सत्यमेव जयते

C&D Waste, Technical Textiles & Fly Ash in Construction






CPWD

CENTRAL PUBLIC WORKS DEPARTMENT

Ministry of Housing and Urban Affairs



Proceedings of Seminar on

USE OF C&D WASTE, TECHNICAL TEXTILES AND FLY ASH PRODUCTS IN CIVIL CONSTRUCTION

December 17, 2018

Edited by Dr K M Soni, Addl DG (TD), CPWD, New Delhi

(The views expressed are purely of the authors and not of the editor or their organizations)

हरदीप एस पुरी
HARDEEP S PURI



सत्यमेव जयते

आवासन और शहरी कार्य
राज्य मंत्री (स्वतंत्र प्रभार)
भारत सरकार
MINISTER OF STATE (I/C)
HOUSING AND URBAN AFFAIRS
GOVERNMENT OF INDIA

Message

I am happy to know that CPWD is organizing one day Seminar on "Use of C&D Waste, Technical Textiles and Fly Ash Products in Civil Construction" on 17 December 2018 in New Delhi.

Preserving natural resources has become one of the major concerns due to their enormous use in infrastructure development. As a developing economy, our country has a vital stake in the evolution of an effective and equitable response to issues relating to sustainable development. There is a strong need to preserve natural resources and make use of waste materials after recycling into resource.

It is a matter of satisfaction that CPWD in the recent times, has encouraged extensive use of C&D Waste & Fly Ash Products and Technical Textile in its construction works.

I congratulate CPWD for organizing this Seminar and bringing together the experts in the field of Technical Textiles, Fly Ash, C&D waste products for dissemination of their views and for promoting the advantages of usage of these products for sustainable development.

I hope that the day long Seminar will be beneficial not only to the CPWD in further increasing the use of these items in their construction works but will also help the participating Departments, professional bodies and private agencies to pool in their collective expertise and strength to give a further impetus to this crucial area.

I wish the Seminar all success.

New Delhi
13 December 2018

(Hardeep S Puri)

Office : Room No. 104-C, Nirman Bhawan, New Delhi-110011; Phone : 011-23061166, 23061162, 23062089 (Fax)

DURGA SHANKER MISHRA

सत्यमेव जयते

SECRETARY
MINISTRY OF HOUSING AND
URBAN AFFAIRS
GOVERNMENT OF INDIA



MESSAGE

I am immensely pleased to learn that CPWD is organizing one day Seminar on “Use of Technical Textiles, Fly Ash, C&D Waste in Civil Construction” in New Delhi on December 17, 2018 to promote use of these items in works.

In the present times, the issue of sustain ability is of prime concern as we are using large amount of depleting natural resources for producing materials such as concrete etc. With the advent of sustainable practices in the construction industry, C&D waste generation and handling issues have been in focus to achieve the sustainable goals for our common future. Recycling and reuse of these wastes will reduce the usage of natural resources.

Recent trend in construction industry to use the alternative source of construction materials such as fly ash and C&D waste products, which can substitute the use of virgin materials in order to reduce environmental impact in terms of energy consumption, pollution, waste disposal and global warming is a welcome step.

I am happy to note that CPWD has already taken effective steps for use of C&D Waste products, Technical Textiles and Fly Ash products in its construction works.

I hope that day long Seminar will give an opportunity to the participants engaged in the Construction Sector to deliberate on various aspects of promotion of use of these items in the Construction Industry.

Place: New Delhi
Date: December 17 2018

(Durga Shanker Mishra)

PRABHAKAR SINGH

सत्यमेव जयते

DIRECTOR GENERAL
Central Public Works Department
Nirman Bhawan, New Delhi



MESSAGE

Our country at present has the distinction of being the fastest growing economy in the world. The country is going through a major phase of industrialization and modernization with a flood of construction and infrastructure projects. The prime challenge today is to create the built infrastructure in a sustainable, clean and environmentally sensitive manner in balance and harmony with the nature.

Being a Principal Engineering Organization of Government of India, CPWD has always encouraged use of Environment Friendly Materials and Energy Efficient Sustainable Technologies in its works. CPWD has been a pioneer in Construction Industry with regards to use of C&D waste and Fly Ash as a resource in its works. We are promoting use of Technical Textiles in our works. We have developed specifications for these products and relevant items have already been incorporated in CPWD Delhi Schedule of Rates to facilitate their extensive use in works not only in CPWD but also by all other Engineering Organizations.

Use of Technical Textiles, Fly Ash, C&D waste products in Civil Construction is being monitored in the Government at the highest level. Ministry of Housing and Urban Affairs is also undertaking regular review for increasing use of these items in the construction works. As a bench mark setter in the Construction Sector, it was decided to hold a Seminar so that CPWD gets an opportunity to share its expertise and knowhow of these items with the various Engineering Departments, builders and private agencies participating in the Seminar.

I am sure that the daylong seminar will give an opportunity to the participants engaged in the constructions sector to deliberate on various aspects of promotion of use of these items in the Construction Industry.

I congratulate Dr. K. M. Soni, Additional Director General (TD), CPWD and his Team of Officers for their relentless efforts in organizing this Seminar and bringing out this useful publication in a very short time.

Place: New Delhi
Date: December 17 2018

11.12.2018
(Prabhakar Singh)

R. K. THATHU

सत्यमेव जयते

DIRECTOR GENERAL (PLANNING)
Central Public Works Department
Nirman Bhawan, New Delhi



MESSAGE

Central Public Works Department is committed to keep pace with the technological advancement and adopt sustainable, energy efficient and new emerging green and clean technologies in its construction activities.

The traditional disposal mechanism for C&D waste in India has been the landfills, which is a great cause of concern from environmental point of view. All over the world, the useful materials from C&D waste are segregated and reused with little or no processing and rest of the material sare recycled and gainfully utilized for manufacturing building materials such as aggregates, sand and components such as bricks, blocks, panels etc. In our country, we are now reorienting our approach and treating this refuse as a resource. Similarly, Fly Ash, which was treated to be a waste product in the past has become a resource at present.

CPWD is already using C&D waste and Fly Ash products in its works. Use of these products has helped conserve natural resources, thereby promoting sustainable development. CPWD is also encouraging use of Technical Textile in its works

For promotion of use of Technical Textiles, Fly Ash, C&D Waste products in Civil Construction, CPWD is organizing one day Seminar on these products. I am sure that deliberations held and recommendations made during the seminar will help Engineering fraternity, Architects, Contractors and Builders in creating awareness about the usage of C&D waste recycled materials, Technical Textiles and Fly Ash Products in construction works for sustainable development.

I wish to acknowledge Dr. K. M. Soni, Additional Director General (TD), CPWD for bringing together the experts and participants of various organizations in this Seminar for dissemination of the knowledge and promotion of these eco-friendly products.

Place: New Delhi
Date: December 17 2018

(R. K. Thathu)

DR. K. M. SONI

सत्यमेव जयते

ADDITIONAL DIRECTOR GENERAL (TD)
Central Public Works Department
Nirman Bhawan, New Delhi



FOREWORD

A large number of infrastructure activities are being carried in the country ranging from construction of habitats to highways, ports and power plants. Since large quantities of C&D Waste are being generated due to demolition of existing structures, use of recycled C&D waste has become very important including other waste materials like fly ash due to environmental concerns. Linked to this challenge is the use of Technical Textiles for multiple functions ranging from stabilization of slopes, reinforcing retaining walls, roads and highways. The Government of India is actively putting in place a regulatory frame-work for use of C&D waste which includes the notification of the Construction and Demolition Waste Management Rules, 2016.

The Central Public Works Department under the guidance of the Ministry of Housing and Urban Affairs has been issuing guidelines, Schedule of Rates and publications for various stakeholders effectively setting the standards for use of products made from C&D Waste, Technical Textiles and Fly Ash. CPWD has also been using C&D waste products in its projects. Construction of Additional Office Complex for the Supreme Court of India, New Delhi and North Avenue Campus are such examples. CPWD has also included C&D Waste Products in Delhi Schedule of Rates.

The proceedings volume of the present seminar on 'Use of C&D waste, Technical Textiles and Fly Ash in Civil construction' contains technical papers on use of C&D waste, Technical Textiles, Fly Ash and AAC blocks. I am confident that this shall be very useful to the engineers working in the field.

I wish to acknowledge the sincere efforts and guidance of officers of Ministry of Housing & Urban Affairs and Shri Prabhakar Singh, DG, CPWD in organizing the seminar and bringing out this publication.

I also thank all officers and organizers of the seminar and others who made the seminar successful in a very short time. I would also like to keep on record the appreciations to Shri Divakar Agrawal, Superintending Engineer, CSQ, Shri D.S. Panwar, Executive Engineer, CSQ and team of officers of CSQ for taking pains and publishing proceedings of seminar in a very short time.

Place: New Delhi
Date: December 17 2018

(DR. K. M. Soni)

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PREVENTION AND RECYCLING OF C&D WASTE

Dr K M Soni, Addl DG (TD) CPWD, New Delhi
Divakar Agrawal, SE (CSQ), CPWD, New Delhi

Solid waste in the country constitutes about one third construction and demolition (C&D) waste hence the objective of solid waste management cannot be achieved without managing C&D waste. Also without segregation of C&D waste, neither municipal waste nor C&D waste can be put up to use for energy recovery and thus most of solid waste is sent to landfill leading to creation of mountains of such waste. Even fire and slide incidences have occurred in the country leading to severe accidents at such sites. Public residing near such dumping yards object for dumping the waste therefore there is a need to adopt effective C&D waste management plan in the country.

Realizing the necessity, the Ministry of Environment, Forests and Climate Change (MoEF & CC), Government of India has notified "Construction and Demolition Waste Management Rules, 2016" for management of C&D waste vide GSR 317 (E) dated 29th March 2016 in which C&D wastes generated by an individual, organization or authority are covered. In the Rules, various government organizations have also been made responsible for promotion and use of C&D waste also as a resource material. Based on these Rules, Central Pollution Control Board (CPCB), Government of India has also brought out guidelines in March 2017.

Unfortunately, only few C&D waste recycling plants have been installed in the country but it is expected that soon such plants would be installed in each town and city.

C&D Waste Management

C&D waste means the waste comprising of building materials, debris and rubble resulting from construction, re-modeling/renovation, repair and demolition of any civil engineering structure. Most of C&D waste comes due to redevelopment and new construction activities.

Any solid waste management plan includes 3Rs i.e. reduce, recycle and reuse. Segregation is first step in the process. In case of C&D waste management, reuse is adopted by salvaging usable materials through "de-construction" technique in place of demolition, defined as planned way of taking out reusable materials from the structure before demolition thus in other terms "Deconstruction" is selective demolition in which salvage, re-use and recycling of the demolished structure is maximized while "demolition" is defined as breaking down structures either manually or by way of using mechanical force. Practically, deconstruction techniques have been started by the demolition agencies in the country as seen in Mumbai (Fig. 1) salvaging all reusable materials except broken brickbats, mortar and concrete.



Fig.1: Waste from "Deconstruction"

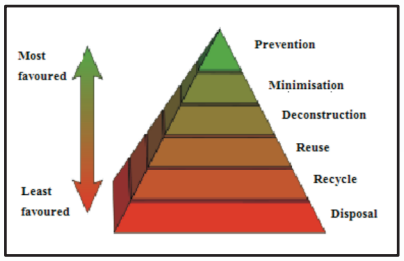


Fig.2: C&D waste management pyramid

C&D waste management hierarchy pyramid is shown in Fig.2 where prevention is most favored choice while disposal least. Reuse of materials saves considerable energy, water and human effort as every material has embodied energy and water. Though recycling requires additional energy and water but overall it is energy and water efficient compared to disposal in the landfill area. Disposal of C&D waste in a landfill requires considerable land and makes it unsuitable for construction of any civil engineering structure hence disposal needs to be stopped.

Prevention and minimization of C&D waste are possible only if structures need not to be demolished. But all the structures have their useful lives and every structure may require demolition after its economic life else it may have safety problems. Thus, demolition cannot be stopped altogether but can be delayed by adopting durability and quality in construction by enhancing the life of structures.

If C&D waste is generated from demolition after the life of a structure, it may be termed as sustainable provided it is reused and recycled but if it is generated from demolition of a structure before expiry of its economic life, it can be termed as creation of C&D waste. Such conditions may be due to poor quality of construction, maintenance or non engineered construction and even for getting additional FSI for personal benefits. For example carpeting of a road having a life of ten years if requires to be re-laid say in five years, it tantamount to creation of C&D waste of same quantities as used originally (Fig. 3). Similarly if a building having a life of 100 years needs demolition in 50 years, it is creation of C&D waste of same quantity as that of new construction (Fig. 4). Thus quality and engineering need to be made part of C&D waste management policy.



Fig.3: Poor quality construction



Fig.4: Non engineered unsafe structures

C&D waste is also generated due to poor techniques adopted during construction and maintenance. For example, re-carpeting is resorted on roads mostly without recycling of already bituminous concrete leading to raising the road level and thereafter relaying of footpaths, kerb stones and drains resulting into creation of considerable C&D waste. Services are not laid in integrated way or through trenches even in new constructions and every time excavation and relaying resorted again leading to creation of avoidable C&D waste. Similarly trench less technology though available is not adopted and road cutting carried out frequently. In some places, the structures are replaced without actual requirements just for utilization of funds by some government agencies. There is a need to stop creation of C&D waste by adopting ethics, quality and engineering helping in prevention and minimization of waste. Life of buildings is also required to be increased by adopting more durable materials and techniques in construction and by doing away "minimum" criterion adopted in construction.

C&D Waste Generation

C&D Waste Management Rules, 2016 classify C&D producing organizations into two categories as C&D waste generators and C&D waste bulk generators. Bulk generators are those generating C&D waste 20 tonnes or more in a day or 300 tonnes per project in a month. As they are generating large amount of C&D waste, greater responsibility has been entrusted to them. They are required to segregate the waste into four categories as concrete, soil, steel - wood - plastic, and bricks and mortar.

C&D waste management plan requires assessment of C&D waste generated. However, there is no standard assessment of C&D waste even in the country and data from different sources vary considerably, varying from 12-15 million tonnes in 2010 to 25-30 million tonnes in 2014 and 165-175 million tones now per year or even more. It is estimated that new construction produces 11% waste in residential and 6% in non residential works while renovation 55% and 36% respectively. Demolition produces maximum waste as 34% in residential and 58% in non residential (Fig. 5).It may be due to demolition not started on large scale in the country.

