SUSTAINABLE USE OF RECYCLED CONSTRUCTION AND DEMOLISHED CONCRETE/MASONRY AGGREGATES IN INDIA

Er. S. K. Singh Gaur[1]

[1]Sr. lecturer, Civil Engineering, A.I.T.H., Awadhpuri, Kanpur

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Abstract - *Many structures that were constructed during 1970 or before are now in need of either major repairs or possible replacement. This is because some of such structures are now reaching the end of their design life, or may not have been constructed according to the specifications or do not receive the required maintenance while in service. Demolition or maintenance work on such structures results in large amount of concrete and masonry rubbles. The advantages of recycling coarse aggregates from discarded old concrete and masonry include lower environmental pollution, reduction in valuable land fill space and savings in natural aggregate resource*

Key Words: *Natural coarse aggregate NCA, recycled coarse aggregate RCA, recycled concrete RC, recycled coarse masonry RCM, construction and demolished aggregate CDA*

1. INTRODUCTION

The construction industry in India is growing very fast at an annual rate of 10 % over last 10 years as against the world average of 5.5 % per annum .The built –up area is expected to increase almost five times from 21 billion sqft in 2005 to approximately 104 billion sqft in 2030 as per C.S.E. report.

There was a tremendous increase in infrastructural development activities in last few decades due to overall development of country in all socio economic fields. As per up dates of Budget 2018-19, infrastructural proposed schemes & reforms are as under:

- Railways, roadways, airways along rail and road linkages and defence and connectivity infrastructure received major emphasis.
- Highest budget allocations for the rail, road and rural infrastructure including rural roads and rural housing.
- A new scheme for revitalising school architecture by the year 2022, 'Revitalising of Infrastructure and Systems in Education' scheme launched.
- Dedicated funding for affordable housing to make schemes like 'Pradhan Mantri Awas Yojana' more accessible.
- 1 crore houses to be built under PMAY out of which 50 lakh houses will be built in the urban area.
- To attain the motto of 'House for all' by the end of the year 2022. 50 lakh more houses will be constructed in the urban areas.
- Target to build 100 smart cities under the ambitious 'Smart City' project among which 99 cities have been selected. Emphasis will be on offering solar facilities, smart road and smart infrastructure.
- Upgradation and renovation work to be conducted for the improvement of 600 railway stations in India.
- New tunnel in Sera Pass will be built in order to promote tourism in India, especially in the north-eastern part of the country.
- Target of constructing 2 crore more toilets under 'Swachh Bharat Mission' in this financial year.
- Under road infrastructure, plans for completion of 9,000 km of National Highway and 3.7 lakh km rural road construction plan.
- Plan to build 2 new planning & architecture schools for IITs and 1 Rail University in Vadodara for boosting railway operation.
- Construction of 1 government medical college for every 3 parliamentary constituencies along with the improvement of 24 district-level colleges.
- Top 10 tourist sites in the country will be converted into exceptional tourist destinations through marketing, branding and private funding.

This immense surge in infrastructural development will need tremendous amount of energy, water & material , but they also create waste . This waste , generated in construction , maintenance and disposal phases of a building , is called construction and demolition (referred as construction and demolition aggregates CDA) waste .This includes wastes from demolished structures , renovation in the real estate sector and construction and repair of roads, flyovers , bridges etc. along with debris produced from natural activities such as landslides & volcanic eruption etc.

Globally, cities generate about 1.3 billion tonne of solid waste per year .This volume is expected to increase to 2.2 billion tone by 2025, says a 2012 report by the World Bank. Building materials account for about half of all materials used and about half the solid waste generated worldwide.

But recycled construction and demolition aggregates (CDA) can be an invaluable source of construction material. In fact the recent controversy in India over sand mining has put the spotlight on the need to recycle and substitute naturally sourced construction material such as sand and stone aggregates.

2. CONSTRUCTION & DEMOLITION WASTE GENERATED IN INDIA

The Union ministry of forest and environment (MOEF) has agreed that there is no systematic database on C&D waste available in India. As per the estimates of Centre for Science and Environment (CSE), since 2005, India has newly constructed 5.75 billion Sq m, of additional floor space with almost one billion Sq m in 2013 itself. If

(according to the Technology Information, Forecasting and Assessment Council's, TIFAC , thumb rule) a new construction generates about 40 to 60 kg of CDA per sq m, then taking an average of 50 kg per sq m, India would have produced about 287 MT of this construction and demolition waste.

