of the supporting and loading rollers , and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.
3. Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers (i.e. span) shall be 3d and the distance between the inner rollers shall be d. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.
4. The specimen stored in water shall be tested immediately on removal from water; whilst they are still wet. The test specimen shall be placed in the machine correctly

centered with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading.

5. The load shall be applied at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.

Calculations:

The Flexural Strength or modulus of rupture (f_b) is given by

$f_b = 3pa/bd^2$

where,

a = the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen

b = width of specimen (cm)

d = failure point depth (cm)

l = supported length (cm)

p = max. Load (KN)

Safety and precautions

- Use hand gloves while, safety shoes at the time of test.
- After test switch off the machine.
- Keep all the exposed metal parts greased.
- Keep the guide rods firmly fixed to the base and top plate.
- Equipment should be cleaned thoroughly before testing and after testing.

Results

a = 15 cm

b = 10 cm

d = 9 cm

p = 0.36 KN

The Flexural strength of the concrete is reported to two significant figures.

Fig 7.6 – Failed Beam Specimen

Chapter 8
Conclusions

The compressive strength test, tensile strength test and flexural strength test were conducted on the concrete samples which had conventional aggregates replaced with 20%, 30% and 40% of recycled aggregates. The following conclusions have been drawn from the analysis of results presented in the present report.

(1) The compressive strength test gave us very positive results with 20% replacement. The strength achieved using the recycled aggregates were acceptable only if compressive strength was to be taken into account like in road construction. T

(2) The values of the tensile and flexural strengths were not achieved up to a satisfactory level and according to the results the use of recycled aggregate is not advisable.

(3) Especially in places where tensile and flexural strength are of major concern like in the case of high rise buildings.

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