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Environmental Sustainability by Use of Recycled Aggregates - An Overview

D. K. Gandhi*, A. A. Gudadhe**, M. T. Ramteke***, N. Thakur****, C. R. Deshpande *****
(Department of Civil Engineering, Datta Meghe Institute of Engineering, Technology & Research, Sawangi (Meghe), Wardha-442004, Maharashtra, India

ABSTRACT
Optimum utilization of available natural resources is the major component to achieve the environmental sustainability. Development in urban infrastructure demands for large quantity of aggregates for construction. Infrastructural waste in the form of demolished aggregates is one of the major components of solid waste. By efficient use of these demolished aggregates in the form of recycled aggregates along with fresh aggregates can achieve a better solid waste management and also cope up with the rising demands of aggregates leading to economy. Present study is an attempt to increase the awareness about economical viability and technical feasibility for the use of recycled aggregates as a construction material in concrete and to show that the use of recycled aggregates is also an efficient measure to reduce the intensity of environmental impact.
***Keywords* -** Environmental sustainability, recycled aggregates, economical viability, etc.

I. INTRODUCTION

Economy of the world depends upon the magnitude of available natural resources. Sustainable development can be achieved by optimum utilization of these available natural resources. Solid waste generation and its management is a worldwide issue. Building demolition waste is one of the major components of solid waste. Due to modernization, demolished materials are dumped on land & not used for any purpose. Such situations affect the fertility of land. As per report of Hindu online of March 2007, India generates 23.75 million tons demolition waste annually. 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.

For production of concrete, 70-75% aggregates are required. Out of this 60-67% is of coarse aggregate & 33-40% is of fine aggregate. As per recent research by the Fredonia group, it is forecast that the global demand for construction aggregates may exceed 26 billion tons by 2012. Leading this demand is the maximum user China 25%, Europe 12% & USA 10%, India is also in top 10 users. 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. The use of recycled aggregate generally increases the drying shrinkage creep & porosity to water & decreases the compression strength of concrete compared to that of natural aggregate concrete. It is nearly 10-30% as per replacement of aggregate. Recycling reduces the cost (LCC) by about 34-41% & CO2 emission (LCCO2) by about 23-28% for dumping at public / private disposal facilities [1]

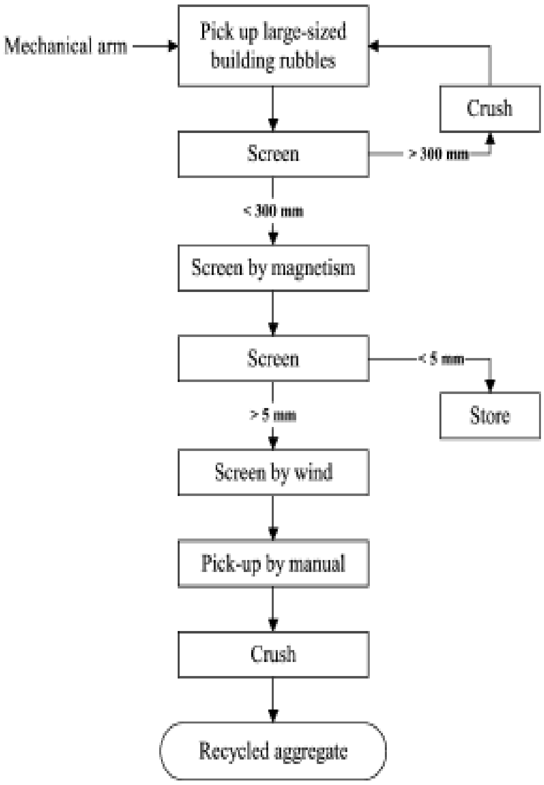
Sustainable development can only be achieved by conserving the natural resources and reducing the impact on environment. The production of fresh natural aggregates involves lot of quarrying and consumption of energy. Developing an awareness regarding optimum use of use of available natural resources and recycling of the available natural resources in the form of recycled aggregates can be an effective alternative. Reuse of concrete rubble exempts the producer from cost of transport and deposition of landfills, which are constantly increasing. Such activity is also environmental friendly by reducing the use of nonrenewable sources of natural aggregate. The systematic management of available natural resources can reduce the use of nonrenewable resources and also energy and fin ally reduces the impact on environment which can lead to economic and sustainable environment.