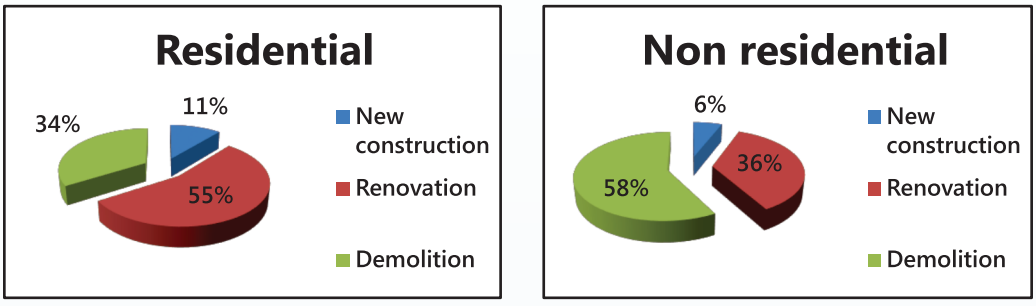


Fig. 5: C&D waste in residential and non residential buildings

As a thumb rule, 40-60 kg per sqm is considered C&D waste in new construction so also in repair and renovation while in demolition as 300-500 kg per Sqm. Major constituents of Indian C&D waste include concrete, soil, bricks, wood, asphalt, and metal. Bricks and masonry, soil/sand and gravel constitute about 60% as per the data of recycling plant of Burari, Delhi. Concrete, brick masonry, and sand/gravel together are around 90%. Bhattacharya et al (2013) also reported from the study of a DST project that about 90% C&D waste is from concrete, bricks and tiles (Fig. 6). As per TIFAC (Technology Information, Forecasting and Assessment Council, 2001, C&D waste in India constituents 36% soil, sand and gravel, 31% brick and masonry. 23% concrete, 5% metal, 2% bitumen, 2% wood and 1% others. Therefore major recycled materials are sand and aggregates and thus products manufactured from C&D waste are tiles, interlocking blocks, concrete blocks and kerb stones. More than 90% C&D waste can be reused and even slurry mixed with soil will be used for horticulture operations and producing mud bricks in future.

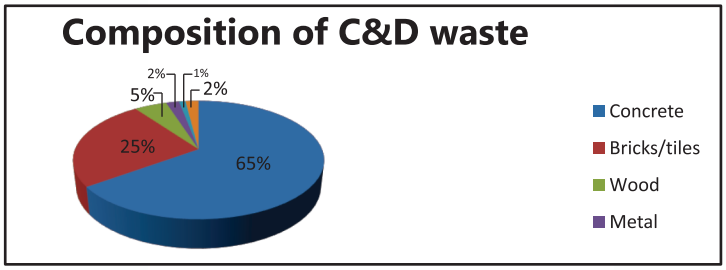


Fig. 6: Composition of C&D waste

Recycling of C&D Waste

Recycling is next desirable method after prevention, reuse and deconstruction. Segregation is first step of recycling hence habit of segregating different types of wastes has to be inculcated at the level where the waste is generated whether home, construction or demolition site. Now Urban Local Bodies (ULBs) are also stressing on segregation. Till complete awareness is generated, ULBs have larger responsibilities in segregation through incentives and awareness programs. ULBs are also required to make available separate dumping yard facilities where public can dump small quantity of C&D waste, preferably near municipal waste dumping facilities. From such dumping yards, C&D waste can be transported to the recycling plants. In absence of such facilities, C&D waste is dumped unauthorized into rivers, seas, lakes, roadsides etc. Some ULBs are already charging tipping fees from the agencies involved in construction, repair/renovation and demolition but for public, generating small quantity, it may continue to be free for the time being.

Recycling of C&D waste needs to be the top priority as large demolition is expected in near future. Redevelopment of the government residential colonies constructed after

independence upto late 1980s has started in various cities. Some of such colonies in Delhi are Moti Bagh, East Kidwainagar, Srinivaspuri, Mohammadpur, Sarojini nagar, Nauroji nagar, Netaji nagar, Kasturba nagar and Thayagraj nagar. Maharashtra Housing and Area Development Authority formed in 1977 has already permitted to redevelop its colonies in Mumbai. Therefore, recycling plants will be required to be installed at the site as well in all the cities.

Three types of C&D waste recycling plants are available as mobile, semi-mobile and stationary. Mobile plant scan be transported to the demolition sites and can be used to process only non-contaminated concrete or masonry waste. In the semi-mobile recycling plant, removal of contaminants is carried out manually and the end product is also screened. Magnetic separation is carried out for removal of ferrous materials. In such a plant, quality of end product is better than that of a mobile unit though not capable to process mixed demolition waste containing matters like metal, wood, plastic etc. Stationary C&D waste recycling plant plants are capable of carrying out all the operations.

First C&D waste plant in India was set up in Burari, New Delhi in 2012 by Infrastructure Leasing & Financial Services Limited (IL&FS) in collaboration with Municipal Corporation of Delhi having a capacity of 2500 tonnes per day on PPP model (operated at 500 TPD capacity) collecting C&D waste from three designated zones as Karol Bagh, Sadar Paharganj and City. The waste is recycled into sand and aggregates and converted to Ready Mix Concrete (RMC), pavement blocks, kerb stones, and concrete blocks (Fig. 7). Second plant of 500 MTP capacity is established in East Delhi, near Shastri Park. A plant has been set up in Ahmadabad having operating capacity of 300 TPD. Gurugram, Hyderabad and Greater Mumbai Municipal Corporations have planned C&D waste recycling plants which are likely to come soon. In Bangaluru, a private plant is installed with operating capacity of 1000 MTP and the corporation is also planning to install a plant. Godrej group has also installed a plant in Mumbai.



Fig. 7: Products from plant of ILFS Environmental Infrastructure & Services Ltd

Many more plants are planned in various cities and in near future, C&D waste recycling plants may be operating in every major city. Hon'ble Supreme Court has also taken a note of

submission of solid waste management policy by the states. Environmental issues are going to take front seat in the country restricting and even restrictions on the use of sand mining, stone blasting and stone crushing by the courts and tribunals. Being a public issue, C&D waste management policies are likely to be monitored by the courts.

But present existing capacity of recycling C&D waste plants is almost negligible compared to the requirements. Government of India and state governments have already started implementing various schemes like Smart cities, PMAY-Urban and Gramin, SBM, HRIDAY, AMRUT etc. Apart from this, private and government construction is also continuing. Further, renovation, repair and maintenance are recurring sources of C&D waste. Thus, infrastructure development is going to generate large amount of C&D waste requiring many C&D waste plants. Under PMAY-Urban itself, government has a target of 20million houses. Even if 50 kg average C&D waste is generated per sqm of area and area of a unit is considered 30 sqm, new construction itself would generate 50*20*1000000*30/1000 tonnes of C&D waste. In such a case 67 number of 500MTPD capacity C&D waste recycling plants operating for next 3 years would be required running for average 300 days in a year only for new construction under PMAY-Urban. In brief even if overall 30 million TPD waste is considered annually based on old data, it would require 200 plants of 500MTPD capacity operating for 300 days in a year however even 10 plants are not in operation in the country.

Initiatives Taken by Government Organizations

Erstwhile Ministry of Urban Development directed states to setup C&D recycling facilities vide circular dated 28th June 2012 in all cities having population over 10 lakhs. Though more than six years have passed, country is yet to see the implementation of such directions. Now Swachh Bharat Mission (SBM) also recognizes the need of C&D waste management. MoEF & CC included integrated waste management in various policies, reports and rules and finally notified "The C&D waste Management Rules, 2016" as mentioned before. These rules may have better impact as NGT and Courts may pass orders in case these are not implemented by the states. The Bureau of Indian Standards (BIS) and Indian Roads Congress have been made responsible under the Rules for preparation of codes using C&D recycled materials and products for wide acceptability and techno-feasibility.

BIS has included recycled aggregates in IS383:2016"Indian Standard on Coarse and fine aggregate for concrete – specification (Third Revision)". These aggregates are classified of two types namely recycled aggregate (RA) made from C&D waste which may comprise concrete, brick, tiles, stone, etc. and recycled concrete aggregate (RCA) derived from concrete after requisite processing. The code was revised in January 2016 permitting use of recycled aggregates upto 25% in plain concrete, 20% in reinforced concrete of M-25 or

lower grade and upto 100% in lean concretes of grade less than M-15.

As per National Building Code, recycled coarse aggregate may be used in concrete for bulk fills, bank protection, base/fill of drainage structures, pavements, sidewalks, kerbs and gutters etc, and up to 30 percent of natural crushed coarse aggregate can be replaced by the recycled concrete aggregate which can be increased upto50 percent for pavements and other areas specific to the standards and practices pertaining to construction of roads. Therefore, confidence is yet to be developed on recycled aggregates for their use in structural members.

Building Material & Technology Promoting Council (BMTPC) released "Guidelines for utilization of Construction& Demolition waste in construction of dwelling units and related infrastructure in housing schemes of the Government" in 2016.

Central Public Works Department (CPWD) published "Guidelines for Sustainable Habitat" in March-2014. CPWD and National Building Construction Company have also recommended use of recycled C&D wastes in their construction activities if the same is available within100 Km from construction site. Recently, CPWD also issued instructions for use of products of C&D waste in Delhi.

CPWD and Stiftelsen SINTEF signed an MoU on 25.02.2016 with the objective of cooperating on all aspects of recycling of C&D waste for an institutional and technical assistance programme on "Treatment and utilisation of Construction and Demolition waste in India" on capacity building and technical support. The Ministry of Foreign Affairs (MFA) of Norway have entered into an agreement with SINTEF allocating a grant to be used exclusively to finance the programme during 2017-21. The goal of the programme is to increase the utilisation level of recovered C&D waste in the building and construction sector in India by increasing the treatment and recycling capacity. Target groups are CPWD, ULBs and other institutions and academia including industry and waste management companies.

Makkar (2018) has reported use of blocks manufactured from C&D waste in Supreme Court additional office complex, New Delhi (Fig. 8) by CPWD, produced from Burari plant, Delhi. These blocks were used in external walls, toilet walls and lift well walls after required tests and when the company was able to produce them of desired compressive strength of 10 MPa, they were used in the project. Pull out strength for the fasteners used in the project was also found satisfactory. The size of the blocks used was 400x200x100 mm and in total 17.50 lakh blocks were used. The supply of the blocks has to be ensured as per the requirements hence it is suggested that before stipulating in the NIT, supply should be ensured.

CPWD has already included block masonry from blocks of C&D waste in DSR and examining use of Recycled concrete and Recycled aggregates in various civil engineering applications.



Fig. 8: Blocks from C&D waste used in Supreme Court additional office complex

Delhi Government has issued an advisory on the use of the products made out of recycled waste in Delhi PWD. Also, all Delhi Government agencies will incorporate a clause in their tenders for mandatory use of a minimum of 2 percent recycled products from C&D waste in all contracts for building works and 10 percent recycled products for road works. Other governments are also going to issue similar guidelines and thus C&D waste is going to be a resource for building industry rather than a waste in future.

CPWD has already incorporated use of C&D waste recycled blocks for masonry works in non structural members and use of aggregates conforming to IS 383. Recycled aggregates have wide scope of its use in road sub bases where large quantities can be utilized. Other possibilities are its use in filling under floors and plinth protection. Use of filter press material which composes clay and silt needs to be researched for filling, horticulture operations and brick making.

Concluding Remarks

Recycling of C&D waste has become essential as per "Construction and Demolition Waste Management Rules, 2016", and also from the environmental and Swachh Bharat Mission requirements. Awareness and capacity building has to be generated among the administrators, engineers, and public as the products from C&D waste can be used like products made from natural materials if they have pass the requisite tests. However to prevent and minimize C&D waste generation, engineers and builders have to implement quality in construction and maintenance works and adopt green technologies.

Private entrepreneurs need to come forward for setting up of C&D waste recycling plants and manufacture quality products. Once such measures are implemented, C&D waste will not remain a waste but will become a resource material.

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C&D WASTE RECYCLED BLOCK MASONRY

B. B. Makkar, Chief Project Manager, Supreme Court Project Zone, New Delhi
D.S. Panwar, Executive Engineer, Supreme Court Project Zone

Construction and Demolition debris (C&D) means materials resulting from the alteration, construction, destruction, rehabilitation or repair of any man made physical structure including houses, buildings ,industrial or commercial facilities and roadways or in general terms it is all non hazardous solid waste resulting from construction and demolition activities.

C&D Waste is the major contributor to pollution in Delhi. New Delhi itself generates 6000-7000 tons of C&D waste per day. The waste generation from new construction and re-construction activities estimated as 35 and 350 kg per sqm works out to be 2000 TPD which is received at landfill sites in Delhi. Similar situation may be in other metropolitan and large cities in India. As per the report of the World Bank in 2012, cities produced 1.3 billion tonnes of solid waste per annum globally and predicted to rise to 2.2 billion tonnes by 2025. According to a study, building materials alone constitute half of solid waste produced throughout the world.

For all natural and scarce resources need of the hour is to implement 3 Rs: Reduce, Reuse & Recycle. In case of C&D waste, recycling of the waste is to be implemented. Maximum utilization of recycled material is to be ensured in new construction activities to save scarce natural resource and to address the issue of disposal of C&D waste.

Requirement of use of C&D Waste

Use of C&D waste recycled products in construction activity will solve many problems including;

(i) Saving of scarce natural resources like river sand, stone, soil etc.

(ii) Energy consumed in mining and extraction of natural resources.

(iii) Traffic congestion and air pollution by elimination of long distance dumping.

(iv) Saving in space requirement for landfills as there is acute space constraints for landfills.

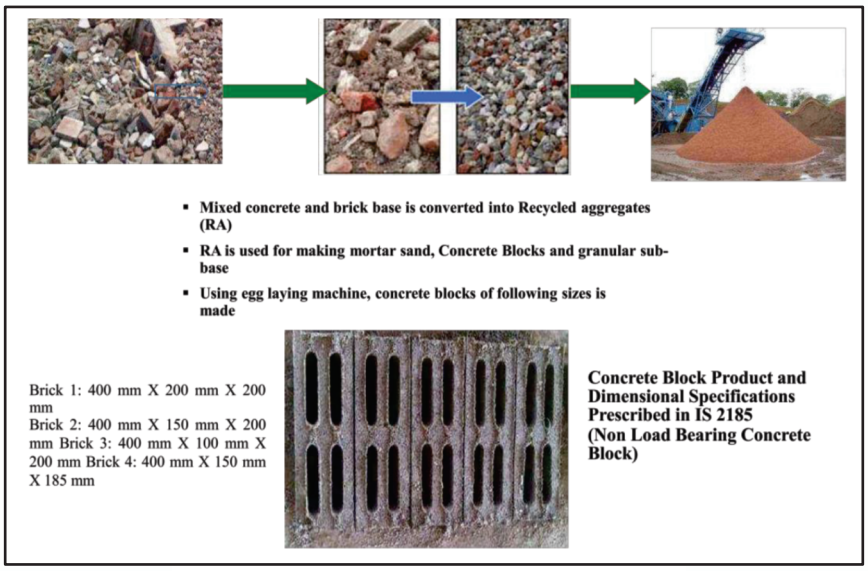
Recycling of C&D Waste

- Concrete and other rubbles (broken bricks, tiles, stone etc.) can be recycled into aggregate.
- Asphalt can be recycled into new asphalt.
- Wood can be recycled into engineered wood.

