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A STUDY ON USE OF RECYCLED AGGREGATE MATERIALS IN CONCRETE FOR ROAD PAVEMENTS

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ABSTRACT

The requirement of concrete aggregate in India is large. Consistent to current annual production of cement of 300 million tons, total requirement of coarse and fine aggregate for utilization in cement concrete, mortar, and plasters of about 1500 MT per year is a safe estimate. Only aggregate from environmental sources are allowed in specifications. But there is difficulty in obtaining natural aggregates for constructions within economic distances. This will help in achieving economy in road construction as well as saving on environment degradation in term of reduced mining and less pollution. Construction and maintenance of roads and highways involve millions of tons of aggregate. Considering the scarcity of fresh aggregate, replacement of part of the fresh aggregate with recycled aggregate is considered in the rural roads. The tests are conducted for various proportion mix of Recycled aggregates and Natural aggregates. M30 grade of concrete is being used for the design. The waste concrete as RCA conserves virgin aggregates, reduces the impact on landfills, decreases energy consumption, and can provide cost savings. Recycled aggregates are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. The procedures of processing C&D wastes, effects of RCA on the properties of concrete and international status of standardization are described. Recent R&D work on use of RCA and fine fractions as replacement of coarse and fine aggregate in high strength concrete is described. This includes unique mixing techniques of virgin and recycled aggregate in concrete mixers.

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I. INTRODUCTION

The use of crushed aggregate from demolition and leftover concrete offers an alternative to natural coarse aggregate in new concrete. However, using 100% recycled aggregate can negatively affect properties like compressive strength and shrinkage if not managed carefully. Fine recycled aggregate below 2 mm is rarely used due to high-water demand. Guidelines typically limit recycled aggregate substitution, with leftover concrete aggregate often preferred due to known properties, unlike demolition aggregate, which may be contaminated and inconsistent. Properly controlled processes can produce high-quality recycled aggregate concrete.

In rural development, road connectivity is essential for economic and social access. Using recycled materials in road construction can reduce costs and promote sustainability. In India and other developing countries, recycled aggregate from dismantled roads helps meet the high demand for construction materials due to rapid infrastructure growth. Aggregates must withstand stresses and wear in road construction, making their properties vital for highway engineers. Recycled aggregate supports sustainable construction and ensures the durability of road networks, crucial for national development.

II.METHODOLOGY

The methodology of the study focuses on the use of recycled aggregates to produce high-quality construction materials. The process involves steps such as crushing, pre-sizing, sorting, screening, and removing contaminants to ensure clean, quality rubble that meets design criteria. Primary and secondary crushers, along with screening systems, process the rubble, with further cleaning done using water flotation, hand picking, air separators, and electromagnetic separators. Quality control is crucial to produce a good final product, avoiding the need for washing as with virgin aggregate.

Construction and Demolition Waste Management:

Recycling and reusing construction and demolition (C&D) waste reduces the need for new materials, decreases landfill disposal, cuts transportation costs, and creates a cleaner project site. Effective C&D waste management minimizes environmental impact by reducing reliance on natural resources and

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lowering emissions from manufacturing and transportation. Segregation of C&D waste at the source enhances recycling efficiency and salvage value. In India, despite the potential benefits, organized efforts for C&D waste management are still limited.

Recycled Aggregate Production:

Ideally, concrete and aggregate plants should be co-located to minimize transportation of leftover concrete. The construction industry generates 12 to 14.7 million tons of waste annually, with 7-8 million tons being concrete and brick waste. Recycled aggregates are produced by crushing and processing materials from demolished structures, ensuring they are clean and free of contaminants. The recycling process involves crushing, sizing, and blending, similar to the production of natural aggregates, using the same equipment and facilities.

Electromagnetic Separation Process

Screening Plant

Concrete Aggregate from Demolition Material:

Recycled aggregates that have been demolished and removed from foundations, pavements, bridges, or buildings are crushed, and processed into various size fractions. Reinforcing steel and other embedded items, if any, are removed and care is taken to prevent contamination by dirt or other waste building materials such as plaster or gypsum. It is prudent to store old concrete separately from other demolition materials to prevent contamination. Records of the history of the demolition concrete – strength, mix designs etc. – would seldom be available, but if available these are useful in determining the potential of the recycled aggregate concrete.