This estimate only account for new construction. Demolition and maintenance /repair related waste also generates additional waste. The waste produced per sq m of demolition is 10 times that generated during construction, as per TIFAC, about 288 MT of construction & demolition waste would have generated in year of study alone because of demolition work assuming 10% of building constructed till that time were demolished .

TIFAC also says building repair or renovations must have produced an average of 155 MT CDA waste, in the year of study .

Thus, the total CDA waste generated in India just by buildings, in one year amounts to an amount approximately 530 MT, which is 44 times higher than the official estimates collected by different agencies in India.

Not surprisingly, in India, if CDA waste is quantified, it will be more than all the other types of solid wastes put together.

Where this all CDA waste is going? A lot of it being used illegally as landfill for water bodies and water lands around urban areas. The rest is just being dumped in open areas, thus affecting the environment adversely.

Indian Construction Industry is highly employment intensive and accounts for approximately 50% of the capital outlay in successive 5-Year Plans of our country. The Projected investment in this industrial sector continues to show a growing trend.

Construction activity leads to generation of solid wastes, which include sand, gravel, concrete, stone, bricks, wood, metal, glass, plastic, paper etc. The management of construction and demolition waste is a major concern for town planners due to the increasing quantum of demolition's rubble, continuing shortage of dumping sites, increase in transportation and disposal cost and above all growing concern about pollution and environmental deterioration.

Construction waste is bulky and heavy and is mostly unsuitable for disposal by incineration or composting. The growing population in the country and requirement of land for other uses has reduced the availability of land for waste disposal. Re-utilization or recycling is an important strategy for management of such waste.

Apart from mounting problems of waste management, other reasons which support adoption of reuse/ recycling strategy are- reduced extraction of raw materials, reduced transportation cost, improved profits and reduced environmental impact. Above all, the fast depleting reserves of conventional natural aggregate has necessitated the use of recycling/ re-use technology, in order to be able to conserve the conventional natural aggregate for other important works.

3. VARIOUS CONSTITUENTS OF CONSTRUCTION & DEMOLITION WASTE IN INDIA

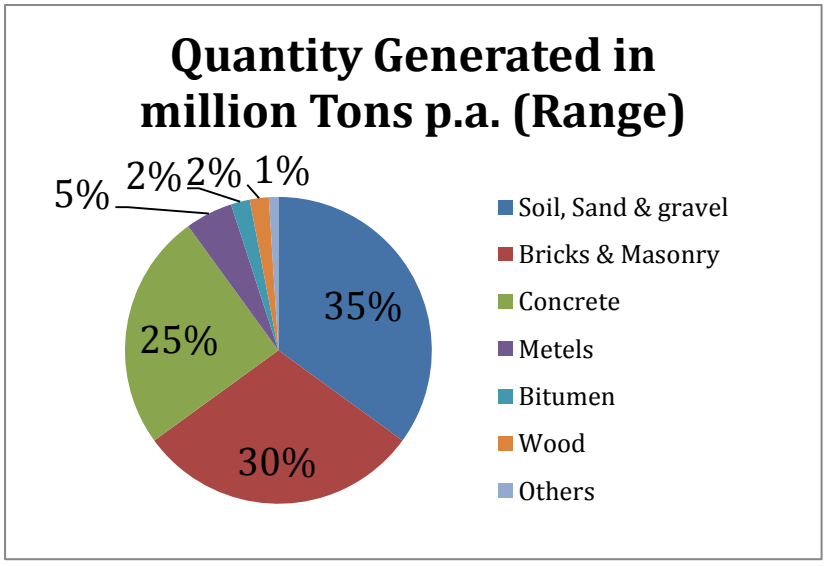
Waste is generated at different stages of construction process. Waste during construction activity relates to excessive cement mix or concrete left after work is over, rejection/ demolition caused due to change in design or wrong workmanship etc.

Concrete appears in two forms in the waste. Structural elements of building have reinforced concrete, while foundations have mass non-reinforced concrete. Excavations produce topsoil, clay, sand, and gravel. This may be either re-used as filler at the same site after completion of excavation work or moved to another site. Large quantum of bricks and masonry arise as waste during demolition. These are generally mixed with cement, mortar or lime. Stone arises during excavations or by demolition of old buildings.