Focus of this paper is on recycled aggregate.

Recycled Aggregate (RA)

RA is made from C&D waste which may comprise concrete, bricks, tiles, stones etc. Recycled aggregate (RA) will typically have higher absorption and lower specific gravity than natural aggregate.



C&D Waste Recycling Plants in National Capital Territory, Delhi

- Burari (2000 TPD)

  IL&FS has set up India's first large scale C&D Waste recycling facility at Burari for North Delhi Municipal Corporation on PPP framework. About 2000 TPD of C&D waste can be processed into aggregates which in turn converted to various end user products.

- Shastri Park (500 TPD)

  IL&FS has set up another C&D waste recycling facility at Shastri Park for East Municipal Corporation on a PPP frame work.

- Mundka (Rohini) (150 TPD)

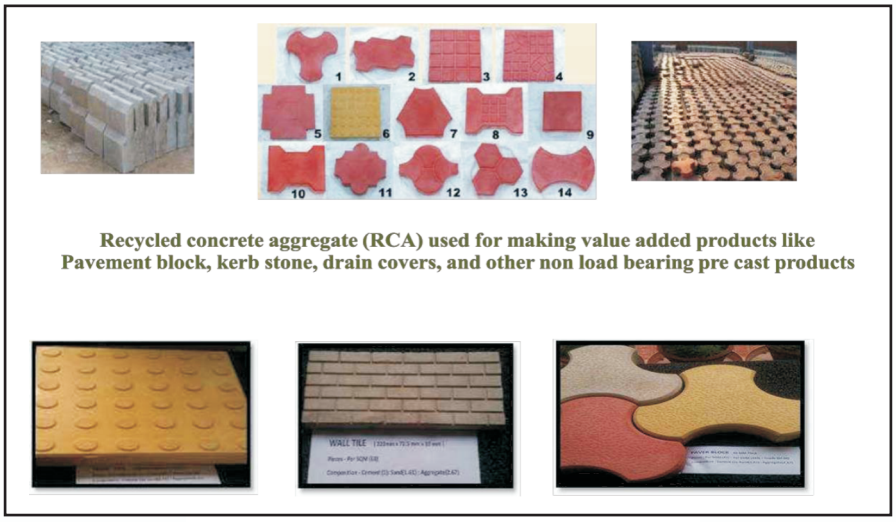
  IL&FS has set up C&D waste recycling facility at Mundka (Rohini) for Delhi Metro Rail Corporation.

C&D Waste Products made out of recycled aggregate

The following products are manufactured from recycled aggregates;

- CC Blocks for masonry
- Paver Blocks

- Kerb stones
- Drain covers
- Filling material





Production of C&D Waste masonry blocks

Guidelines for Use of C&D Products

As per the guidelines issued by the Government of India, CPWD has circulated guidelines for use of C&D waste recycled products to all field staff for implementing the same. Regular monitoring by the Directorate for effective implementation of guidelines is being done.

Directions have been issued by the MoHUA for use of recycled material and products. CPWD has issued directions that suitable clauses and items of recycled products shall be incorporated in the contract document by NIT approving authority to ensure 10-20% mandatory use of recycled materials and products for all CPWD projects in NCT.

Case Study

Additional Office Complex for Supreme Court of India

Additional Office Complex for Supreme Court of India has been constructed by CPWD near Pragati Maidan, New Delhi on a land area measuring 12.19 Acres. The building complex is designed to be a state of the art environment friendly centrally air conditioned office complex with all modern facilities. This new building complex has five functional blocks and one service with the car parking facility for 1800 cars. The foundation provided is raft foundation with soil anchors provided below the raft to counter uplift due to high water table pressure.

The block work required for exterior wall masonry works was to fulfill two necessary conditions in addition to having green building material. One was to have sufficient pullout strength so as to bear the fasteners installed to support the dry cladding stone and other was to have water absorption within permissible limits.

About 18 lakhs C&D waste recycled Blocks have been used on this project for masonry work. The properties of the blocks are as given in the followings:

- Size - 400x200x100 mm
- Weight per block - 15 to 16 Kg
- Grade of concrete - M10
- Compressive strength - 10 to 15 N/mm2
- Water absorption - 10 to 12%

Testing of C&D Blocks

No code is available currently for masonry units made by C&D recycled waste which generates the need for separate IS Code with details of minimum requirement of strength. However Specification, test procedure and acceptance criteria is presently governed by IS 2185 part-1, code for Specification for Concrete masonry units and thus presently being used for testing etc. for C&D waste blocks. There should be separate IS code for C&D blocks mentioning proper grades, details of materials minimum requirement of strength. Testing procedure and its acceptance criteria shall also be specified in this separate IS Code.

Advantages of C&D Waste Recycled Blocks

- Best use of construction & demolition waste
- Good strength for masonry work
- Saving natural resources like earth & coal
- No pollution as no burning of coal/wood
- Saving time by giving more speed in work
- Better bonding in finishing work
- Fewer joints results in considerable saving in mortar as compared to normal masonry

Practical difficulties in using C&D Blocks

- Irregular supply of materials
- Heavy in weight
- Not easy to handle
- Not smooth finish
- Higher wastage
- Difficulty in cutting to pieces.

Cost Comparison (Based on present rates)

It is observed that the rates of traditional bricks and C&D waste recycled blocks are comparable as given below;

Traditional Bricks

- Weight of brick = 3 Kg
- Rate per Brick = Rs 5 + GST (5%)
- 500 bricks consumed per cum
- Rate of masonry Rs.7700 per cum

C&D Blocks

- Weight of block= 15 Kg
- Rate per Block = Rs 28 + GST(18%)
- 125 Blocks consumed per cum
- Rate of masonry Rs.7500 per cum



C&D Waste Block Masonry

CONCLUSIONS

- The high level of construction and demolition (C&D) waste generated from the construction industry is a major threat to the environment and human well being.
- Natural resources are depleting day by day so it is need of the hour to reuse the waste product and by product for sustainability.
- In order to mitigate prevailing environmental problems, it is imperative to engage sustainable measures in the management of this waste.
- More and more promotion of reuse and recycle of materials recovered in order to promote healthy and sustainable environment.
- Traditionally used clay bricks should be banned completely.
- Number of C&D waste recycling plants need to be increased from metro to other cities to increase more and more C&D waste recycled products.
- A separate BIS Code is required for C&D waste materials and products.

ROLE OF ARCHITECTS IN MANAGEMENT OF C&D WASTE

Usha Batra, ADG (Arch), CPWD, New Delhi

Abstract

Construction industry consumes 50% of natural resources and is responsible for 42% GHGs. With the fast development of society on all the fronts, lots of construction, demolition and refurbishing is going on everywhere. All these activities generate considerable waste and its disposal is a challenge. Quantum of Construction & Demolition (C&D) waste is increasing day by day in India, as a result of increasing activities of construction, maintenance, retrofitting and demolition giving rise to environmental problems. The fast growing concept of 3R's in waste management, namely Reduce, Reuse and Recycle, is important for conservation of 3E's, namely Energy, Economy, and Environment.

Even though there is high potential for large- scale reusing as well as recycling of such waste, trend is at very low level in India. There is significant gap in its demand and supply of natural stones/aggregates, which can certainly be reduced to some extent by recycling construction and demolition waste. For effective utilization of C&D waste, it is important to develop a waste management plan. Architects have significant role to play in reducing and reuse of C&D waste through effective planning, design as well as during execution.

Since the concept of appropriate management of C&D waste is new in this country, awareness and education is necessary to change the mindset and attitude of all stake holders. Three case studies show the challenges faced and innovative solutions used to object and achieve the sustainable goals which were appreciated globally.

Introduction

With the development of society on all the fronts, mega construction activities are seen everywhere, rather increasing exponentially. Also, the demolition of existing structures, which have outlived its service life, is going on simultaneously. Also due to ongoing trend of reconstruction, just for creating more space in order to meet the present requirement, even healthy structure are being demolished. Many structures require reconstruction or renovation due to natural disasters like earthquake etc. All such activities are generating huge amount of C&D waste. Disposal of such debris in a safe environment is a big challenge for the builders, developers, owners and government.

It is estimated on a conservative basis that over 25-30 million tons of C&D waste is generated annually that clogs rivers, blocks traffic and occupies dumping space. In addition, few construction agencies also dump such waste over wetlands. Rising pollution levels due to construction have very bad impacts on health.



Waste generated in
(new construction Gurgaon)



Bhuj (demolition) due to disaster

As per TIFAC, new construction generates 40-60 kg per sqm, building repair 40-50 kg per sqm and demolition of building 300-500 kg per sqm of C&D waste. Therefore demolition must be avoided as far as possible.

It is important to understand that natural resources are depleting day by day and the area available for land filling is also reducing at a good rate. Recycling also costs less than dumping C&D waste in almost all cases. It is therefore imperative to look for alternative methods that would lead to sustainable living. Utilizing C&D waste is certainly better solution over causing depletion of natural resources.

On one hand the disposal of debris is a challenge, on the other hand there is an acute shortage of natural aggregates for construction activities. Reduction of this demand in a small way is possible by reusing or recycling of construction and demolition waste generated from the construction activities. Regulated use of this material can lead to saving in virgin raw material and consequent reduction in waste disposal, besides reducing air pollution.

The Swachh Bharat Mission under MoHUA envisages processing of 100% solid waste generated in cities/towns by 2nd October 2019 as a key objective, including C&D waste. All states are to set up C&D waste recycling facilities in all cities with population over 1 million.

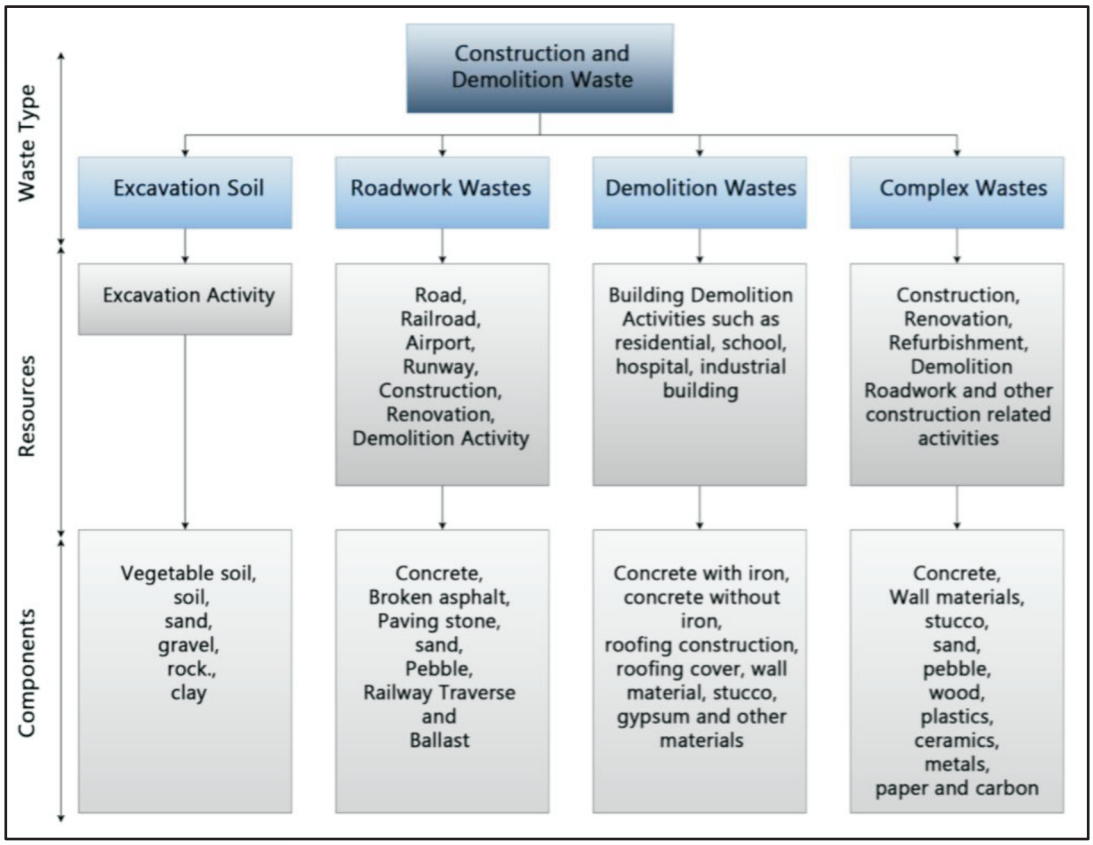
Promotion of C&D Waste Management

Despite long life of the materials/ products used in construction, their eventual demolition or redevelopment produces significant waste for land disposal unless re-used. There is a need to understand the potential and technical aspects of use of recycled concrete aggregates along with best practices in implementation and enforcement for achieving the aim of sustainable development / environment. Establishment of effective strategies and enactment of laws and regulations is essential to achieve this. In addition, incentives to users of the recycled products is necessary to promote its use.

As an initiative by CPWD, MoU was signed between CPWD and SINTEF Norway, an independent research organization recognized for C&D waste management studies, utilization and recycling technology on 25.02.2016 in New Delhi to facilitate cooperation on

all aspects of recycling of C&D waste management, human resource development, capacity building and scientific research in the field of recycling of C&D Waste etc.

Source and the Components of Waste Generated



The waste from hospitals, schools and factories is considered hazardous as it may contain toxic waste present in laboratories. Therefore, for effective utilization of C&D waste, it is important to develop a waste management plan taking into account the economic and environmental factors, which would help us in understanding the nature of the waste and the way it should be treated for utmost utilization.

Recycling Potential of C&D Waste Products

C&D waste can be utilized in buildings for structural Members and other building components apart from site preparation, landscaping and in roads etc. For example;

- Aggregate, reinforcement can be reused in structural members like slab, foundation, etc.
- Materials like bricks, doors, gypsum board, fibre ceilings, shingles etc can be reused in building components like, wall, doors and roofs.
- Stones, bricks, tiles and other materials can be used in landscaping, paving and laying of roads, solar reflective terracing, sculpture and art works.



Various forms of reuse of C&D waste

Role of Architects

Architects have significant role to play in reducing the waste generated from construction projects in four major areas of the design process mainly i.e. design, construction techniques, building materials specifications and education.

- In design stage, considering whole life approach and flexibility in the design to accommodate future expansion or alterations.
- By choosing the form, size and shape of the building in such a way that reduces the use of excess building material.
- Specifying the materials and techniques that save the material usage.
- Use of standard sizes and prefabricated components.
- By educating the client and other stakeholders for appreciating waste minimization benefits.
- Making creative use of left over waste in murals, sculptures and art works.

