Use Of Recycled Aggregate In Concrete

-BY Mr. Tushar R Sonawane
RESEARCH GRADUATE MAEER'S MIT PUNE,

Prof. Dr. Sunil S. Pimplikar
H. O. D. CIVIL ENGG. DEPARTMENT, MAEER'S MIT PUNE.

ABSTRACT

Use of recycled aggregate in concrete can be useful for environmental protection. Recycled aggregates are the materials for the future. The application of recycled aggregate has been started in a large number of construction projects of many European, American, Russian and Asian countries. Many countries are giving infrastructural laws relaxation for increasing the use of recycled aggregate. 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 like compressive strength, flexural strength, workability etc. are explained here for different combinations of recycled aggregate with natural aggregate. Codal guidelines of recycled aggregates concrete in various countries are stated here with their effects, on concreting work. In general, present status of recycled aggregate in India along with its future need and its successful utilization are discussed here.

1. INTRODUCTION

1.1 Prelude – Need for Recycled Aggregate:-

Urbanization growth rate in India is very high due to industrialization. Growth rate of India is reaching 9% of GDP. Rapid infrastructure development requires a large quantity of construction materials, land requirements & the site. For large construction, concrete is preferred as it has longer life, low maintenance cost & better performance. For achieving GDP rate, smaller structures are demolished & new towers are constructed. Protection of environment is a basic factor which is directly connected with the survival of the human race. Parameters like environmental consciousness, protection of natural resources, sustainable development, play an important role in modern requirements of construction works. 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.

Out of the total construction demolition waste, 40% is of concrete , 30% ceramic's, 5% plastics, 10% wood, 5%metal, & 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 & 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% & CO_2 emission (LCCO$_2$) by about 23-28% for dumping at public / private disposal facilities.

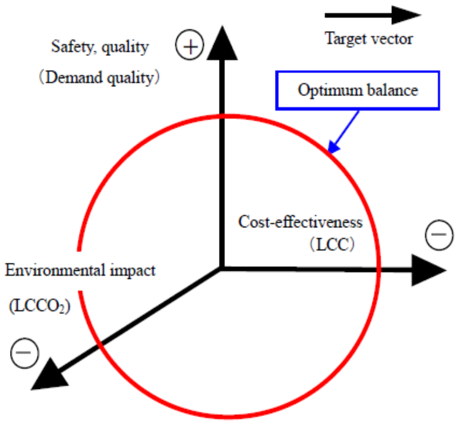


Figure. - Evaluation of recycling

1.2 Advantages of recycling of construction materials -:

- Used for construction of precast & cast in situ gutters &kerb's.
- Cost saving: - There are no detrimental effects on concrete & 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 & 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 or disadvantages of recycling of construction material:-

- 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 & creep.

1.4 Objectives of the study:-

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

1.5 Methodology:-

Plain cement concrete (PCC) & reinforce cement concrete is collected from sites (i.e. Sri SavitribaiPhule Polytechnic, Pune &MangaolGrampanchyat School, Mangaol, Haveli, Pune) respectively. This collected material is crushed by hammer to separate the aggregates & reduce their sizes in smaller fraction. On these separated aggregates various testes are conducted in laboratory as per Indian Standard code & their results are compared with natural aggregates. Recycled aggregate reduces the impact of waste on environment. By using some percentage in construction sector, cost is saved, due to reduction of transportation & manufacturing process.

1.6 Anticipated Findings:-

- All the results of tests should satisfy the IS requirement of natural aggregates.
- Recycled aggregate will be feasible for construction to replace natural aggregates.
- Cost saving due to reduction of transportation & crushing process of natural aggregates.
- During the recycling process, remanufacturing technology and the quality of recycled products would be the barriers.

2. LITERATURE REVIEW

Selected international experience has been outlined here which has relevance for the Indian situation:

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

a) 85 million tons of Construction & 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 & 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[1] (2011) insist that the available resources should be used appropriately & whenever recycled it should be done at the national level with the help of GULF COOPERATION COUNCIL (GCC) & 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 & 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 & sand locally available exits. Conservation of natural sources, saving natural resources, energy transportation & reduction of pollution are advantage.

Guide for Cement & 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 & the associated environmental cost of exploration & transportation waste minimization & 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 byproducts 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 tones, 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, Modhera[5] (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 byproducts 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 Malešev[4] 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 al[2] (2010) insist that the use of recycled aggregates in concrete is both economically viable & technically feasible. In addition to demolition waste sources, RA can also be composed of excess Concrete materials returned to the plant.

Mirza and Saif[3] 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[7] 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[10] et al find out the scenario in India presence of Construction & 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 & Demolition waste has potential use after processing and grading, Utilization of Construction & Demolition waste is quite common in industrialized countries but in India so far no organized effort has been made.