II. LITERATURE REVIEW

Selected international experience has been outlined here which has relevance

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 & 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 & Demolition waste (1995) etc. C) Netherlands – More than 40 million Construction & 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 & Demolition waste at landfills. D) USA – Construction & Demolition waste accounts for about 22% of the total waste generated in the USA. a) Reuse and recycling of Construction & 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&D in Japan is focused on materials which can withstand earthquake and prefabrication [1] Recycled aggregates are composed of the rubble from the demolition of buildings roads, and other sources such as returned concrete. RAC can be produced in various grades, including non-structural landscaping, pavements and even structural applications. The challenges to maintaining stringent mechanical performance standards while using RA in concrete mixes have been overcome by adapting either the batching process or reducing the proportion of recycled material. Tam et al. (2005) have adapted the mixing process into two stages- the first to coat the aggregate in rich cement slurry, and the second to complete the addition of mixing water. The authors found that this technique filled micro cracks along the interfacial transition zone and also allowed fresh paste to reach the surface of the mineral aggregate. The American Concrete Pavement Association reports that the problem of high water absorption capacity in RA has been addressed by simple techniques such as presoaking aggregates prior to batching (American Concrete Pavement Association 2009). The suitability of RA for concrete applications has been investigated by many. In general, concrete containing some proportion of RA has been found to have slightly diminished mechanical properties in comparison to material incorporating purely virgin aggregates. Tupcu and Sengel (2004) created concrete specimens with target strengths of 16 MPa and 20 MPa and then replaced virgin aggregates with recycled aggregates at the rate of 30, 50, 70 and 100%. It was found that the compressive strength decreased at a rate proportional to the addition of recycled aggregates. Tu et al. (2006) explored the use of recycled aggregates in high performance concrete (HPC). The research group tested concretes in strength ranges suitable for structural applications (20-40 MPa) that had been created with either recycled coarse or recycled coarse and fine aggregates. It was determined that a strength reduction of 20-30% could be expected due to aggregate replacement. Overall, the consequence of replacing virgin aggregates with RA has resulted in 10-30% reductions in compressive strength, with the least impact being found in mixes that only include recycled coarse aggregates (Ajdukiewicz and Kliszczewicz 2002; Chen et al. 2003; Topçu and Günçan 1995; Topçu and Sengel 2004; Tu et al. 2006; Xiao et al. 2005). Evangelista and de Brito (2007) added crushed fine aggregate to concrete mixtures and found declining performance in terms of elastic modulus, tensile strength and abrasion resistance. Compressive strength was not significantly impacted and the authors speculated that the fines contribute both hydrated and anhydrates cement to the mix and thereby improved compressive strength. [2]

III. GENERAL PROCESS TO OBTAIN RECYCLED AGGREGATE [3]



IV. TECHNICAL FEASIBILITY

- Although it is not feasible to replace fine natural aggregate by fine recycle aggregate but it can be stated that recycled aggregate obtained from crushed concrete can be used as a full value component of new concrete. The procedure of preparing concrete mixture containing recycled aggregate resembles the one with the natural aggregate it is how ever necessary to adjust the waters ratio in order to obtained the desired consistency of mixture. [4]
- There is possibility to produce RAC with properties comparable with properties of NAC. [4]
- Compressive straight of recycle aggregate concretes in which the natural gravel is replaced in the range of 25% to 100% is in the comparable range with strength of NAC. [4]

Basic technical properties studied by (Michal Boltryk et al) showed that recycled aggregates from crushed concrete of average strength can be feasibly used.

- series NAC – concrete mixture with natural aggregate exclusively,
- series RAC1 – concrete mixture with 25% of recycled aggregate, series RAC2 – concrete mixture with 50% of recycled aggregate,
- series RAC3 – concrete mixture with 75% of recycled aggregate

4.1 TEST RESULTS & PROPERTIES STUDIED BY DIFFERENT AUTHORS

4.1.1 (Michal Boltryk et al)

Concrete compressive strength was tested according to the standard PN-EN 12390-3. Results presented in Figure 1 show that the highest compressive strength after 28 days was achieved by specimens with 25% and 75% of recycled coarse aggregate. The difference however insignificant and equals about 4% in relation to NAC. After 90 days of hardening the highest compressive strength achieved NAC and the lowest RAC1 (25% of recycled coarse aggregate). The difference reached 8.3%. The 90-day compressive strength of RAC3 (75% of recycled coarse aggregate) is the closest to compressive strength of NAC. Rinsing the dust fractions from recycled aggregate improved cohesion between aggregate grains and cement paste and in this way improved strength of the interfacial zone.