Reduction in Wastage of Materials during Planning, Designing and Construction

During planning material wastage can be reduced by:

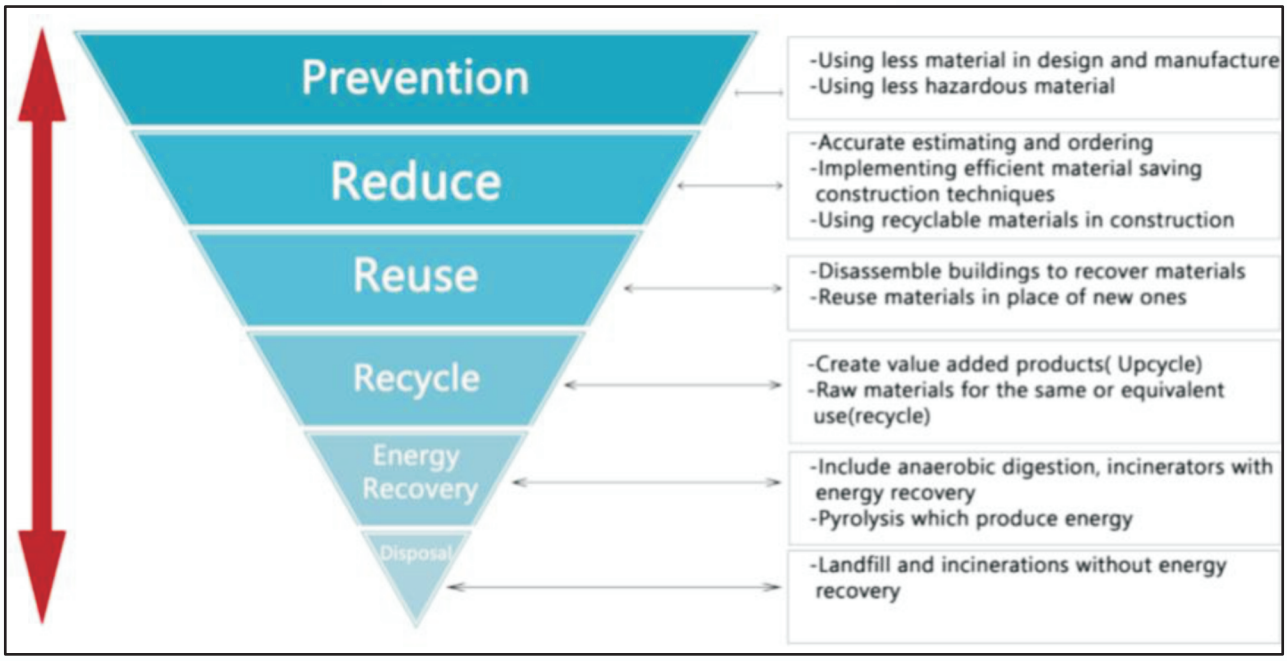
- Exploiting existing contours / gradient adopting varying plinth levels thereby avoiding extra cutting and filling.
- Adopting uniform and regular shaped buildings in plan and elevations without affecting the aesthetics.
- Using repetitive modules wherever feasible.

During design material wastage can be reduced by:

- Providing fewer variations in sizes and specifications of members and openings for ease of interchange ability and substitution.
- Making provision for services cut-outs in slabs and walls or providing services by methods that permit easy installation/replacement as and when required.
- Providing service trenches on roadsides to minimise damage during repairs.
- Preparing a maintenance plan/schedule based on the specifications used to achieve the desired service life with minimum maintenance.

During construction, material wastage can be reduced by:

- Providing and laying plumbing pipes and electrical conduits during concreting and walling, instead of cutting chase later on, or at least using a chase- cutting machine to minimize cutting volume followed by minimal repair
- Making use of couplers in place of laps for steel reinforcement bars.



Innovative Steps to Prevent/Reduce Waste

The 3R's (Reduce, Reuse and Recycle) are the key concepts in conservation of resources and sustainability of environment. The primary effort, therefore, should be to engage in waste prevention and minimise the use of natural resources. Prevention is financially advantageous as it reduces the use of new construction materials and disposal of old from the site. Therefore one must ensure that:

- Materials are ordered on an "as needed" basis to prevent over supply and excess scrap waste on site.
- Materials are ordered in required shape, dimensions and form.
- Correct storage and handling of construction materials to minimise damage/waste e.g. keeping deliveries packaged until they are ready to be used.
- Correct sequencing of operations and assigning individual responsibility to sub-contractors for the purchase and management of raw materials and wastes arising from their activities, ensuring that available resources are not expended in an extravagant manner at the expense of the main contractor.
- Renovations are carried out by retaining and repairing the existing elements as far as possible with the introduction of new items only where necessary.
- Deconstruction / planned demolition is done to facilitate reuse of building elements.
- Modular construction/Pre cast units are used in new constructionswhich improves the quality, reduces the construction time, is economical and reusable.
- Durable materials are used for the structural as well as for non-structural members to increase the life of structures.
- Periodic and preventive maintenance is done to enhance the service life of the building thereby reducing the frequency of replacement.
- Layout/Design is open & flexible and can be easily adapted for other uses over time.
- Design is documented, including all services to ensure that alterations, maintenance and deconstruction are easier and less wasteful.
- Renovation are carried out rather than Demolition to avoid double hit on scarce resources i.e. waste generated and throwing away lakhs of rupees by replacing it with materials as well as huge amount of embodied energy.
- Practice of refurbishing room interior with every new officer only for choice based upliftment must be discouraged.
- Ready Mix concrete is used to reduce wastage and landfill sites. Less finishes are used to reduce the associated material waste.

Reusing and Recycling of C&D Waste

Reuse of construction and Demolition waste does not require any further processing to convert into a useful product. The items which are usable directly are screened out from the debris and put to intended use without further processing. This is possible by preparing an effective deconstruction plan instead of just converting the standing structure into debris

within minutes. Useful products like doors and windows, bricks, reinforcement, from RCC components, structural steel etc. can be taken out with little extra efforts and put into reuse without much processing.

Therefore such materials should be reused on site or salvaged for subsequent reuse to the greatest extent possible. Storage of salvaged material can facilitate its reuse on future projects. Architectural features should ideally be reused in the refurbishment of retained structures on the same site whereas "Architectural salvage sales" can allow the public to acquire material resources that have been removed from de-commissioned buildings. Excavated top soil can be carefully set aside and used as landscaping material in the completed development. Innovative initiatives to avoid the need for disposal should be investigated based on the concept of 'appropriate use'.

Once the reusable items are taken out, the leftover waste is now available for recycling into useful products to extend the service to environment. Worldwide in developed countries there is enough activity of recycling of such wastes whereas it has recently started in India. In New Delhi, first pilot plant came up at Burari in North Delhi, in 2009 of capacity 500 TPD, 2nd was set up at Kidwai nagar in 2014 of 150 TPD and subsequently at Shastri park of 500 TPD and Jahangirpuri 2000 TPD. In case, construction materials made of recycled wastes do not have the same properties as required, these can gainfully be used in units which may not be subjected to the full design load or may be required for shorter service life e g. road base and sub-base for service roads and rural roads, railings for boundary walls, aggregate for lower grades of concrete or some temporary constructions.

Case Studies

Three case studies have been chosen to show the efficiency and potential of various recycled materials.

Case Study I

The Nalawala Hall, Fairfield City Council

It is Australia's largest straw bale community building designed with environmental sustainability that exemplifies the use of recycled concrete among other construction and demolition waste re-use. Recycled materials were procured and used as building components as well as structural members e.g. concrete, window frame and doors, waste straw and milk bottles etc.

The main body of the hall was built from straw bales rendered with mud. Recycled materials have been used for doors, frames and fittings. Paints and finishes used are environment friendly. The construction is done by local residents and some volunteers. It incorporates the world's first concrete load-bearing foundation slab which is 95 per cent recycled and is never before implemented anywhere in the world. Five tonnes of waste straw for the straw bale construction has been used and 800 milk bottles of plastic waste are re-used as toilet

partitions.

The recycled concrete used has been produced by the council's own in-house construction material recycling operation in partnership with local concrete supply company Metro mix.

The hall has been in use since 2008 and the concrete slab is performing well.



Interior view of Nalawala Hall

The project has not only benefitted environment by converting waste straw into a valuable building resource but avoided greenhouse gas generation as straw is often burned. It has an additional benefit of thermal comfort as insulation factor of wall constructed is 10 times the double-brick cavity wall.

The use of good quality recycled materials can raise the confidence of architects and, builders, to use them.

Case Study II

The Olympic Park, London Capacity 80,000

It was constructed on once heavily contaminated industrial land with challenge of reclaiming the site.

Materials available on site were put to use in new construction demonstrating the efficient use of materials available on site and also to minimise post-event construction waste.

The project was focussed on sustainable development as the embodied energy required to build the structures of that huge scale was going to be much larger than the energy consumed while hosting the event and therefore it was planned by cutting down on material cost, transportation of materials and producing less waste on site.

C&D waste available on site has been reused and recycled in site planning as well as structural members for environment and economic benefit.

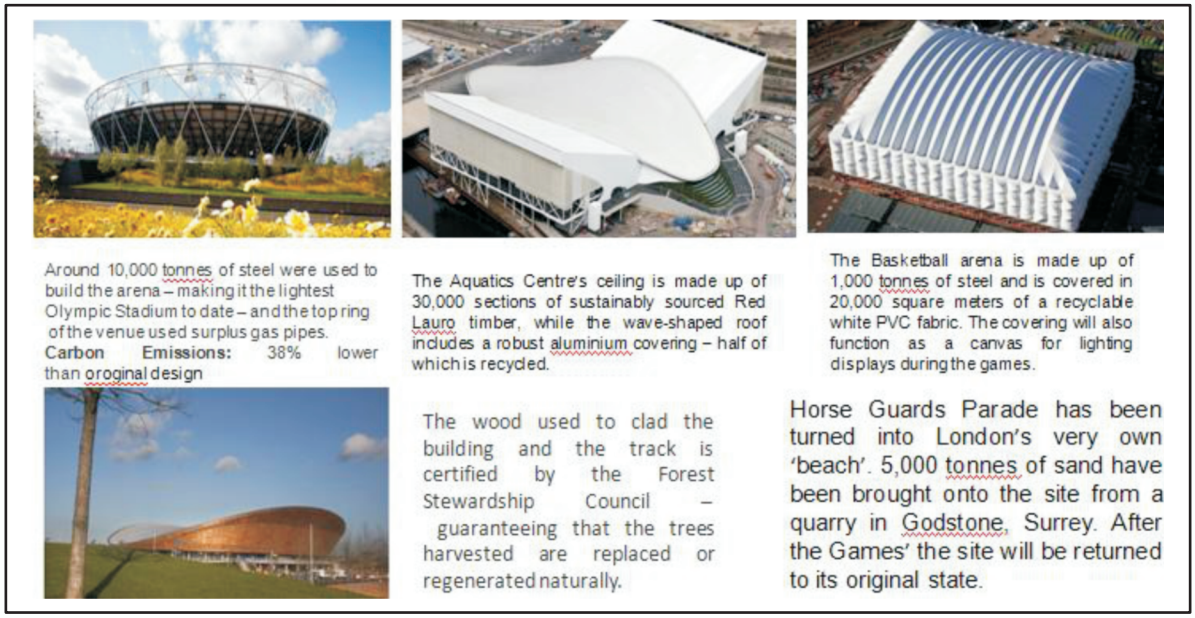
Materials recycled were timber from trees that were removed, 80,000 tonnes of excavated soil, aggregates, bricks, scrap metals, aluminium, and granite stone.



Earlier situation of the site



Olympic Park post construction



Use of recycled waste in various parts of buildings.

Recycling up to 98% of the reclaimed material not only reduced its energy consumption but also made it a good example of sustainable design for hosting mega events. More than £1m of waste was avoided through sustainable design, procurement and construction processes and more than 90% of construction waste was diverted from landfill.

New and untested products presented concerns over deliverability and performance and therefore professional indemnity, liability and reputation. To achieve sustainable goals, challenges were accepted and innovative solutions executed which were appreciated globally.

Case study has shown the way to use recycled waste on huge scale and can be followed in India as well.

Case Study III

Vadi School, Rajkot by Architect Surya Kakani

An enormous amount of debris waste was generated after Bhuj Earthquake in 2001. Due to absence of technology and knowledge about recycling, it was transported to various landfill sites. The Architect thought of making use of this in rebuilding practice.

He used materials like rubble from broken buildings, fly ash waste from GEB Thermal Plant, gypsum from sanitary ware factory located nearby and lime waste from Tata Chemicals Ltd., Mithapur in the primary building block.

The trusses for the roof are made from steel pipes brought from the ship breaking works at Along and the roofing itself incorporates the renewable matting of date palm leaves on the bamboo framework over which is laid thatch as final layer, choosing an environment friendly path and utilizing full potential of the waste available in the locality . Almost every layer from roof till foundation has been justified with the nature by;

- Use of earthquake rubble in the walls
- Plastering of walls with gypsum procured from the waste generated by sanitary ware industry in the neighbourhood.
- Making trusses for the roof from steel pipes brought from the ship breaking works located nearby.
- Use of fly ash waste which was obtained from GEB Thermal Plant.



Exterior



Interior



Courtyard

It exhibits how different materials can be put to use in construction and how waste can be put to use as a potential building material.

Inspired by the use of C&D waste effectively after earthquake disaster avoiding huge amount of land filling due to debris generated, Architect used this waste in rebuilding practice. It is generally accepted that use of recycled materials pose a threat of construction failure. However, in this case, architect has efficiently used the materials showing way to all others who are afraid of using recycled materials in building construction.

Conclusions

- Natural resources are depleting day by day and the area available for land filling is also reducing at a fast rate leaving the only option of using the extensively produced C & D waste.
- The fast growing concept of 3R's in waste management, namely Reduce, Reuse and Recycle, is important for conservation of 3E's, namely Energy, Economy, and Environment.
- Architects have significant role to play in reducing the waste generation while planning, designing and construction and implementing better waste management plans in redevelopment.
- Potential, technical aspects, best practices in implementation and enforcement for reuse of C&D waste need to be deeply studied to achieve the aim of Sustainable development / environment
- Since this is a new area in our country, information and education is necessary to change the mind-set and attitude of the public and all the stake holders.
- Redevelopment should be carried out by 'deconstruction' instead of outright demolition.
- Building materials having longer life must be promoted.
- Pilot demonstration project must be taken up in each state by changing and implementing the relevant regulations and by -laws etc.