Metal waste is generated during demolition in the form of pipes, conduits, and light sheet material used in ventilation system, wires, and sanitary fittings and as reinforcement in the concrete. Metals are recovered and recycled by re-melting. Timber recovered in good condition from beams, window frames, doors, partitions and other fittings is reused. However, wood used in construction is often treated with chemicals to prevent Termite infestation and warrants special care during disposal.

Bituminous material arises from Road planning, water proofing compounds, breaking and digging of Roads for services and utilities. Other miscellaneous materials that arise as waste include glass, plastic material, paper, etc. The total quantum of waste from construction industry is estimated to be 12 to 14.7 million tons per annum. Quantity of different constituents of waste that arise from Construction Industry in India is estimated as follows (As per TIFAC 2000 Report):

Constituent	Quantity Generated in million Tons p.a. (Range)	% of Different Constituents
Soil, Sand & gravel	4.20 to 5.14	35
Bricks & Masonry	3.60 to 4.40	30
Concrete	2.40 to 3.67	25
Metals	0.60 to 0.73	5
Bitumen	0.25 to 0.30	2
Wood	0.25 to 0.30	2
Others	0.10 to 0.15	1



Contractor executes construction project on a labour contract basis or on turnkey basis. Small housing projects, executed by owners, are predominantly executed on labour contract basis and strict supervision is required to control waste generation during construction process. Typically, waste generation ranges between 5 to 7%. In larger projects, where execution is on turnkey basis or through one's own team of professionals, material wastage is within 3%.

Services of demolition contractor are taken when old building is to be demolished due to deterioration of the building or to make way for construction of a new building. Demolition contractor specializes in planned deconstruction so that recovery of good material can be maximized for re-use. Recovery rate varies from 25% in old buildings to as high as 75% in new buildings.

4. RECYCLING OF CONSTRUCTION & DEMOLITION WASTE AS A REMEDY

Recycling of demolition waste was first carried out after the Second World War in Germany to tackle the problem of disposing large amounts of demolition waste caused by the war and simultaneously generate raw material for reconstruction.

Considerable research has been carried out in U.S.A, Japan, U.K, France, Germany, and Denmark etc. for recycling concrete, masonry & bricks, bituminous and other constituents of waste from Construction Industry. These studies have demonstrated possibility of using construction waste to substitute new materials of recycling.

In view of significant role of recycled construction material and technology in the development of urban infrastructure, Technology, Information, Forecasting and Assessment Council (TIFAC) have commissioned a techno-market survey on 'Utilization of waste from Construction Industry.

5. PRESENT STATUS OF PRODUCTION & REUSE OF CONSTRUCTION & DEMOLITION WASTE IN INDIA

Management of solid waste is the responsibility of Municipal Bodies or health officers. They notify landfill sites for disposal of solid waste. Whereas responsibility of removing the construction & demolition waste is primarily of the builder or the owner, it is usually assigned to the demolition contractor. Items, that cannot be re-used, are disposed off to landfill site.

Hard core material from demolition operation is required for land fill activities to provide daily cover over domestic waste, bulk fill capping, hard standings etc. Some Municipal Corporations require demolition waste for their landfill activities, while others want to minimize it to prolong useful life of landfill sites. However, all respondents are unanimous that in the long run, recycling of waste from construction industry is necessary in view of limited landfill space and increasing quantum of demolition waste.

Different constituents of waste are not segregated prior to disposal. Municipal Authorities incur cost of Rs 60 to 80 per ton of waste, but presently no charge is levied by them on the owner or builders.

Builders/ Owners bear the cost of transportation, which at present range between Rs. 250 to Rs 500 per truckload depending on the distance of demolition site from landfill area. Though directives exist for disposal of waste to landfill areas, presently penal action against violators is practically not taken.

Presently management of waste from construction industry in India, comprise of the following elements:

- Re-use of materials salvaged in good condition during demolition.
- All metal items are sent for re-melting through scrap dealers.
- Disposal of other items to low lying sites.