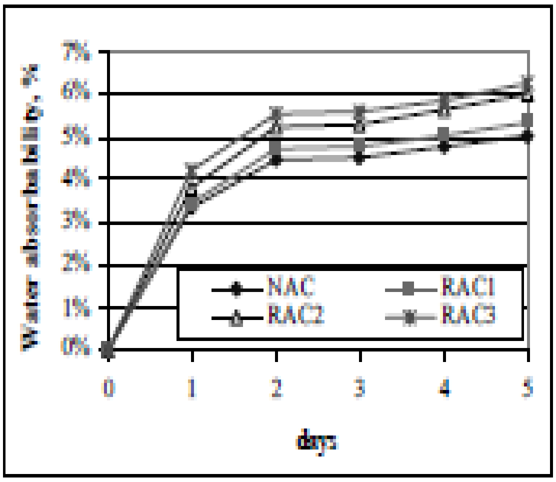


Figure 1

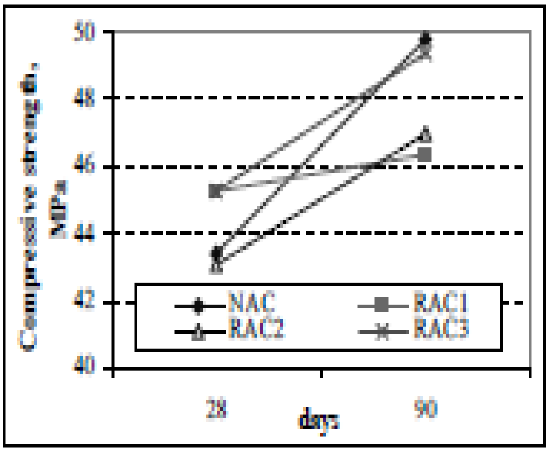


Figure 2

Water absorbability was determined on the basis of mass difference of specimens saturated with water and dried in 105^{0}C. The results are given in Figure 2. As it can be seen in this figure, water absorbability of concrete increases with the increase of recycled aggregate content. This is caused mainly by the increased water absorbability of the recycled aggregate in relation to the natural gravel. Remains of old mortar attached to recycled aggregate grains increase porosity and it results in increased water absorbability. Replacement of 75% of gravel by recycled aggregate (RAC3) resulted in increase of concrete water absorbability of about 24% in relation to NAC. [4]

4.1.2 Basic technical properties studied by (G. Murali1,et al ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 2, Mar-Apr 2012, pp.407 -410)

It is observed from the Fig 1. Compared to natural aggregate concrete the compressive strength of recycled aggregate was decreased by 18.76%. The recycled aggregate treated with water has increased 4.93%, nitric acid by 11.88%, sulphuric acid increased by 5.38% and hydrochloric acid increased by 7.17% than the recycled aggregate. Fig 2 shows that the split tensile strength of recycled aggregate was decreased by 9.55% than the natural aggregate. The strength of water treated recycled aggregate was increased 3.25%, strength of nitric acid treated recycled aggregate is increased by 5.69% , sulphuric acid treated recycled aggregate increased by 3.66%, and hydrochloric acid treated recycled aggregate increased by 7.17% than the recycled aggregate. It can be seen from the Fig 3. the flexural strength of recycled aggregate was decreased by 17.39% compared to natural aggregate, and the strength of water treated recycled aggregate was increased by1.75%, the strength of nitric acid treated recycled aggregate increased by 8.77%, sulphuric acid treated recycled aggregate increased by 3.51% and hydrochloric acid treated recycled aggregate increased by 3.51% than the natural aggregated concrete of average straight can be feasibly used . The test results showed that the flexural, compressive and split tensile strength of the recycled aggregate concrete is found to be lower than the natural aggregate. However the strength of recycled aggregate concrete can be improved by the water and acid treatments. Furthermore Recycled aggregate treated with nitric acid displayed the decent result compared to the hydrochloric and sulphuric acid and from economical point of view; water and acid treated recycled aggregates can be used in place of natural aggregates for temporary structures