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PHYSICAL, CHEMICAL AND CO_2-BINDING PROPERTIES OF AGGREGATES RECYCLED FROM C&D WASTE

Dr. Christian J. Engelsen, SINTEF Building and Infrastructure, Norway

Abstract

Construction and demolition waste (C&D waste) is one of the biggest waste streams in most countries. The heavy inorganic part (from concrete and masonry) could be processed and refined into recycled aggregates. This type of aggregates could substitute natural aggregates in a range of user applications like road construction, landscaping and concrete production. This will save natural resources, decrease transportation, reduce land filling and bind CO_2 through increased carbonation. In the current study, the physical and chemical properties determined over time were found to be relatively stable during the extensive sampling periods. Most of the parameters were complying to the requirements in IS 383. For some parameters, such as specific gravity and fines content, small modifications in the recycling process will decrease the fine particle content to the desired level. However, RCA with higher contents can be used in other applications like for example concrete block production.

Regarding the inherent added-value properties of recycled aggregates, it was found that recycling of C&D waste contributes significantly to CO_2-binding by increased carbonation. Partly substitution of natural aggregates with recycled concrete aggregates further increase the binding potential since the cement paste and the recycled aggregates also will bind CO_2. The field study showed that by including the recycled material in the retaining wall, the binding capacity increased from 134 to 151 kg CO_2 / m3, i.e. an increase of 12%. Furthermore, if 10% of the cement consumed in concrete is recycled, minimum 5 million tons of CO_2 may potentially be bound due to the recycling. To utilize this potential fully, concrete recycling into recycled aggregates is decisive due to increased speed of carbonation, as the surface area has increased order of magnitudes after crushing the concrete. Hence, this binding potential can be considered as a significant added value in many circular economy initiatives, as one of the fundamental principles of circular economy is to maintain the material resources as far as possible in a closed loop i.e. decrease or prevent waste formation.

1. Introduction

Construction and demolition waste (CDW) is one of the biggest waste streams globally. The heavy inorganic part (from concrete and masonry) could be processed and refined into recycled aggregates. This type of aggregates could substitute natural aggregates in a range of user applications such as road construction, landscaping and concrete production. This will save natural resources, decrease transportation, reduce land filling and bind CO_2 through increased carbonation. The revised framework for waste management in the EU (WFD, 2008), which was adopted in 2008, includes a target for recovery of CDW. Within 2020,

the preparing for re-use, recycling and other material recovery of non-hazardous construction and demolition waste (excluding naturally occurring material) shall be increased to a minimum of 70% by weight. The target was added during the final negotiations of the Directive text and instructions for verifying compliance were established in 2011 (Arm et al., 2017). Norway has implemented the WFD and must comply to this target through the partnership of the European Economic Area. The directive is intended to be an overall key driver for circular driven economy for C&D waste. In India, the estimates for the annual CDW generation vary from 50-500 million tons. However, more accurate figures could be calculated for Delhi where the generation is around

3000-4000 tons per day. Thus, it is challenging to meet the demands for treatment and recycling.

On the other hand, the large CDW volumes are huge material resources and can be processed and recycled into aggregates. Recycled aggregates can be used in a many building and construction applications including road construction, ready-mixed concrete and concrete block production, landscaping materials, cement clinker production etc. In the literature, the abbreviations for recycled aggregates are many. In India, the common abbreviations are RA (recycled aggregates) and RCA (recycled concrete aggregates), which basically differentiate between a production feedstock of mixed CDW and only concrete rubble, respectively. The terminology is given by the standard IS 383 (Coarse and fine aggregates for concrete)1.

Recycled aggregates can also contain various contaminants such as chlorides, sulphates, carbonates, organic matters, etc., depending on the source of the parent concrete. These contaminants can affect the compressive strengths of concrete with RCA (RAC) by up to 15%, or make the concrete more susceptible to leaching (Ng and Engelsen, 2018). For satisfactorily high-quality levels of concrete, recycled aggregates must comply with some minimum requirements, mainly concerning chemical stability and physical–mechanical characteristics (e.g. EN 12620 and IS 383). Furthermore, according to the Japanese standard for RAC, the amount of harmful materials in RCA with density less than 1200 kg/m3 is limited to 2 kg/m3, whereas materials with density < 1950 kg/m3 at 10 kg/m3 (Ng and Engelsen, 2018). Hence, the quality of the recycled aggregates produced are crucial. In this relation it is important to verify stable quality over time.

Another inherent property of recycled aggregates is the ability to bind CO_2 by carbonation. This aging process normally occurs when air or water-borne CO_2 dissolves in the concrete pore water and react with Ca2+ to form stable $CaCO_3$, which is precipitated in the pore system. Upon carbonation, the pH of the concrete pore water is decreased to around 9. Although it is a well- known naturally occurring ageing process for concrete, the carbonation phenomena is quite complex as it involves a series of chemical reactions and physical processes. Thus, it is difficult to give a complete physio-chemical description of all processes involved. Carbonation mainly involves decalcification of the Ca-bearing hydrate phases when different polymorphs of $CaCO_3$ are formed. In addition, the Mg-bearing

hydrate phases (OH-hydrotalcite and CO_3-hydrotalcite) will also carbonate by forming $MgCO_3$ and $Al(OH)_3$ when the hydrotalcite phases become unstable at pH less than 10. The former carbonation process is predominant since the average MgO content in Portland cement is less than 2%. Carbonation is well-known to be detrimental for concrete with steel reinforcement as the passive layer at the steel surface is broken at pH <10, which means that the steel is no longer protected against corrosion. Thus, for durability reasons of reinforced concrete, the carbonation speed is a critical factor. However, carbonation is in most cases not detrimental for concrete without reinforcement as it forms a denser concrete with increased compressive strength when precipitation of $CaCO_3$ occurs. Concrete is in many cases not fully carbonated after its primary service life. When recycled aggregates are produced from CDW, the surface area of concrete increases tremendously and the carbonation speed will increase. Hence, the remaining CO_2-binding potential can be utilized.

In this study, RA and RCA are used as defined in IS 383. In addition when both types are mentioned, recycled aggregates is used.

In the current study, crucial properties of RCA have been determined over time at a recycling facility in Delhi. Details regarding this part of the study can be found in Engelsen et al. (2019). Moreover, new knowledge regarding carbonation and CO_2-binding capacities has been used to calculate CO_2-binding potentials in concrete with and without RCA. In addition, estimates of the CO_2-binding potential in India are given. The study is part of the Indo-Norwegian project (C&D-WIN). The project is supported by the Royal Norwegian Embassy New Delhi and will continue to the end of 20202.

2. Materials and methods

2.1 Sampling

The sampling of RCA was conducted at Burari C&D waste recycling plant in Delhi. This plant has installed the wet recycling processes (CDE technology). In addition, the plant has a dry processing support line for feedstock that contains mostly concrete rubble. The sampling was conducted in the period of November 2017 to February 2018. The feedstock material contained largely concrete and concrete masonry units intermixed with some soil. Small fractions of bricks and ceramics could be found occasionally. These quantities were initially evaluated to have low influence on the final RCA properties due to their relative small share.

The sampling represented a daily production shift by collecting sub-samples from the conveyer belts every 1-2 hour during the whole working shift, i.e. 5 sub-samples. These samples were mixed and homogenized to one daily bulk sample. The sampling program was developed by SINTEF who was present at site together with Bureau Veritas during the sampling period. A total of 4 daily bulk samples were prepared and analyzed during the sampling period at Bureau Veritas in Delhi and at SINTEF and ALS Laboratory in Norway.

2.2 Physical and chemical properties determined in RCA

The RCA samples were reduced in volume by splitting, quartering, crushing and pulverization. The reduction of the laboratory samples to test samples and to final test portions

was conducted according to NS-EN932-2 and NS-EN 15002.

The cement paste content was assessed for all samples since the mortar content in RCA often represents the weaker bonding in the interfacial transition zone (ITZ) between the RCA particle and the cement paste (Ng and Engelsen, 2018). It has been shown earlier that the acid soluble content can serve as an indicator for the cement paste content in RCA (Engelsen et al., 2009). Hence, the acid soluble content was determined according to the procedure described in Engelsen et al. (2009).

In 2016, Central Public Works Department (CPWD) under Ministry of Housing & Urban Affairs (MoH&UA), Govt. of India has signed a Memorandum of Understanding (MoU) with the Foundation for Scientific & Industrial Research (SINTEF, Norway). The institutions agree to facilitate collaboration on all aspects of waste management and building technology with special emphasis on best available technology on recycling of construction and demolition waste.

In addition, the following properties determined according to Indian standards (IS 2386) will be presented:

- Classification of coarse RCA
- Particle grading
- Shape of coarse aggregates (combined elongation and flakiness index)
- Specific gravity and water absorption
- Aggregate abrasion value of coarse aggregates, by Los Angeles (LA)
- Soluble chloride and sulphate

In addition, the acid soluble contents of sulphate and chloride were determined according to EN 1744-1 and IS 14959-P-2, respectively.

2.3 CO_2-binding capacities of different cement types

The binding of CO_2 is due to the carbonation of the hydrated cement paste. In 1000 kg Portland cement that consists of 95% clinker, around 620 kg of $CaOCO_3$ can theoretically be converted to $CaCO_3$ by consuming CO_2 from the air (in further calculations 600 kg of CaO was used). Thus, the theoretical CO_2-binding capacity in Portland cement is 471 kg CO_2 /ton. In order to be able to estimate the CO_2-binding by concrete, the normal binding capacity was calculated. This corresponded to a carbonation degree equal to ~70%

conversion of total CaO to $CaCO_3$, as shown above. The calculated CO_2-binding capacities for commonly used cements are shown in Table 1 (Engelsen et al., 2016). Earlier laboratory experiments have confirmed the CO_2 binding potentials. In these studies, the amount of CO_2 bound to crushed concrete has been measured by direct consumption of CO_2, rather than calculating the quantity based on carbonation depth (Engelsen et al., 2005). The binding capacities in Table 1 were used in the CO_2-binding potential for the total cement consumption in India.

Cement type (kg/t)	Fly ash (%)	Slag (%)	CO_2-binding capacity
CEM I	Not applicable	Not applicable	330
CEM II/A-V1	20	Not applicable	255
CEM II/B-S2	-	33	294

Table 1 CO_2-binding capacities for normal and blended cements

1 Siliceous fly ash with a glass content of 65% consisting of 35% S_iO_2 and 15% Al_2O_3 and where 80% of the glass phase has reacted over time, the consumption of calcium hydroxide per gram fly ash; 0.80 x 0.65 x 0.35 x 1 x MCa(OH)2/$_M$SiO2 = 0.22 g to form C-S-H of C/S = 1 not available for carbonation; 0.80 x 0.65 x 0.15 x 3 x MCa(OH)2/MAl2O3 = 0.17 g to form C3AH6 presumably available for carbonation [Fernàndez-Carrasco et al 2012].

2 Blast furnace slag with composition of 40% CaO, 9% MgO, 11% Al_2O_3 and 40% SiO_2. 70% of the CaO in the slag was assumed to be able to carbonate.

3. Results

3.1 Acid soluble content

The acid soluble content is shown in Table 2 and was found to be in the region of 19-33% (Engelsen et al., 2019). These contents were considered to be slightly higher than what normally can be found in only concrete rubble (Engelsen et al., 2009). The presence of different types of mortar from masonry usually contribute to increase the cement paste content. Furthermore, the acid soluble contents were inorganic in nature as the TOC levels were less than 1%. Hence, considerable amounts of cement paste were present in the RCA. In addition, it can be seen that the cement paste is accumulating more in the finest particle size, i.e. in RCA 0/3 mm. It is emphasized that these recycled aggregates were produced from a dry process line. In a wet recycling process, a significant amount of the cement paste can be removed by washing and scrubbing.

Daily sampling number	RCA 0/3 mm	RCA 3/10 mm	RCA 10/20 mm
1	not determined	26	not determined
2	27	25	23
3	32	29	19
4	33	29	27

Table 2 Acid soluble content given weight% as the arithmetic mean of 3 replicates

3.2 Particle grading and classification of coarse aggregates

The sieving analysis revealed that the RCA 10/20 mm was entirely according to the requirements in IS 383. Regarding the samples RCA 0/3 mm and RCA 3/10 mm, the content of particles less than 75 µm was typically higher than the criteria of 10% and 1%, respectively. Decreasing the fines content by for example a washing step will most likely result in compliance with IS 383 for RCA 0/3 mm (Zone-II) and RCA 3/10 mm.

The classification of coarse aggregates (3/10 mm and 10/20 mm) showed that only small amounts of clay masonry was found in all tested samples. The content of concrete, mortar and unbound masonry was in the region of 40-50%. Furthermore, bitumen, glass, metal, wood and gypsum were not found.

3.3 Other important physical and chemical properties

Based on previous analysis (cement paste content and classification), some variation between the sampling periods was found. The impact of this variation on the other important properties are shown in Figure 1. Water absorption and specific gravity were found to be relatively stable, except for one sample. The results also showed the expected difference between the three different particle sizes, i.e. highest density and lowest water absorption for the coarsest fraction. Furthermore, the combined elongation and flakiness, aggregate abrasion (by LA) and the acid soluble sulphate content were evaluated to be relatively stable over the sampling periods. The acid soluble chloride content varied but at a low concentration level. Some chloride results in the sampling period 2, were found to be around and insignificantly above the IS 383 criteria of 0.04%. Except for the specific gravity of RCA 0/3 mm, the results complied to IS 383.

It is emphasized that part removal of the fines will lead to lower chloride content and increased specific gravity, in particular for the RCA 0/3 mm fraction. Decreasing the fines content without installing a washing step, may be conducted by installing a by-pass or reduce the entering of overflow materials into the recycling process.