According to findings of survey, the most dominant reason for not adopting recycling of waste from Construction Industry is "Not aware of the recycling techniques". While 70% of the respondents have cited this as one of the reasons, 30% of the respondents have indicated that they are not even aware of recycling possibilities. The response of industries, which can use the recycled product, indicates that presently, the specifications do not provide for use of recycled product in the construction activity. Sixty Seven percent of the respondents from user industry have indicated non-availability of recycled product as one of the reasons for not using it. Concrete and masonry constitute more than 50% of waste generated by the Construction Industry. Recycling of this waste by converting it to aggregate offer dual benefit of saving landfill space and reduction in extraction of natural raw material for new construction activity.

6. CONVENTIONAL METHODS OF RECYCLING & REUSE OF CONSTRUCTION & DEMOLITION WASTE IN INDIA

Basic method of recycling of concrete and masonry waste is to crush the debris to produce a granular product of given particle size. Plants for processing of demolition waste are differentiated based on mobility, type of crusher and process of separation.

There are three types of recycling plants Viz. Mobile, Semi-Mobile and Stationary plant. In the Mobile plant, the material is crushed and screened and ferrous impurities are separated through magnetic separation. The plant is transported to the demolition site itself and is suited to process only non-contaminated concrete or masonry waste.

In the semi-mobile plant, removal of contaminants is carried out by hand and the end product is also screened. Magnetic separation for removal of ferrous material is carried out. End product quality is better than that of a Mobile unit.

Above plants are not capable to process a source of mixed demolition waste containing foreign matter like metal, wood, plastic, hardbound etc. Stationary plants are equipped for carrying out crushing, screening as well as purification to separate the contaminants. Issues necessary to be considered for erection of a Stationary plant are: plant location, road infrastructure, availability of land space, provision of weigh-bridge, provision for storage area etc.

Different types of sorting devices and screens are used for separating contaminants from end-product and grading the recycled product in various grain sizes. Vibrating screens, star screens or disc-separators are used for removal of impurities. Three main processes used for purification are:

- Dry Process
- Wet Process
- Thermal Process

Properties of recycled aggregate have to be compared to those of natural aggregate to evaluate its suitability for applications in construction industry. Density of recycled aggregate is lower and water absorption is higher than that of original aggregate. This is primarily due to mortar adhering to the concrete and higher porosity of bricks that are recycled.

7. PROBABLE USES OF CONSTRUCTION & DEMOLITION WASTE IN INDIA

Non awareness of recycling possibilities is one of the main barriers due to which waste is disposed to landfill. Absence of technology for recycling is another major hurdle for recycling of construction waste.

Once technology is known, availability of feedstock in sufficient quantities and of requisite quality is another bottleneck for its widespread use.

The acceptability of the recycled material is hampered due to poor image associated with recycling activity in India. Customer specifications do not permit use of materials recycled from Waste.

Cost of disposal of waste from construction industry to landfill has a direct bearing on recycling operations. High dumping costs induce diversion of waste for recycling.

The problem of dumping huge quantity of waste caused by a disaster and the difficulty in finding sufficient quantity of building material for reconstruction can be solved by recycling this waste. Usually, quick removal of debris is necessary to start the rehabilitation the waste can be reused for strengthening riverbanks or for producing aggregates for construction of road or building blocks. Experience of recycling operations at two disaster sites, have proven the feasibility of recycling demolition waste. In one of project, most of the debris had been transported and temporarily disposed off. Yet, recycling was carried out successfully. These experiences are relevant to India, in view of damage suffered in recent earthquake in Kumauni and Garhwali regions.

The raw material for construction is costly in hills due to high cost of transportation. Similarly, cost of waste disposal is also high thereby making recycling an attractive proposition. However, present volume of concrete, bricks and masonry waste are low to justify investment in recycling units.

Technology for producing recycled aggregate from concrete, bricks and masonry is quite simple. A mobile unit is best suited to process demolition waste of uniform quality. It can be procured at low investment. It can be useful for low quantum of waste and can be moved to the demolition site avoiding cost of Waste transportation. A fixed recycling plant requires higher volumes of demolition waste to justify high investment in complex, screening and separation systems, which are necessary to process mixed demolition waste. It has to be located in a place, where large volume of waste is available and the market for recycled product is close by. Unless the market for recycled aggregate is developed, economic viability of such a unit would be questionable. Indian manufactures are producing crushers, which can be used with suitable modification in a recycling unit to break concrete, bricks and masonry. A comparative study shows that a jaw crusher or impact crusher may be used.