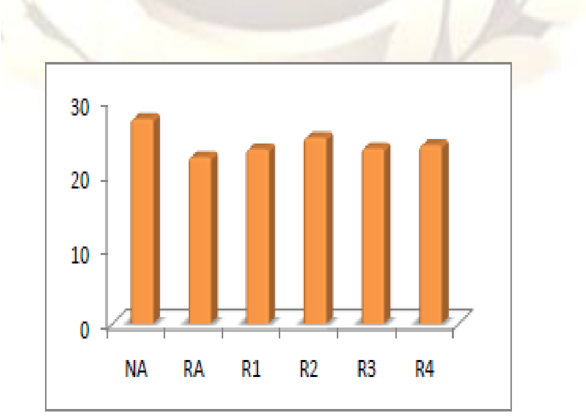


Fig 1: Compressive strength of concrete (N/mm^2) Vs Type of aggregate

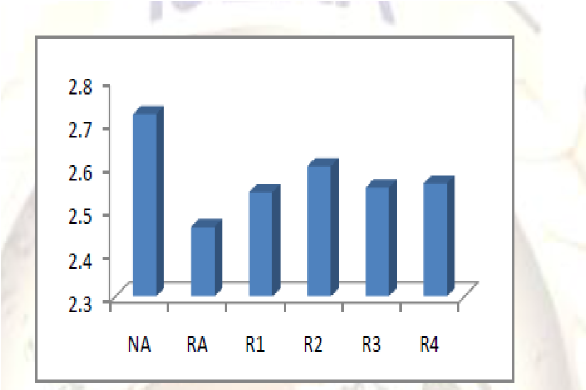


Fig 2: Split tensile strength of concrete (N/mm2) Vs Type of aggregate

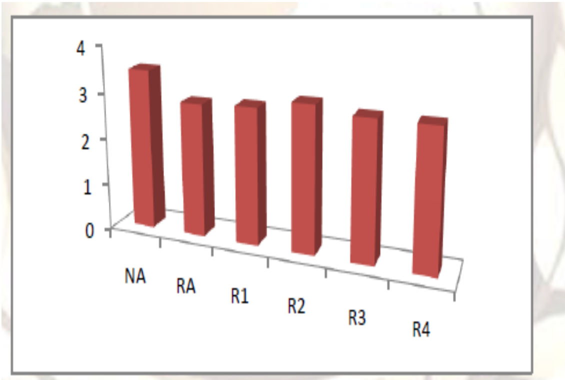


Fig 3: Flexural strength of concrete (N/mm2) Vs Type of aggregate

AVERAGE TEST RESULTS [5]

Notations	Compressive Strength (N/mm^2)	Split Tensile Strength (N/mm^2)	Flexural Strength (N/mm^2)
NA (Natural Aggregate)	27.45	2.72	3.45
RA (Recycled Aggregate)	22.3	2.46	2.85
R1 (Recycled Aggregate with Water Treatment)	23.4	2.54	2.9
R2 (Recycled Aggregate Treated with Nitric Acid)	24.95	2.6	3.1
R3 (Recycled Aggregate Treated with Sulphuric Acid)	23.50	2.55	2.95
R4 (Recycled Aggregate Treated with Hydrochloric Acid)	23.90	2.56	2.95

V. ECONOMICAL VIABILITY

Wide range of use such as in different infrastructure project such as roads, it can be effectively use as a soil stabilization material. Use of recycle aggregate can lead to economical benefit in various areas.

- Eliminate the expense of aggregate material import and export. [6]
- Recycled aggregate yield more volume by weight (up to 15%) which improve project cost. [6]
- Reduce disposal costs - Disposal of concrete rubble and other waste construction materials by dumping or burial is a less attractive and more expensive option. Reconstruction of urban streets and expressways results in an enormous amount of waste concrete being generated and creating a massive disposal problem. Recycling can therefore alleviate some of these problems and offer savings to the owner agencies in terms of material acquisition and disposal costs. [7]
- Less fuel burnt in delivery. Production of virgin aggregate can use more fuel to crush due to larger initial size of rock needing to be crushed to desired grade. [7]
- Minimize the quarrying charges and other taxes.

VI. WAY TO SUSTAINABLE ENVIRONMENT THROUGH USE OF RECYCLED AGGREGATE

- Use of recycled aggregate can lead to reduction of land fill areas and other environmental hazard which may cause health problem[8]
- Use of recycled aggregate can lower the waste management cost which can improve world economy as a whole
- Use of recycled aggregate can directly reduce the use of natural aggregate which lead to sustainable development and sustainable environment.
- Recover concrete is generally inert thus less chemical effect[8]
- Use of recycled aggregate after suitable recycling process can remove the hazardous material in the construction demolition waste thus reducing the soil pollution and water pollution which may likely to take place by way of percolation of rain water through landfill.
- Use of recycled aggregate can reduce the transportation of the virgin aggregate thereby reducing the fuel consumption which may reduce the CO emission and reduce air pollution. [8]
- Reduction in the road and vehicle use can also reduce the air pollution and noise pollution to certain extent.

VII. CONCLUSION

It can be stated that the concrete rubble after proper processing can be used as a substitute of natural gravel in the production of concrete mixtures for temporary structures. By efficient use of these demolished aggregates in the form of recycled aggregates along with fresh aggregates can achieve a better solid waste management and also cope up with the rising demands of aggregates leading to economy in terms of costs and also environmental friendly leading to the sustainable environment.

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