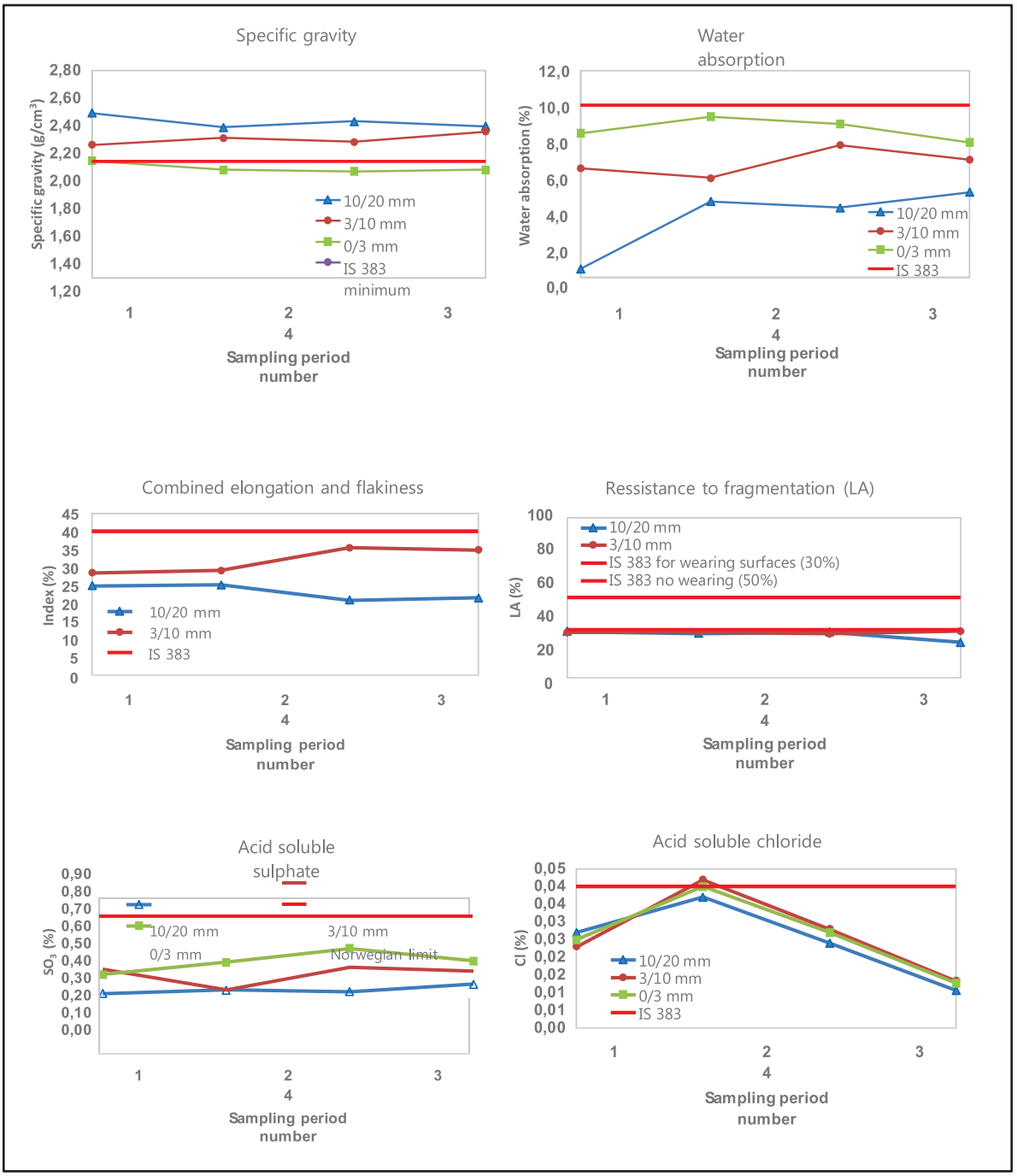


Figure 1 Variation in time of important properties of RCA (Engelsen et al., 2019)

3.4 CO_2-binding capacity of concrete including RCA

Based on the binding capacities in Table 1, the binding potential for a model concrete was found to be around 100 kg CO_2 / m_3, assuming a Portland cement content of 300 kg/m3. One way to increase the CO_2-binding potential in concrete and stimulate the circular economy, is to partly replace the natural aggregates with recycled concrete aggregates. Hence, the cement paste and the cement paste in the RCA have the potential to bind CO_2. High replacement level of natural aggregates has been demonstrated earlier. In a full-scale

demonstration project, 100% of the coarse natural aggregate fraction was replaced with crushed concrete, and a CEM I content of 407 kg/m3 was used (NPRA, 2007). It can therefore be shown that the fresh concrete had a binding capacity of 134 kg CO_2 / m_3 without recycled materials. Furthermore, it can be assumed that the cement paste content in the recycled coarse aggregates is 13% and that the carbonation level was 30% from the primary use (before crushing). Thus, including the recycled material in the retaining wall, the binding capacity increased to 151 kg CO_2 / m3, i.e. an increase of 12%. It is emphasized that the assumptions made above are conservative. Furthermore, the calculated and measured binding capacities are considered to be realistic. They are not representing the theoretical binding potentials, which are significantly higher. However, to fully utilize the total binding capacity, carbonation throughout the concrete depth is needed.

3.5 CO_2-binding potential by recycling of C&D waste based on the annual cement consumption in India

Applying the cement chemistry of the hydrate phases, a realistic binding of 200 kg CO_2/ton cement has been calculated for Indian concrete. It has been assumed an average clinker factor of 0.75. Furthermore, accounting for a total annual Indian cement consumption of 300 million tons, the emission during cement production is 180 million tons, i.e. 600 kg CO_2/ton cement. Due to carbonation, 10-20% of the emission are re-absorbed in service life, i.e. the remaining binding potential is around 18-36 million tons. If 10% of the cement consumed in concrete is recycled, minimum 5 million tons of CO_2 may potentially be bound due to the recycling.

4. Conclusions

The results show that relatively stable physical, chemical and environmental properties were determined during the extensive sampling periods. Most of the parameters were complying to the requirements in IS 383. For some parameters like specific gravity and fines content, small modifications in the recycling process could easily decrease the fine particle content to the desired level. However, RCA with higher contents of fines have shown excellent properties, in for example, concrete block production. Hence, efforts should be made by all stakeholders to increase the use of recycle materials.

The CO_2-binding potential to cement based products has been shown to be significant. Partly substitution of natural aggregates with recycled concrete aggregates further increase the binding potential since the cement paste and the recycled aggregates will bind CO_2. To utilize this potential fully, concrete recycling into recycled aggregates is decisive due to increased speed of carbonation, as the surface area has increased order of magnitudes after crushing the concrete. Hence, this binding potential can be considered as a significant added value in many circular economy initiatives, as one of the fundamental principles of circular economy is to maintain the material resources as far as possible in a closed loop, i.e. decrease or prevent waste formation.

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INDUSTRIAL WASTES: A SOURCE OF GREEN BUILDING MATERIALS

Dr. Vimal Kumar, Secretary General, Centre for Fly Ash Research & Management (C-FARM), New Delhi and Former Mission Director & Head, Fly Ash Unit, DST, GoI
G. K. Jha, Senior Scientist, C-FARM, New Delhi

Abstract

Large scale urbanization, expansion of city boundaries and re-development of residential as well as commercial centres are signs of development and progress. The resultant impact on the environment and sustainability throws a serious challenge because of excessive exploitation of natural resources for construction materials and indiscriminate dumping of industrial wastes including C&D waste.

The serious magnitude of the problem has lead the Government, researchers and technocrats to device techniques, methodologies and policy frameworks to source and utilize building construction materials from the by-products and co-products of industries that have so far been considered as wastes.

The paper provides an overview of sourcing of green building materials from various industrial wastes.

Key words: green building material, green construction, waste utilization, industrial waste, waste recycling.

Introduction

The demand of building materials for 2021-22 has been reckoned by Building Materials and Technology Promotion Council (BMTPC), Ministry of Housing & Urban Affairs, Government of India as cement 380 million tonne, steel 50 million tonne, bricks 600 billion numbers, aggregate 400 million cubic meters and timber 40 million cubic meters. Data show that there is a considerable amount of shortage of conventional and traditional building materials. On the other hand there are hundreds of million tonne of industrial waste generated & dumped every year, causing serious concerns about environmental pollution and occupation of precious & in short supply land area. The shortage of building materials as well as threat to the environment by the industrial waste materials can be abated by a paradigm shift by accepting the building materials derived from industrial wastes. This move has started. It needs to supported and facilitated for large scale fructification.

Conventional Building Materials

Traditionally materials like clay, sand, stone, gravels, cement, brick, block, tiles, distemper, paint, timber and steel are being used as major building components in construction sector. All these materials have been produced from the existing natural resources and will have intrinsic distinctiveness for damaging the environment due to their continuous exploitation. Nevertheless, during the process of manufacturing various building materials, especially

decomposition of calcium carbonate, lime and cement manufacturing, high concentration of carbon monoxide, oxides of sulphur, oxides of nitrogen and suspended particulate matter are invariably emitted to the atmosphere. Exposure to such toxic gases escaping into the environment does lead to major contamination of air, water, soil, flora, fauna, and aquatic life finally affecting human health and their living conditions. The cost of construction materials is increasing indiscriminately.

Use of industrial wastes and discarded bye products is of significance in developing building material components, providing a solution for the problems being faced in the housing industries. Presently, only about 20% of the solid waste is being used out of the total waste generation in India while developed countries are utilizing 45 to 90% of the waste generated in their country. Details on the availability of solid wastes of various kinds from different sources, their present utilization and recycling potentials for safe, sound and substantial development are summarized in this paper.

Green Building Materials from Wastes

Fly Ash

Fly ash a residue of burning of coal/ lignite in thermal power plants holds potential to be used for building constructions. Over the decades electricity generation in the country has remained coal dependant to the extent of 60-70%. With Indian coal resources of about 300 billion tonne, and limited resources of other forms of energy, the dependence of power sector on coal is destine to continue for foreseeable future. Current annual generation of about 240 million tonne fly ash from about 140 utility and 80 captive coal /lignite based thermal power plants of 1,90,000 MW (approx) capacity is projected to grow to around 1000 million tonne per year by 2031-32 with expanding power sector.

Fly ash is a good material for construction sector with varied range of applications viz. manufacture of cement, part substitution of cement, manufacture of building components like bricks, blocks, tiles, etc., as a geo-technical material for construction of embankment and reclamation of low lying areas, landscaping and plinth filling, etc. as summarized below:

Fly ash bricks, blocks and tiles

Bricks, blocks, tiles including paver blocks and kerb stones are major building construction components required in large quantities. About 150 billion clay bricks are produced annually consuming 375 million tonne top soil, 25 million tonne coal and emitting about 40 million tonne CO_2. Bricks, blocks and kerb stones are manufactured using cement as a binder, which is energy intensive and emits CO_2 during its production process in addition to consumption of limestone and coal that are scarce resources. Fly ash provides sustainable, eco friendly and economical solution.

The initial years fly ash-lime-gypsum technology for manufacture of fly ash bricks with ash content of 15-25% gradated to 40-50% ash content and also use of cement as a binder. Use

of cement or lime and gypsum from natural resources improved the quality and reproducibility of acceptable brick quality as compared to use of sludge lime, phosphogypsum, etc. Further, technological breakthroughs have been made in fly ash brick, block and tile manufacturing to reduce consumption of cement, lime and gypsum by developing the strength through mineralization. This technology has made fly ash bricks more eco-friendly, economical and possible to increase ash content up to about 80%. S&T pursuits continue to improve the existing technologies or to get new breakthrough. Application of geo-polymerization technology to manufacture of fly ash bricks, blocks and tiles that increases the ash content to more than 90% and reduces the curing time to less than 7 days is on the verge of commercialization.

The technological developments in manufacture of fly ash bricks and blocks have also been adapted for manufacture of paver blocks, kerb stones and tiles, etc.

The accelerated durability by tests on fly ash bricks, including clay fly ash bricks wherein clay is substituted by fly ash up to 25-60%, in aggressive environments of acidic, alkali and saline solution; SO_x, NO_x, CO_2, chloride and UV rays and wetting and drying, etc. prove fly ash bricks, manufactured appropriately, to be equal or better than clay bricks. It may be categorically noted that the quality of bricks, blocks, tiles, etc. and for that purpose of any product depends upon the sincerity in use of proper raw materials and production process guidelines.

Fly ash is available at widely dispersed locations and government policies are in place to ensure its hassle free availability. Thus, fly ash is the solution required by the building construction industry to meet the objectives of bulk and unhindered supply of material vis-à-vis saving of top soil and CO_2 emissions.

Fly ash based cellular light weight concrete block

CLC blocks, air water cured or autoclaved with use of fly ash are fast becoming a common building construction material. Use of fly ash makes the blocks lighter (than without fly ash), economical and eco-friendly. The CLC blocks in addition to reducing the dead load of the building and thus economizing on structural cost also provide insulation and thus a saving of about 15% of energy consumption for heating/ cooling of the habitat. Autoclaved CLC blocks have distinctive advantage of consistent quality, however, at an additional cost. The desired density and load bearing capacity of CLC blocks can be achieved with appropriate mix design and selection of foaming technology. Inter connected pores increase water absorption and permeability.

Flowable CLC has also been used to provide 4-6 inch insulation layer on the roof top and also as a low density fill material in inverted beam constructions and at places like bathrooms, etc. This flowable material is also amenable for construction of EWS habitats with in-situ casting of walls & slabs to increase the speed of construction, reduce the cost and make structure insulating as well as safe in seismic conditions.

Cement and Concrete

Fly ash is an alumina-silicate mineral possessing pozzolanic property. The mineralogical analysis of fly ash indicates presence of large quantity of glassy/ amorphous matter. The fineness of fly ash and presence of calcium oxide adds to its reactivity. These properties of fly ash make it a performance enhancer for cement and concrete. Fly ash makes concrete denser and thus reduces the porosity and ingress of water and damaging gases. This improves durability and life of concrete, especially reinforced concrete as the reinforcements are protected against corrosion. BIS has permitted use of fly ash as a part substitution of OPC up to 35% and similar percentage of fly ash in PPC. The R&D and field demonstration have successfully proved OPC substitution by fly ash up to 50-60%. In bulk concreting and concrete pavements substitution of OPC by fly ash up to 66% has been demonstrated through use of roller compacted concrete technology and this is a trend worldwide.

Thus, fly ash provides ample opportunities to make concretes in building construction and allied structures including roads economical, eco-friendly and durable.

Aggregates

Fine and coarse aggregates are becoming scarce day by day. Mining of river sand has adverse effect on charging of acquirers, aquatic bio-system as well as river course. Manufacture of natural coarse aggregate creates nature imbalance and pollution. Environmental issues have made the courts of low to issue a number of directions in this regard.

Manufacture of fly ash based coarse aggregates; sintered as well as air cured, has been developed and demonstrated successfully at lab scale. Suitability of these fly ash aggregates for concretes of various grades as well as for road pavement constructions has been established. Technologies are available for implementation at large scale.

Fine aggregate substitution can be obtained from fly ash through either hydro cyclone or fluidized bed separation technology or through agglomeration of fly ash. Lab scale results are encouraging and need to be scaled up for application at commercial level.

Substitute of wood panels, ply wood and corrugated sheets

Fly ash based composite materials have been developed and prototype facilities established for manufacture of panels for use as door shutters, table tops or other similar applications. Same process technology has been adopted for manufacture of ply wood substitute, partition panels and corrugated roofing sheets. These materials have also been used to manufacture furniture of various types including storage cabinets, almirahs as well as water cooler bodies, bathing tubs, etc.

Fly ash based composite materials are termite proof, water proof, heat and fire resistant, UV radiation resistant and have long durability even in outdoor exposed conditions.

Termite resistant plinth filling material

Plinth fill material is inadvertently required in most of the building constructions. Further, most of the locations are challenged with termite. Termite propagates through soil and walling material and results in heavy damage to wooden furniture and fixtures.