Recycling of bituminous material by hot in-situ recycling technique is advantageous due to savings in consumption of asphalt and energy, avoidance of material transportation and possibility of using the technique for road maintenance and repairs. Cold in-situ technique is more suited to roads having lighter traffic, which appear less probable in Indian conditions. Hence, a thorough evaluation is warranted before its adoption.

Recycled aggregate can be used as general bulk fill, sub-base material in road construction, fills in drainage projects and for making new concrete.

While using recycled aggregate for filler application, care must be taken that it is free of contaminants to avoid risk of ground water pollution. Mixed debris with high gypsum, plaster, should not be used as fill.

Use of recycled aggregate as sub-base for road construction is widely accepted in most countries. It is possible to use crushed concrete as coarse fraction of gravel in sub-base for road, but crushed brick is not suitable owing to its high bitumen requirement and high void content.

For using recycled aggregate to make new concrete, water absorption of the recycled aggregate must be determined in the laboratory to decide the mix design. Use of fine recycled aggregate for concrete making is not recommended as it increases the water demand and lowers the strength and durability of concrete. Pre-soaking of recycled aggregate is suggested to take care of high water absorption so that concrete of uniform quality is produced.

Concrete made from recycled aggregate has lower compression strength caused by the bond characteristic of recycled aggregate and the fresh mortar. Fraction of less than 2mm of recycled aggregate brings about the largest reduction in strength of recycled aggregate concrete (RAC). Fine aggregates also reduce frost resistance of recycled aggregate concrete. Drying shrinkage of recycled concrete is higher than that of concrete with conventional aggregate. Workability of concrete decreases with increased portions of demolition waste. Upto 30% of natural coarse aggregate can be substituted, by coarse recycled aggregate, without any impact on the quality of concrete.

Feasibility analysis has been carried out for a 25000 tons/annum recycling plant to produce recycled aggregate from waste concrete and Masonry & bricks. The location of the recycling plant should be so chosen that there is (a) Availability of feed stock (b) Market for recycled product and (c) It is difficult to dispose of the waste by other means. Equipment like Crushers, conveyors, screens etc. can be sourced from Indian manufacturers, who supply similar machines to Natural aggregate producers. Necessary modifications for adapting the equipment for crushing concrete/ Masonry/ Bricks can be carried out. Due to marked preference of the customers to use natural aggregate, Recycled aggregates have to be marketed at a discount to achieve sale of 25000-tons/ year in 2/3 years time. The unit is viable but its operation is highly sensitive to fluctuations in sale price of recycled aggregate and capacity utilization of the plant.

8. PROBLEMS ASSOCIATED WITH USE OF CDA WASTE

Problem associated with use of recycled aggregate, for manufacture of new concrete, is the possibility of contaminants in original debris passing into new concrete. Such impurities reduce the strength of the concrete. Waste glass is a problem because it is alkali reactive with cement paste under wet conditions. Organic substances like wood, textile fabrics, paper and other polymeric materials are unstable in concrete. Paints may entrain air in concrete.

Test results of aggregate properties and concrete properties prove repeatedly recycled concrete to be both durable and of good quality in all respects. Therefore, existing concrete structures, in addition to providing an aggregate source for the immediate future, may continue to generate an adequate supply of aggregate for concrete construction in the more distant future after once being recycled.

Recycled aggregate of best quality for concrete production is obtained when it is graded. Although there are no standards drawn up in India for recycled aggregate and recycled aggregate concrete, specification drawn in other countries are useful as a guideline.

In Hot in-situ recycling, the upper layer of the road is pre-heated and the asphalt is loosened by milling devices. It is mixed together with recycling agent and the mixture is spread along the road and compacted.
In India, recycling of bituminous material is not practiced. In developed countries, special purpose machine has been built, which carry out the total process of hot in-situ recycling. It is important that the project for recycling is properly evaluated to ensure that the potential benefits of hot in-place recycling are realized.

9. MEASURES NEEDED TO PROMOTE THE USE OF CONSTRUCTION & DEMOLITION AGGREGATES

Creating awareness & dissemination of information is essential to build public opinion and instill confidence in favor of recycling option. There is a need to create market for the recycled products by involving the Construction Industry to use recycled materials in their construction projects.