The author suggests the following:-

Hierarchy	Plan
The principle of '3R' – reduction, reuse and recycle is applicable for C&D waste	With a good plan during construction or demolition, it is possible to minimize waste generation by reducing wastage (reduction), followed by reuse or salvage of the materials of items like door/window frame, panes and shutters etc.

The last in the list of priority recycle is possible by way of segregation of the components, crushing the large aggregates and using the different size grades.

Working Sub-Group on construction and demolition waste

Presence of Construction & 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 & 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 & Demolition waste has potential use after processing and grading. Utilization of Construction & 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&D 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 & 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 & 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 & 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&FS. The study “Feasibility study on use of Construction & 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 & 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&FS Waste Management and Urban Services Ltd. would also build a ‘test’ road using processed C&D waste with technical assistance of CRRI which would then be monitored for more than a year.

3. Efforts would be made for market development of processed C&D waste.

Relevant rules and guidelines

1. C&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&D waste in a comprehensive manner which is likely to have significantly positive impact on the overall scenario of waste management and cleanliness.

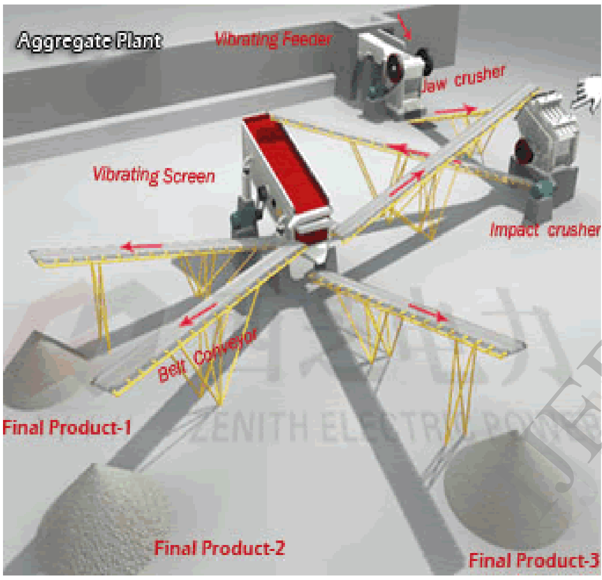
3. LOGISTICS OF RECYCLED AGGREGATE PRODUCTION

For use of leftover concrete aggregate, the ideal situation is where the concrete plant and aggregate plant are on the same site thus minimizing the cartage of the leftover concrete to the crushing plant. The use of mobile crushing plants strategically located can reduce the demolition concrete and recycled aggregate cartage distances and can be justified on larger projects.

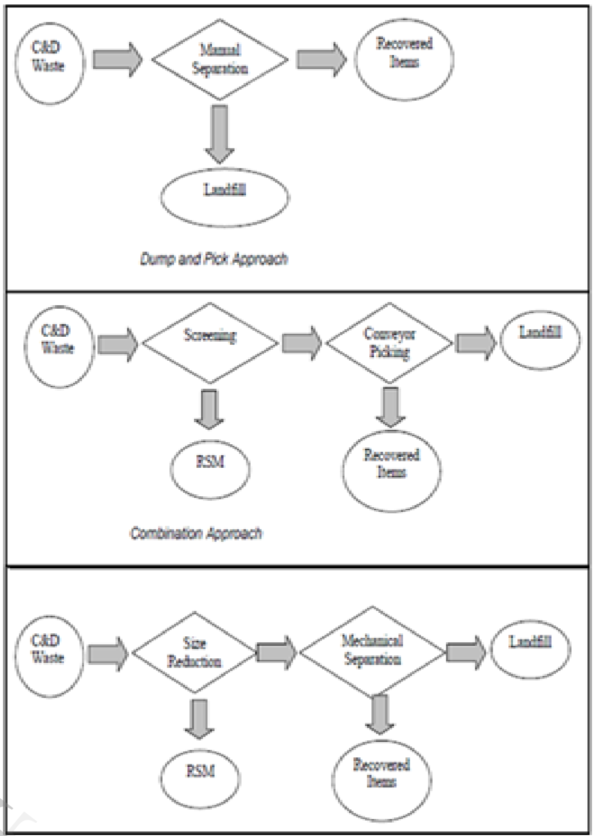
3.1 Production of Concrete Aggregate from Demolition Material

Recycled aggregates to be produced from aged concrete that has been demolished and removed from foundations, pavements, bridges or buildings, is 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 to other demolition materials to help avoid 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.

Aggregate crushing plant



Working Sequence of Aggregate crushing plant



Flow chart: Aggregate Recycling

3.2 Processing

Most recyclers use a jaw crusher for primary crushing because it can handle large pieces of concrete and residual reinforcement. Impact crushers are preferred for secondary crushing as they produce a higher percentage of aggregate without adhered mortar.