Fly ash, by virtue of its good geo-technical properties has been proved to be suitable material for filling of low lying areas as well as plinth areas. Fly ash is also termite resistant and termite migrates away from fly ash filled plinth and other areas. To avoid filled fly ash to get air borne, the fly ash filled areas need to be covered with built area alternatively with soil or grass, etc.

Phosphogypsum and fluorogypsum

Phosphogypsum and fluorogypsum are the bye products of manufacture of phosphoric acid and hydrofluoric acid generally used for manufacture of fertilizers. Both of these materials are generated in sufficient quantities, about 6 million tonne and 3 million tonne per year respectively and are categorized as waste material because of some adulterants and hence low level of utilization.

Chemically both the materials are rich in $CaSO_4$ $2H_2O$, low in Al_2O_3, SiO2, and Fe_2O3. The presence of phosphate (P_2O_5) and fluorine (F) in both these materials make them hazardous.

Technologies have been developed and are available for detoxification of phosphogypsum as well as fluorogypsum from the ill effects of phosphate and fluorine. The processed phosphogypsum and flourogypsum are good part substitute of natural gypsum for manufacture of cement, gypsum boards, flooring tiles, fly ash bricks and binder materials, etc.

Sludge Lime

It is a bye product of many industries such as acetylene, paper mill, sugar, fertilizer, sodium bromate and soda ash. Annual generation in India is around 6 million tonne. Chemically it is rich in CaO (50%) with moisture content of about 40-45%. The other constituent include SiO_2 (<1%), Fe_2O3 (1%) MgO (0.3%), SO_3 (0.2%) and Na_2O (1%). Thus, this material is a good part substitute of lime stone. However, the deleterious constituents/ contaminants restrict use of these bye products. The sludge lime of fertilizer unit also known as phosphochalk contains P_2O_5 (1.5 – 2%), fluorine (2%) and SO_3 (5-10%). The sludge lime from paper mills, sugar plants and chrome industry (chromium sludge) has high alkali content. In addition chromium sludge has about 10% and carbide sludge also contains 2-3% chromium.

Use of bye product sludge limes in clinker raw mix for cement industry immobilizes the deleterious constituents. However, a part of these contaminates escape through flue gases. Other applications of sludge lime in construction industry include manufacture of bricks, blocks, stabilization of soils and manufacture of masonry cement as well as a binder along with pozzolona.

Slags

Slags are generated in metal refining industries like steel, zinc and lead, etc. Steel industry generates blast furnace slag to the extent of about 30 million tonne a year and BOF slag (steel slag) about 10 million tonne a year. Blast furnace slag is latently hydraulic material and is glassy in nature. Its glass content is about 90-95%. The granulated blast furnace slag after grinding is very reactive and useful for cementitious applications. Pozzolona slag cement can be manufactured with GGBS content ranging up to 70%. GGBS has also been successfully used to develop binding material along with other additives.

BOF slag is non-hydraulic and crystalline in nature. It contains Fe_2O_3 in the range of 20-30%. By virtue of these properties steel slag has applications restricted to fill material for low lying areas, road embankments and for use in raw mix of clinker in cement industry.

Lead and zinc slag production in the country is about one million tonne a year. These have found use in pozzolona slag cement up to 35-45%, clinker raw mix up to 5-10% and for land fill applications.

Jarosite, another by-product/ waste of zinc industry has been successfully used as a retardant in cement concrete industry.

Red mud

About 5 million tonne red mud is generated in the country annually by aluminum industry. Chemically red mud contains 15-20% Al_2O_3, 20-30% Fe_2O_3, 12-16% CaO, 10-13 TiO_3 and 3-5% alkalies. Technologies have been developed to use red mud for manufacture of bricks, blocks and tiles along with other additives like fly ash, slag, phosphogypsum, sludge lime, etc. Red mud is also useful as a material for filling of low lying areas, construction of embankments and use in clinker raw mix in cement industry.

Mining waste

Mining operations are the primary activity in any industrial process and major sources of pollutants include overburden and tailings. In coal mining operations about 50% of the material is separated as colliery shale or hard rock. This spoil is used as filler in haul roads and is also used for producing fine aggregate. Studies on potential use of different mining tailings in bricks have revealed that copper tailing (60%) can be effectively used to achieving strength of 190 kg/cm2 in brick manufacturing cured under firing.

The beneficial use of overburden is production of sand, which is scarce everywhere in the country. The produced artificial sand can be a good substitute of river sand. The sand can be manufactured to proper gradation. When fine particles are in proper proportion, the sand will have fewer voids. Plants for manufacture of sand from coal mine overburden are already in operation at two of the Singareni Colliery mines in the State of Telangana. The sand produced at these two plants is being successfully used for mine stowing in lieu of river sand. It's working out to be much economical. There are plans to set up more such plants and also to

segregated, the balance waste can be processed to produce usable building materials such as coarse aggregates, fine aggregates, bricks & blocks, pavers, tiles, pre cast elements and metal, glass, plastics, etc. and can be sent to smelters/ re-processors.

The Government and civic bodies are now very alert and active on the front of C&D waste management. C&D Waste Management Rules, 2016 already exists. Four plants, summarized below are operational for recycling of C&D waste.

Burari, New Delhi

India's first plant for recycling of C&D waste has been commissioned during 2009 at 10 acre site at Burari, Jahangirpuri in North Delhi by Infrastructure Leasing & Financial Services (IL&FS) under an agreement with North Delhi Municipal Corporation. The plant was initially set up to process 500 tpd (tonnes per day) C&D waste. Processing of 1200 tpd was achieved during 2014 and Delhi Pollution Control Committee has awarded the permission to expand the capacity to 2000 tpd.

The products being manufactured at this facility are sand, coarse aggregate, Ready Mixed Concrete (RMC), bricks, blocks, curb stones, pavement blocks, hollow bricks etc.

Shastri Park, New Delhi

Second plant in Delhi for recycling of C&D waste has been commissioned at Shastri Park in East Delhi at 2.5 acre site to process 500 tpd C&D waste. The plant has been built in partnership with IL & FS, which would run it for 15 years before transferring it to EDMC.

Ahmadabad, Gujarat

Ahmadabad Enviro Projects Pvt. Ltd. (AEPL) has commenced a 100 tonne per hour capacity plant for recycling of C&D waste in phase wise manner from December, 2013. The plant is fully operational since June, 2014 and is located at Pirana, Ahmedabad.

Vikhroli, Mumbai

Godrej Construction have commissioned a C&D waste processing plant at Vikhroli during early 2017 to manufacture 36000 blocks and 54000 pavers per day by using the produce of processed C&D waste.

Earlier Experiences:

Kharghar, Mumbai

Youth for Unity and Voluntary Action (YUVA), a non profit, non Govt. organization recycled 1500 tonne of C&D waste during 2002-06 at CIDCO-YUVA Building Centre (CYBC), Kharghar. CYBC is a joint venture of City and Industrial Development Corporation of Maharashra Ltd. (CIDCO) and YUVA. The C&D recycling demonstration plant manufactured building materials like bricks, blocks, paving blocks, concrete, sand substitute and coarse

aggregates. The laboratory test results proved the quality of end products. The products were used by private builders. However, Govt. projects could not accept the products for want of standards, specifications and departmental approvals.

East Kidwai Nagar, New Delhi

M/S Enzyme India Pvt. Ltd. has set up C&D waste recycling plant in 2014 on PPP model with 100% buyback by NBCC with a capacity of 150 tpd at the project site of "Re-development of East Kidwai Nagar, New Delhi". The construction project involved demolition of 2444 existing houses and allied structures, construction of 4747 houses covering 60 lakh sq. ft. area and commercial area of 12 lakh sq. ft. on a plot area of 86 acres with 12.7 lakh sq. ft. green area.

The recycled produce of C&D waste like fine aggregate, course aggregate and manufactured soil are being used directly for construction as a fill material and also in manufacture of downstream products like RMC, bricks, blocks, tiles, pavers, etc. These products are generally of good quality and are available at an economical price.

The bricks, blocks, tiles & other products manufactured by use of recycled C&D waste and also the fine and coarse aggregate produce are of good quality and are available at competitive prices.

Quality of recycled C&D waste products

The building construction products manufactured at Burari, New Delhi; Pirana, Ahmedabad and YUVA-CIDCO Centre, Mumbai have been taken up by various R&D and user agency's laboratory tests for quality evaluation. The building construction components manufactured at the C&D recycling plants such as bricks, blocks, paving blocks and kerb stones, etc. have satisfactorily met the requirements of 75-150 kg/cm2 compressive strength and water absorption below 20 per cent.

Use of fine aggregates and coarse aggregates manufactured by recycling of C&D waste has also been validated scientifically for part replacement of natural aggregates up to 50%. Illustrative results are given in Table-1 and 2 below:

Table-1: Results for replacement of natural fine aggregate by recycled fine aggregate

Sr. No.	Replacement %	Compressive Strength as per IS-516 (MPa)			
		07 days	28 days	56 days	90 days
1.	0	25.93	38.98	46.14	52.00
2.	25	31.84	42.90	51.16	58.80
3.	50	34..27	46.14	53.87	61.82
4.	75	30.55	39.87	47.15	53.62
5.	100	24.77	37.97	44.42	51.30

Source: Nikhil Kaushik, V.V. Arora and P.N. Ojha, National Council for Cement and Building Materials, India

Table-2: Results for replacement of natural coarse aggregate with recycled coarse aggregate

Sr. No.	Replacement %	Compressive Strength as per IS - 516 (MPa)			
		07 days	28 days	56 days	90 days
1.	0	25.93	38.98	46.14	52.00
2.	25	26.28	44.48	51.59	55.29
3.	50	25.36	38.56	45.05	51.31
4.	75	22.80	36.42	41.54	45.50
5.	100	21.60	32.29	37.18	41.62

Source: Nikhil Kaushik, V.V. Arora and P.N. Ojha, National Council for Cement and Building Materials, India

Good amount of data has been generated on quality aspect of the recycled building construction products manufactured from C&D waste. Accordingly, Bureau of Indian Standards (BIS) has amended IS:383, the specification of coarse and fine aggregates in January, 2016, permitting part substitute of aggregates from natural source by aggregates manufactured from recycled debris, as given below in Table-3.

Table-3: Extent of Utilization Permitted by IS: 383(2016)

Sr. No.	Type of Aggregate	Maximum Utilization		
		Plain Concrete (%)	Reinforced Concrete (%)	Lean Concrete (Less than M-15 Grade) (%)
(i)	Coarse aggregate			
(a)	Recycled concrete aggregate (RCA)	25	20 (Only up to M-25 Grade)	100
(b)	Recycled aggregate (RA)	Nil	Nil	100
(ii)	Fine aggregate			
(a)	Recycled concrete aggregate (RCA) (SeeNote 1)	25	20 (Only up to M-25 Grade)	100

To sum up, re-use and recycling of C&D waste is no more a concept. It is a reality. It is being practiced worldwide. A few plants have started functioning in India. Technologies are available. Mindset has started changing. The formalization through legislative means supported by Standards, & Specifications of end products and transparent guideline by the Civic bodies can boost use of C&D waste, which would reduce pressure on natural resources and the environment.

Conclusions

The building construction sector has a major challenge to meet the growing requirement of housing including the backlog and projected requirement of EWS beneficiaries under "Housing for All Mission". The scarce building construction materials would put additional challenges. The environmental concerns further restrict the exploitation of natural resources. Under such a scenario it is imperative to promote and use green building materials produced from industrial waste materials. Use of co-products/ bye products of various industries, so far discarded as waste, appear to be the possible win-win option from environment protection point of view also.

RECYCLIC POTENTIAL OF CONSTRUCTION & DEMOLITION (C&D) WASTE

Shishir Bansal, Chief Engineer, DTTDC, New Delhi

Abstract

With the fast development of society on all the fronts, lots of construction activities are seen everywhere. Simultaneously, the demolition of existing outlived structures is going hand in hand. Both the activities generate lot of waste and its disposal is a challenging job for the engineers. Thus, the Construction & Demolition (C&D) waste is a major waste stream, the quantum of which is increasing as a result of increasing construction, maintenance, retrofitting and demolition activities in India. Even though there is high potential for large scale reusing as well as recycling of this waste material, production of recycled aggregates with properties comparable to natural aggregate, recovered from C&D waste is currently at very low level in India. There is a huge demand for natural aggregates in the construction sector with a significant gap in its demand and supply, which can certainly be reduced to an extent by recycling construction and demolition waste. Since the concept of appropriate management of C&D waste is new in this country, information and education is necessary for public support as well as to change the mindset and attitude of all stake holders.

Introduction

With the development of society on all the fronts, large construction activities are seen everywhere, rather increasing exponentially. Also the demolition of existing structures which have outlived their service life is going on simultaneously. Structures are also demolished due to ongoing trend of reconstruction of even healthy structures just for creating more space in order to meet the present requirement. When the structures were created long time back, the population was less and hence the need of dwelling units was also not much. Therefore lavish sized structures were created with more in area, but lesser in numbers. Now, need is to create more units in that much area and therefore the trend is for reconstructing the house with vertical expansion and creating more dwelling units. All such activities are generating huge amount Construction and Demolition waste. Disposal of such debris in a safe environment is a big challenge for the builders, developers and owners.

On one hand the disposal of debris is a challenge, on the other hand there is an acute shortage of natural aggregates for construction of buildings. Reduction of this demand in a small way is possible with the reusing or recycling of construction and demolition waste generated aggregates. Hence, the construction sector must accept the use of C&D waste recycled aggregates wherever feasible. This will lead to a saving in natural materials and consequent reduction in waste disposal.

Promotion of C&D Waste Management

Since the concept of C&D waste management is new, it is essentially required to spread the

education and information in order to gain the public support. The present mindset of public and their attitude towards the waste generated from construction and demolition sites is required to be changed which is possible only with the education in this field. It is required to sensitize not only the Engineers, but all stakeholders including regulatory authorities in construction industry. One must understand the reuse potential of C&D waste, technical aspects in the use of recycled concrete aggregates, best practices in implementation and enforcement for achieving the aim with an ultimate motive of Environmental sustainability.

Recycling cost is influenced by transportation distance and amount of waste concrete to be recycled. CO_2 emission is influenced by transportation distance. It is important to minimize C&D waste generation and maximize reuse/recycling as the construction industry is consumer of tremendous amount of natural resources and energy as well as emitter of GHGs. Establishment of effective strategies and enactment of laws and regulations is essential to achieve this. In addition, provision for some incentives to users of the recycled products deems to be necessary to promote the use. It is essential to assess the life-cycle as it provides quantitative tool to assess environmental impact of C&D waste reuse/recycling.

Reusing and Recycling of C&D Waste

Reusing C&D waste

Reusing of C&D waste is different from recycling. It does not require any further processing to convert into a useful product. The items which are usable directly are screened out from the debris and put into the intended use without further processing or further energy input for conversion into the useful product. Thus reusing a waste item is a better service to the environment and the environment is saved from impacts due to recycling activities. For example, full bricks can be screened out of the demolition debris and used as it for building a partition wall. Otherwise same would have been converted into smaller pieces for using it as an aggregate or brick bats for plinth protection etc.