Development of standards for recycled materials would provide producers with targets and users an assurance of quality of material. Standards formulated in other countries can be a guideline for development of specification in our country.

Commissioning of a pilot plant as a demonstration unit can help in breaking barriers against recycling of construction & demolition waste. Imposition of charge on Sanitary landfill can induce builders and owners to divert the waste for recycling.

Government support and commitment is vital for development of recycling industry. Development of policy supported by proper regulatory framework can provide necessary impetus. It will also help in data compilation, documentation and control over disposal of waste material.

Low returns from investment in recycling units can be offset by providing suitable fiscal incentives by the Government for gestation period. These are warranted in the long-term interest of reducing pollution and conserving valuable resources.

Environmental impact of recycling has both advantages and disadvantages. Advantages are reduced disposal of waste to landfill sites and reduced mineral extraction. Disadvantages are problems of Noise and Dust emission and risk of ground water pollution. The problem of noise can be managed by using silencers and providing acoustic enclosures while water spray is useful to control dust emission.

Based on evaluation of the technology, review of Waste Management practices in India and other countries, and assessment of constraints to recycling option in the country, following recommendations along with implementation & action plan are proposed:

There is a need to create awareness about the problems of waste management and the necessity to adopt reuse and recycling options for waste from Construction Industry. It is recommended that Seminars, Conferences and Workshops be held in different parts of the Country. Simultaneously, other media should also be exploited to create an environment in favor of Recycling.

Interpretation on the above may result in bringing out publication/ brochures highlighting the short and long term benefits of recycling strategy and indicating case histories of utilisation of construction industry waste, especially in India. Circulation of these brochures especially in construction industry research departments, field/design organisations in Central/ State government may generate sufficient confidence for promotion/ adoption of recycling strategy for their works. Equally important is the need to generate sufficient Database regarding efficacy and field adoptability of the recycling strategy in the country.
A coordinated action should be taken up by NGO's, environmentalist, government offices and industry representatives. The recycling technology for construction waste has to be established on a pilot scale in India. It is recommended that pilot scale plant for producing recycled aggregates is established and application of recycled aggregates in different construction activities is demonstrated. Central Road Research Institute or Central Building Research Institute may be involved to put up a pilot plant and establish use of recycled aggregate in road and building construction. The most common application of recycled aggregate in other countries is its usage as sub-base material in construction of roads. At first, recycled aggregates should be tried for this application. Produce from Pilot plant should be evaluated by Central Road Research Institute for using it as sub-

base for Road. Accordingly, specifications for Road construction should be modified so that recycled aggregate is used in this application.

Manufacturers of Crushers, screens and separating equipment should be involved to provide necessary equipment for the recycling unit. Presently, manufacturers of such equipment in India are suppliers to Natural Aggregate Industry. Suitable modifications, as may be required, can be carried out by manufacturers to their product for processing Construction Waste. Manufacturers of Crushers, Screens and material Handling Equipment should take up this work. Quality standards/ codes of Practice regarding various aspects of product control and acceptance criteria for use of recycled aggregate in recycled aggregate concrete and other works should be formulated. This would help in setting a target product quality for producers and assure the user of a minimum quality requirement, thus encouraging him to use it. Specifications drawn in other countries like Japan, Netherlands, and Germany etc. can be a useful guideline.

BIS in coordination with Construction Industry, Research Laboratories involved in producing recycled aggregate should take up this work.

Government should formulate and implement policy for Management of waste from Construction and other Industries. It should clearly set out goals for recycling of Waste as a means of reducing pollution and conserving valuable resources. Government of India in consultation with State governments, Pollution Control Boards should formulate this plan.

Such an elaborate system can be developed and implemented in two steps. In the short term, requirement of applying for permission for demolition process with mandatory requirement to provide details of the projected quantities, types and disposal routes can be introduced. In the long term, along with permission for demolition, commitment of segregation of constituents of waste and recycling should be submitted. Government of India should undertake this work in coordination with Construction Industry, Municipal Corporations and Pollution Control Boards.

Based on success of demonstration unit, Municipal Authorities of Metropolitan cities should put up facility for recycling of construction and demolition waste adjacent to their landfill sites. The waste from Construction Industry can be used in this plant for making recycled aggregates. Charges should be imposed on disposal of construction waste to landfill site. This is to induce the builders/ owners to divert the waste to recycling.