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Aggregate crushing plant

Working Sequence of Aggregate Crushing Plant:

The Crusher Supervisor oversees the operation, cleanliness, and maintenance of the crusher plant. Maintenance should be convenient but far enough from the plant to allow for future expansion. The supervisor must choose the appropriate type of crusher based on the quarry rock available. Rock is compressed between two V-shaped surfaces; one is stationary, and the other moves like a jaw. Efficient road networks within the plant are essential to prevent congestion, reduce haul time, and ensure safety. Roads should support heavy loads, have proper drainage, and be maintained regularly. Dust control measures and berms on turns are necessary, with speed limits enforced within the crusher area.

Recycled Aggregates System:

The recycled aggregates system involves processing recycled aggregates through several phases: waste reception, pre-screening, screening, crushing, conveying, magnetic separation, washing, secondary screening, secondary crushing, and material transport and storage. This system supplies aggregates produced from recycling construction and demolition waste, asphalt, and spent rail ballast. It excludes building demolition as it applies to both recycling and destruction. The majority of recycled aggregates come from construction and demolition waste (84%), with asphalt (14%) and rail ballast (2%) also contributing. *Table for Construction and demolition wastes in various countries (Million Tonnes)*

Country	Amount per year	year
Germany	223	2003
China	200	2005
South Korea	61.7	2013
India	14.7	2001
	10-12	2012

Recycled aggregate obtained after processing.

Demolition waste before processing

Materials Used:

The materials utilized in the road construction must demonstrate adequate physical and mechanical properties, complying with the required range specifications. Therefore, typical Italian road materials with known characteristics

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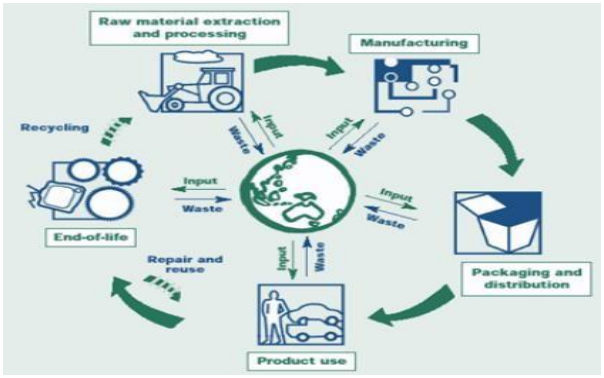
were considered for the construction. The information included in the construction Inventory concerned virgin aggregates, bitumen, recycled materials (RAP) and industrial by-products Materials data and costs were recovered from quarry in the proximity of the construction site. Wearing course was composed by polymer modified porous asphalt mix, whereas traditional bituminous mixtures were considered for binder and base layers. Two types of mixes were used in subbase layer: the first one on the top, composed by cement bound granular mix, and the second on the bottom, composed by granular unbound mix. RAP re-use was carried out with a hot in-place recycling method: RAP was sent in plant and mixed with virgin aggregates and bitumen.

In the subsequent sections, the materials used for the present experimental work are discussed.

Life Cycle Analysis (LCA):

Life-Cycle Assessment (LCA) evaluates the total environmental impact of a product from raw material extraction to disposal. LCA measures energy requirements, emissions, and material use throughout a product's life cycle. It helps establish environmental footprints, compare systems, validate green claims, and identify improvement opportunities. LCA ensures that short-term gains do not result in long-term deficits, supporting sustainable development by reducing emissions, waste, and resource consumption.



Steps Involved in LCA Analysis

Life Cycle of CDW

Internationally, Construction and Demolition Waste (CDW) generation is about 70 million tons in the UK, with India landfilling 14 million tons annually, 56% from construction. Traditional demolition uses explosives to quickly and cheaply destroy buildings but mixes

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waste, making recycling difficult. Selective demolition carefully dismantles buildings to recover and recycle materials, producing reusable secondary materials. This method, though yielding higher recovery rates, is costlier due to its time-consuming, organized, and equipment-intensive nature.

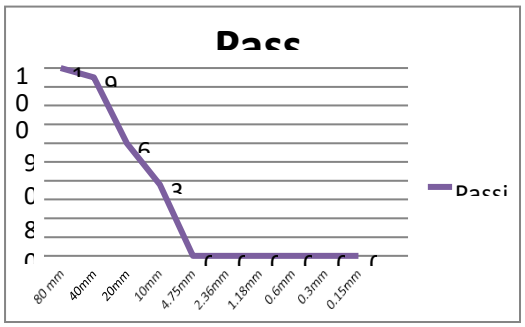
RESULTS

Aggregate Crushing Value Test

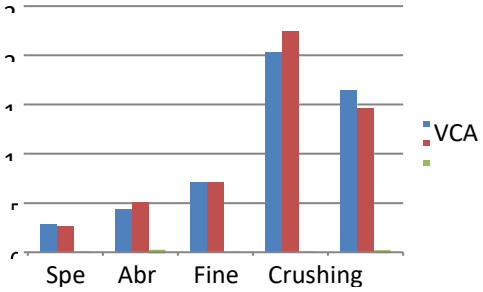
- Determine the aggregate crushing value of coarse aggregate.
- Assess suitability of coarse aggregates for use in different types of roads.