Most recycling plants have both primary and secondary crushers. The primary crusher usually reduces material down to 60-80 mm which is fed into a secondary crusher. The material from the secondary crushing then passes through two screens that separate the aggregate into sizes greater than 19 mm, between 19 mm and 7 mm, with the material finer than 7 mm being removed (and used as road metal). The plus 19 mm material is fed back into the secondary crusher. The 7-19 mm fraction is screened to produce coarse aggregate complying with the grading requirements of NZS 3121:198615.

3.3 Recycled Wash Water and Aggregate Recovery

Trucks returning from site to be washed out discharge into a ‘concrete reclaimed’ where the coarse aggregate and coarse sand are recovered from the ‘liquid’ fines for reuse. Coarse aggregate recovered from fresh concrete can be recycled and considered as equivalent to virgin aggregate, provided the mortar is adequately washed out.

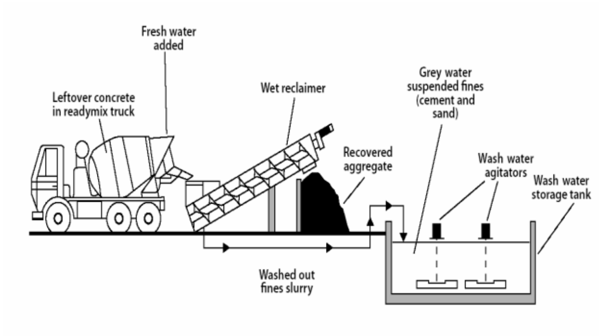


Figure - Typical system for recycling wash water/aggregate recovery

Typical rural low volume ready mixed plants operate a recycling system that settles the solids from the fines out of suspension and then allows reuse of the clear wash water. The solids that have settled are periodically removed and allowed to dry, prior to disposal to landfill. For larger plants the amount of solid material to be disposed of is prohibitive, and a recycled wash water system (see Figure) is typically used.

3.3 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 & manufacturing guidelines for recycled coarse aggregate concrete. Quality control covers the three respective processes for the material-

a) Original concrete
b) Recycled coarse aggregate
c) Recycled coarse aggregate concrete.

As a result of examination, any material that does not adapt the quality requirements of the construction specification and/or manufacturing guidelines at any of three processes is restricted from use.

4. TESTS ON RECYCLED AGGREGATE

Demolished material of reinforced cement concrete (RCC) & PCC is used for recycling in foundation. The life of RCC demolish material is 25 yrs. Such mated crushing, sieving & separation process are done by manual crushing method. On demolish material, aggregate tests are conducted which are mentioned in Indian Standard code for natural aggregate & check feasibility.

4.1 Properties of Recycled Concrete Aggregate

4.1.1Particle Size Distribution:

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 & tertiary crushing, whereas the same can be obtained after primary & 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.

Table 1:

SR. NO.	PARTICULARS	VALUES	
		Natural Aggregate	Recycled Coarse Aggregate
1	Specific Gravity	2.4-3.0	2.35-2.58
2	Water Absorption	0.29%-0.3%	0.3%-0.32%
3	Bulk Density	1678.2 KN/m^3	1469.8KN/m^3
4	Crushing Values:	18.4%	36.3%
5	Impact Values:	17.65%	35.2%

4.1.2 Specific Gravity:

The specific gravity in saturated surface dry condition of recycled concrete aggregate was found from **2.35 to 2.58** which are less but satisfying the results. If specific gravity is less than 2.4, it may cause segregation, honeycombing & also yield of concrete may get reduced.

4.1.3 Water Absorption:

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.

4.1.4 Bulk Density:

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

4.1.5 Crushing and Impact Values:

The recycled aggregate is relatively weaker than the natural aggregate against different mechanical actions. As per IS 2386 part (IV), the crushing and impact values for concrete wearing surfaces should not exceed 30% & for other than wearing surfaces 45% respectively. The crushing & impact values of recycled aggregate satisfy the BIS specifications limit. From crushing & impact test it is found that use of recycled aggregate is possible for application other than wearing surfaces.

4.2 Compressive test on cubes:

The average compressive strengths of cubes cast are determined as per IS 516 using RCA and natural aggregate at the age 3, 7, & 28days and reported in Table2. As expected, the compressive strength of RAC is slightly lower than the conventional concrete made from similar mix proportions. The reduction in strength of RAC as compare to NAC is in order of 8-14% and 10-16%for M-30 & M-40 concretes respectively. The amount of reduction in strength depends on parameters such as grade of demolished concrete, replacement ratio, w/c ratio, processing of recycled aggregate etc. As per test results the strength of recycled aggregate cube is more than target strength, so RCA can be used for construction purpose.