Municipal Corporation Authorities of Metropolitan Cities should take up this work under guidance of agency, which has put up the pilot plant. If necessary, assistance from foreign consultants/ experts may also be taken.

Mobile recycling units should be used at sites where demolition waste of one type is being generated for example demolition of railway platform, airport runway, waste of prefabricated concrete structure etc. Once the concept of recycling is widely accepted, Mobile units can be owned by Organizations undertaking demolition work. Large scale construction companies who in their course of business have to frequently undertake demolition of structures can also have their own mobile recycling units.

The builder/ owner must segregate different constituents of waste before its disposal to landfill site. In this respect, Municipal Authorities can impose a differential charge so that disposal of mixed waste is charged at a higher price than segregated waste. The builders/ owners/ demolition contractors should maximize segregation of waste constituents. Municipal authorities to introduce differential Landfill levy.

To take care of the problem of noise and dust emission associated with recycling, suitable measure like erection of acoustic screening around the equipment, use of mufflers/silencers and water spraying equipment should be made mandatory in a recycling unit.

Equipment manufacturers should ensure incorporation of these features in their machines.

- In the initial phase, fiscal incentives should be provided by the Government to the recycling industry by way of:

  - Financing the purchase of equipment at lower interest rate
  - Tax exemptions/ holidays.
  - Subsidy during initial gestation period of the recycling plant.

- Government of India in coordination with State Governments should provide the Tax exemptions/ holidays. Municipal authority that will benefit should provide subsidy while Financial Institutes should provide assistance for purchase of equipment at lower interest rates.
- Hot Recycling technique for recycling of bituminous material should be taken up for R&D. A small pilot plant should be established. Based on this experience, Hot In-situ technique should be developed. Alternatively, equipment available from abroad for Hot In-situ process may be evaluated for financial viability. Central Road Research Institute should undertake this exercise.

- Estate developers and builders undertake demolition of old buildings in urban centers to develop new complexes for residential/ commercial use. They should be educated and involved in recycling activity so that the demolition waste generated is used at the same site, leading to substantial saving in cost as follows:

  - Reduction in cost of transportation of demolition waste for disposal.
  - Reduction in material cost by utilizing recycled aggregate produced from demolition waste.
  - Savings accruing in transportation cost of raw material.
  - Estate builders and property developers should take the initiative, since they are going to benefit by way of cost reduction in their new construction project.
- Lot of demolition waste is caused by natural calamities and disasters like earthquake witnessed recently and few years ago in Kumauni/ Garhwali region. Possibility of recycling such waste for reconstruction locally should be explored with the help of International agencies having expertise in this field. Government of India/ State Governments should take the initiative and encourage local administration to explore such possibility by taking help of agencies experienced in carrying out this type of rehabilitation work.
- Necessary R&D work should be taken up for developing technology for reconstruction of houses utilizing waste from construction Industry.

Central Building Research Institute/ National Building Organization should take up this assignment. Time has arrived to accord priority to environmental pollution and sustainable development. Recycling of waste from Construction Industry achieves this objective.

10. CONCLUDING REMARKS

Though there has been extensive research carried out on recycled/ demolished waste yet there is neither simple and cost effective method nor any approved design mix theory available for use of construction and demolished waste .Though RCA can be used up to 25% to 30% replacement level of NCA without significant adverse effects on hardened, fresh and durability properties of concrete .Yet further investigations are needed to confirm the beneficial effects of RCA for more effective use in construction industry. After thoroughly reviewing the literature on RCA/RCM, the following research needs have been identified.

- To study on the potential use of RCA in the production of high strength, high performance, light weight concrete.
- To study the potential use of RCA/RCM on performance of concrete specimens by replacing coarse aggregate partially or fully.
- To study the addition of super plasticizer in improvement of workability and strength of concrete specimens prepared with RCA/RCM as coarse aggregate.
- To study the effect of aggressive chemical environment on concrete blended with RCA/RCM.
- To investigate the effect of RCA/RCM on target concrete strength on durability and fire resistance of concrete
- To study on the effect of RCA/RCM on the plastic shrinkage, rheological properties and segregation resistance of concrete.

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