Sieve size	Weight retained	Sieve size	Weight retained	Sieve size
80 mm	0	0	0	100
40mm	250	250	5	95
20mm	1750	2000	40	60
10mm	1600	3600	72	38
4.75mm	1400	5000	100	0
2.36mm	0	5000	100	0
1.18mm	0	5000	100	0
0.6mm	0	5000	100	0
0.3mm	0	5000	100	0
0.15mm	0	5000	100	0

Table for sieve analysis for recycled aggregate



Graph for the variation of % of passing on each sieve.



Graph is for the comparison of the recycled and virgin aggregates.

Graph showing the comparison properties of the recycled and Virgin aggregates Utilizing recycled aggregate is certainly an important step towards sustainable development in the concrete industry and management of construction waste. Recycled aggregate (RA) is a viable alternative to natural aggregate, which helps in the preservation of the environment. One of the critical parameters that affect the use of recycled aggregate is variability of the aggregate properties. Quality of the recycled aggregate is influenced by the quality of materials being collected and delivered to the recycling plants. Therefore, production of recycled aggregate at an acceptable price rate and quality is difficult to achieve due the current limitations on the recycling plants. These issues concern the clients about the stability of production and variability in aggregate properties. The main goal of

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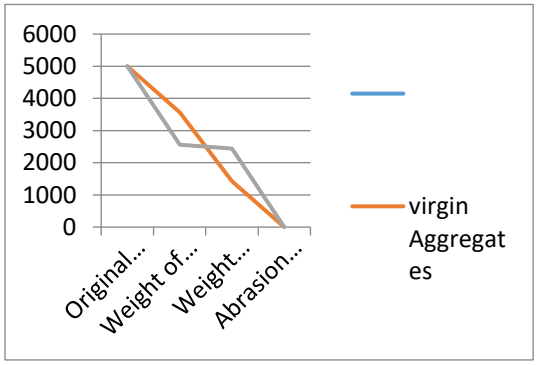
the current research project is to investigate variability of aggregate properties and their impact on concrete production. Aggregate strength, gradation, absorption, moisture content, specific gravity, shape, and texture are some of the physical and mechanical characteristics that contribute to the strength and durability of concrete. Therefore, it is necessary to evaluate these properties before utilizing the aggregate.

Type of Aggregates	Original weight of aggregate sample W1 g	Weight of aggregate	Type of Aggregates	Original weight of aggregate sample W1 g
recycled Aggregates	5000	3570	1430	28.6%
virgin Aggregates	5000	2560	2440	48.8%

Table above is the Los Angeles Abrasion Test Results



Graph indicates the increasing trend of Abrasion Value

Picture above is for the slump cone recycled aggregate.

Slump test is the most used method of measuring consistency of concrete which can be employed either in laboratory or at site work. For the present work, slump tests were conducted. The apparatus for conducting the slump test essentially consists of a metallic mould in the form of frustum of a cone having the internal dimensions as under:

- Bottom diameter: 20 cm
- Top diameter: 10 cm
- Height: 30 cm

III.CONCLUSIONS

The strength recommended for this experimental study was 30N/mm2. In the experimental investigation done it was shown that (70%NCA+30%) got the maximum strength of 32.10. This strength is much more than the required strength hence (50%NCA+50%RCA) is taken as the required strength 30.69.

When the water cement ratio used in recycled aggregate mix is reduced, tensile strength and modulus of elasticity are improved. The RCA replaced mixes have greater water absorption and porosity than normal mix but within the permissible limits. These properties can be modified by reducing the w/c ratio. abrasion clearly indicate that RCAs are of lower quality than VCAs as they contain mortar from past studies it is cleared that

10% extra water and 5%extra cement should be preferred to produce a rich mix by using RCAs. Recycled aggregate materials produce harsh mixes with lower workability than VAs. New standards should be introduced for recycled aggregates so that these materials can be used successfully in future.

IV.FUTURE SCOPE

That proper design mixes with different percentage of recycled concrete aggregates with virgin aggregates should be prepared to achieve the adequate strength of the concrete and to reduce the consumption of VA.

By using RCA, the burden of construction wastes can be reduced to a suitable extent. A suitable code of practice for recycled concrete aggregates should be prepared in which strength parameters about RCA are described.

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