Table 2: Compressive strength-

Compressive Strength	Replacement Of Natural Aggregate			
	0%	10%	20%	30%
M30-3Days	20.63 N/mm^2	16.38 N/mm^2	19.05 N/mm^2	18.46 N/mm^2
M30-7 Days	33.13 N/mm^2	23.83 N/mm^2	31.93 N/mm^2	28.05 N/mm^2
M30-28 Days	47.53 N/mm^2	42.28 N/mm^2	43.92 N/mm^2	40.27 N/mm^2
M40-3 Days	31.59 N/mm^2	28.44 N/mm^2	27.56 N/mm^2	25.78 N/mm^2
M40-7 Days	56.67 N/mm^2	53.69 N/mm^2	51.69 N/mm^2	49.78 N/mm^2
M40-28 Days	64.42 N/mm^2	60.44 N/mm^2	56.22 N/mm^2	54.22 N/mm^2

4.3 Flexural Strength-

The average flexural strength of recycled aggregate are determined at the age 7, & 28 days varies from 3.30 N/mm^2- 5.637 N/mm^2 respectively. The reduction in flexural strength of recycled aggregate as compared to NAC is 3 -16% respectively, so it is satisfactory.

Table 3: Flexural Strength-

Flexural Strength	Replacement Of Natural Aggregate			
	0%	10%	20%	30%
M30-7 Days	3.58 N/mm^2	3.04 N/mm^2	3.52 N/mm^2	3.30 N/mm^2
M30-28 Days	4.98 N/mm^2	4.71 N/mm^2	4.805 N/mm^2	4.601 N/mm^2
M40-7 Days	4.69 N/mm^2	4.57 N/mm^2	4.48 N/mm^2	4.396 N/mm^2
M40-28 Days	5.818 N/mm^2	5.637 N/mm^2	5.436 N/mm^2	5.334 N/mm^2

Inferences from table nos. 2 & 3:

From table no. 2 & 3 it is observed that the M30 grade & M 40 grade of concrete satisfy the results for 10%, 20%, and 30%. As compared M 30 grade of concrete the strength reduction in M 40 grade of concrete is more as per results.

5 Conclusion-

1. Use of recycled aggregate up to 30% does not affect the functional requirements of the structure as per the findings of the test results.
2. Various tests conducted on recycled aggregates and results compared with natural aggregates are satisfactory as per IS 2386.
3. Due to use of recycled aggregate in construction, energy & cost of transportation of natural resources & excavation is significantly saved. This in turn directly reduces the impact of waste material on environment.

References:-

1. Akmal S. Abdelfatah and Sami W. Tabsh “Review of Research on and Implementation of Recycled Concrete Aggregate in the GCC” Advances in Civil Engineering Volume 2011 (2011), Article ID 567924.

2. Brett Tempest; Tara Cavalline; Janos Gergely; David Weggel “Construction and Demolition Waste used as Recycled Aggregates in Concrete: Solutions for Increasing the Marketability of Recycled Aggregate Concrete” 2010 Concrete Sustainability Conference, © National Ready Mixed Concrete Association.

3. F. A. Mirza and M. A. Saif, “Mechanical properties of recycled aggregate concrete incorporating silica fume,” in Proceedings of the 2nd International Conference on Sustainable Construction Materials and Technologies, Coventry University and The University of Wisconsin Milwaukee Centre for By-products Utilization, Ancona, Italy, June 2010

4. MirjanaMalešev, VlastimirRadonjanin and SnežanaMarinković “Recycled Concrete as Aggregate for Structural Concrete Production”www.mdpi.com/journal/sustainability30 April 2010.

5. Parekh D. N. and Dr. Modhera C. D. “Assessment of Recycled Aggregate Concrete” publish by JERS/Vol.II/ Issue I/January-March 2011.

6. S R Yadav, S R Pathak, “Use Of Recycled Concrete Aggregate In Making Concrete- An Overview” 34th Conference on OUR WORLD IN CONCRETE & STRUCTURES: 16 – 18 August 2009, Singapore.

7. Y P Gupta “USE Of Recycled Aggregate In Concrete Construction:A Need For Sustainable Environment” 34th Conference on OUR WORLD IN CONCRETE & STRUCTURES: 16 – 18 August 2009, Singapore

8. Best Practice Guide for the use of "Recycled Aggregates in New Concrete" published by the Cement & Concrete Association of New Zealand (CCANZ) in October 2011.

9. The Institution Recycling Network Mark Lennon "Recycling Construction And Demolition Wastes" A Guide for Architects and Contractors April 2005

10. Working Sub-Group on construction and demolition waste 16th April, 2009

11. http://nbjk.org/cjp/policy.htm

12. http://www.concretetechnologyforum.org/2010CSCDubaiProceedings

13. IS code 2386, IS code 516

IJERT