Since reusing of C&D waste is always more advantageous, it is essential to have more and more reusable materials in debris. This is possible, if sufficient precautions are taken while a building is demolished. There should be an effective deconstruction plan instead of just converting the standing structure into debris within minutes. Useful products like doors and windows, bricks, reinforcement from RCC components, structural steel can be taken out with little extra efforts and put into reuse without much processing.

Recycling of C&D waste

Once the waste generated from C&D waste has been segregated and reusable items are taken out, the left over waste is now available for recycling. Recycling of this waste into useful products to extend the service to environment is a challenge. Worldwide in developed countries enough activity of recycling of such wastes is taking place but at present, in India, the recycling of C&D waste has started now only and has to go a long way in this direction. In New Delhi, 1st pilot plant started functioning at Burari in North Delhi, but it requires many

such plants to fulfill the needs in Delhi looking at the recycling potential of waste generated daily in New Delhi. About 5000 MT of recyclable waste is believed to be generated daily in New Delhi.

Reuse and Recycling Potential of Different C&D Waste Products

The amount of C&D wastes in India was estimated to be 10 – 12 million tonnes annually in 2000 which has now increased manifold and the proportion of concrete estimated as 23 to 35% of total waste. Considering 30% percent of C&D wastes of 12 million tonnes as concrete, and 50% of the concrete as coarse aggregate, the total available recycled concrete aggregate (RCA) in India is of the order of 1.8 million tonnes annually.

Concrete

Concrete is primarily a composition of cement, coarse aggregates, fine aggregates and water, further processed by addition of industrial products/ by products for enhancing the properties. Engineers are mainly dependent on nature for obtaining the coarse and fine aggregates as well as water for the chemical reaction with cement. Scarcity is there for all these naturally occurring materials and need is there to explore alternative sources. Even for the water with required properties, shift is towards the use of waste water after due treatment. One of the alternative sources of coarse aggregates is recycled concrete aggregates (RCA) which are obtained from the processed C&D waste. During and after the demolition of any concrete structure, the demolished concrete waste is taken to a recycling plant and there crushed into the required sizes which is called the Recycled Concrete Aggregate (RCA).



Fig 1: Recycled Coarse Aggregates (RCA) after processing

Sometimes, good sized precast element are also obtained during the demolition, which have a potential of being reused or otherwise, these are also crushed and converted into the recycled aggregates. Limitation is there in use of these recycled aggregates. The production of concrete in India is governed by BIS and IRC codes i.e. IS: 456, IS: 1343 or IRC: 112. All these codes allow the use of naturally occurring aggregates only conforming to IS: 383. To

overcome these limitations, it is necessary to make a special provision of use of Recycled aggregates in combination with naturally occurring aggregates. Thus, use of recycled aggregates can be there with different quantum of their share by suitable replacing the component of naturally occurring aggregates. It will help out not only in meeting the situation where there is acute shortage of natural resources, but also a step towards the sustainability.

In our bye laws or environmental law, framing of rules will be required for the use of C&D waste. C&D waste management rules 2016 have already been framed by the Ministry of Environment, Forest & Climate Change. If we look at other countries like Norway, Japan and Korea, a major junk of demolition waste is recycled and is being used as a partial replacement of natural aggregates and concrete thus produced is being widely used in these countries.

Bricks/Blocks

Bricks are important building material in the construction of residential as well as non –residential buildings in this country. It is also a significant component of the total C&D waste on new residential construction sites. Its demand figures are next to concrete as a building material. Bricks are largely treated as waste when broken or damaged from the brick production line or from construction site due to poor internal handling and excessive cutting. Brick is a maintenance-free component of the structure which is durable during the complete service life of the building. The high durability property of the brick makes it environmental friendly in the sense that after the demolition of the structure, it can be reused repeatedly and the left over volume which is non-reusable can be recycled for other beneficial purposes. Generally, a building is not required to be demolished due to deterioration in the engineering properties of the bricks. It is for different reason or different needs other reasons that the building has outlived its useful/economical service life and required to be replaced with new structure. During the demolition process itself, bricks obtained are stacked for next use in its original form after the removal of mortar which is chiseled out and make the brick ready for reuse or recycling, if not reusable.



Fig 2: Demolished Bricks

Bricks, after the removal of the stuck up mortar remain reusable for restoration or for new homes and projects. Recovered bricks can be used like a fresh lot of bricks without any further processing. These can also be laid on as brick pavers or for landscaping or any other artistic creations. Brick paved streets are aesthetically pleasing and rain water also percolates through the pavement. Also, a brick surface is cooler in hot months. These street advantages make bricks a good choice in driveways. Bricks on edge are also sometimes used as economical pavement solutions in smaller compounds.

Bricks which cannot be reused directly can be disintegrated into smaller sized aggregates or brick chips to be used as construction materials. These recycled bricks products are strong and durable enough in comparison to the original. Bricks from demolition sites can be recycled as road base and construction fill and also as light weight concrete.

Construction debris consisting of bricks can be recycled into brick aggregate through screening, crushing, re-screening and blending, which can then be used as pavement base material by proper mix proportions with cement and fly ash. Brick waste which are not suitable for recycling into the pavement base materials can be used in construction/land fill. Concrete prepared from crushed brick aggregates has good engineering and also better thermal properties but has greater shrinkage than ordinary concrete. Sometimes, during the manufacturing of bricks, due inadequate burning, or sometimes due to over burning, whole lot is turned into the production waste. Though this waste is different from construction and demolition waste, but it can also be recycled like C&D waste and can be suitable used for production of precast elements like paver blocks, kerb stones, interlocking tiles by mixing with cement and using as a concrete mix.

Tiles

Generally, it is difficult to extract tiles from the walls in proper shape and size in order to find them suitable for reuse. It also depends upon the type of the tiles, their life span and the existing conditions. Seepage behind the walls due to leaking water pipes makes them totally non usable. Still tiles extracted from walls, even if these are broken pieces, provide an excellent opportunity to the artists /designers for making murals or other decorative master pieces. Broken tiles can also be used aggregate after crushing.

If the tiles can be extracted or removed from the wall in good shape and size, these are reused for the same purpose after the removal stuck up mortar and then glued with suitable adhesives available in market today. Creative items like artifacts, table tops, special effects in drive ways, pedestrian subways etc. can be smartly created by reusing for a wide variety of projects. Nek Chand's Rock Garden in Chandigarh, which is internationally renowned, is a perfect example of such reuses.

The broken tiles can be further crushed into smaller sizes and can be a partial replacement of gravel and crushed stone in making concrete.

Timber

The waste timber is not only produced from the demolition of the building, but also from construction of wooden building wherein lot of timber waste is generated. Each source has its own system of recycling and reuse of recovered timber from the demolition of a building or the construction of a building. Whenever a building is decided to be dismantled, timber products like doors and windows are the items which are removed as first step and that too in original form. Timber products have a quality of a long service life which is much longer than the life of the building itself. Hence, in general such products unless eaten by the termites or damaged due to fire do not lose the Engineering properties for a long time and can be used multiple times and thus an environmentally friendly product.

The waste timber which has not been recovered in its original form or non-usable in same shape and size can be recycled into new particleboard, medium density fibre boards, animal bedding or used to make renewable energy. Timber used for recycling has to be free from any other demolition products like concrete, mortar, aggregates, sand, bricks, plastic, metals, tiles etc. Wood chips are produced from good quality wooden waste such as large size lumbers. Some of the particleboard producing companies and the pulp and paper producing companies are still using the recycled chip for their products. Chipped or shredded wood is also used as a sewage sludge bulking medium and other products lime pallets.

Metals

Amongst the metals, steel and aluminium are the two major products obtained as waste during the construction as well during the demolition of a building. Structural steel obtained during the demolition of a steel structure or left over steel during the construction can be reused directly without much processing. The members can be resized as op the requirement and can be reused directly. Aluminium scrap can be put into reuse by the solid bonding process. If a care is taken in initial stages i.e. during designing with a valid deconstruction plan, then the reusable scrape can be increased to a much greater extent like house hold appliances, without taking the routing the scrap through a foundry. Reusing a steel beam its existing form is better than re-melting it and rolling a new steel beam, i.e. the energy used to re-melt the beam is saved.

Steel waste occurs during the construction and refurbishment of buildings and when they are ultimately demolished and the material becomes available for recycling. Waste from the manufacture of steel construction products can be easily collected and segregated for recycling. Steel generates almost nil wastage on the construction site. Waste steel which is reusable is equally good in durability criteria and the quality is also well maintained while making products like fire hydrants, steel furniture and also ecologically sustainable.

As far as aluminium is concerned, it is recyclable multiple times and is always on demand with the need to preserve the environment. Our raw materials vary considerably based on whether we are using primary or recycled aluminum. We must take into account the different sustainability impacts of sourcing primary aluminum from the mined substance bauxite, or recycled aluminum from either pre- or post-consumer sources. Recycling scrap aluminium

requires very less energy in comparison to the energy requirement of new aluminium. Because aluminum is infinitely recyclable, it can be reused in applications vastly different from its previous purpose, and it can also be recast into its original form. These properties make aluminum an ideal material for use in premium applications, even after being recycled many times.

Plastic

Scrap or waste plastic recovered from demolition or construction site is reprocessed and transformed into the entirely different useful products. Typically a plastic is not recycled into the same type of plastic, and products made from recycled plastics are often not recyclable. When compared to other materials like glass and metals, plastic polymers require greater processing to be recycled. The most-often recycled plastic HDPE (high-density polyethylene) is reduced to plastic lumber, tables, roadside curbs, benches, truck cargo liners, stationery (e.g. rulers) and other durable plastic products and is usually in demand. Other application of recycled plastic is in the preparation of a road surface that includes recycled plastic: aggregate, bitumen (asphalt) with plastic that has been shredded and melted at a temperature below 220° C (428 °F) to avoid pollution. Such road surfaces are very durable and monsoon rain resistant.

Excavated Material

Excavated materials are many times contaminated and require special handling and disposal. It may include hazardous as well as non-hazardous material. Excavated contaminated material that can be re-used will be decontaminated prior to re-use, or if not suitable for re-use will be transported to appropriate treatment facilities or approved landfill sites. If the excavated materials are found suitable for re-use as road fill base material, cut and fill quantities will be balanced to avoid any off-site disposal. Excavated soils will be retained on site for re-use as backfill while hard rubble will be crushed and re-used on site. Unsuitable material for engineering fill can be used for landscaping.

Asbestos

Generally, asbestos is disposed as hazardous waste in landfill sites. The demolition of buildings containing large amounts of asbestos based materials have to be deconstructed piece by piece or the asbestos has to be removed carefully before the structure can be demolished. Asbestos can be recycled by transforming it into harmless silicate glass, porcelain stoneware tiles, porous single-fired wall tiles, and ceramic bricks. Current removal procedures require a completely sealed area, using vacuum to prevent any particles from escaping. Workers must wear heavy protective equipment. It is important to ensure that asbestos waste has been wetted and sealed in heavy-duty plastic prior to transportation to an approved landfill.

Asphalt Concrete

Demolished asphalt concrete can be utilized as aggregates for asphalt concrete. Also, the demolished asphalt concretes can be used for land fill.

Guidelines to be Followed in Recycling of Demolition Waste

The agencies responsible for generation of wastes should segregate the generated wastes having potential for reuse/recycling. The Engineer-in-charge will select structure's type and materials that are suitable for reuse/recycling, use recycled aggregates, and ensure proper treatment of wastes generated from such development. The waste generation from construction should not only be minimized, but should also minimize the hazardous effect from the generated wastes.

Agencies (or sub-contractors):

Various agencies or sub-contractors to be involved are to be linked up with the steps in this process of C&D waste reuse and recycling. Some of such steps can be listed as waste collection and transportation, intermediate waste treatment i.e. receiving the waste, its segregation and further suitable comprehensive treatment before putting into the use. The cost for C&D waste separation, storage, treatment, reuse/recycling should be included in the Estimated Cost by the Engineer-in-charge while according Technical sanction and preparing tender documents.

There are important duties to be either assigned or as a dutiful contractor, he may be establishing himself like, he should establish step-by-step demolition plan. Contractor may establish treatment facility at site only. He should report expected amount of wastes by type and treatment plan at the beginning of construction. There should be effective utilization of recycled aggregates and Safe treatment of hazardous waste like asbestos.

Contractor may be asked to submit Environmental Management Plan during Construction.

C&D waste information on web

All C&D waste information by contractor and by those involved in its treatment waste treatment companies are to be put on public domain in order to improve the rate of use of demolished concrete for e.g. application of recycled aggregates. Further to have a stronger data base of C&D waste, users reusing the C&D waste or recycled waste after treatment and processing can contribute a lot. This will help in substantial reduction on the amount of wastes and promotion of recycling or reusing the C&D waste.

Demolition Plan

It is required to adopt a systematic approach while demolishing a building in order to minimize the waste and its best use. A recommended approach can be to follow a sequence of segregation of household waste as first step followed by mechanical and electrical equipment, exterior and interior finishing materials, roof finishing and water-proofing

materials, then structure as a last resort. Demolished C&D wastes need to be brought out of field immediately or temporarily stored in a designated area for the C&D wastes.

C&D Waste Recycling Facility in New Delhi

One pilot plant set up IL&FS Environmental Infrastructure and Facilities Ltd. for North Delhi Municipal Corporation is functioning at Burari, Delhi. After the collection of C&D waste, the material is routed through the Weighbridge to the processing site, wherein silt and loose soil is separated and used for land filling. Processed C&D waste is used for sub base of roads and for making bricks, paver blocks & kerb stones. The capacity of the plant is 500 T per day.



Fig 3: C&D Waste Management Plant setup by IL&FS at Burari

There are designated collection points where containers and skips are placed as a first storage point of C&D waste where the waste is brought in by private persons. As an additional measure, sufficient vehicles are also in operation to collect the waste from various locations of the city as per the services required from pick up points.



Fig 4: Containers and skips



Fig 5: Mobile crusher



Fig 6: C&D Waste Utilisation : Test Road



Fig 7: C&D Products : Pavement Blocks and kerb stones

Conclusions

Concrete has become a high tech material and its production is used by economists as a measure of a country's economic strength. Aggregates from natural sources are getting scarce over the years. The situation has forced us to explore aggregate from alternate sources. It is important to minimize C&D waste generation and maximize reuse/recycling as the construction industry is consumer of tremendous amount of natural resources.

Research & Development is to be promoted by Government. There is lack of public awareness and it is required to spread the Information, Education and Communication in order to Garner Public Support and change the attitude of Public and Staff. Data and results should to be posted in Public Domain.

CONSTRUCTION & DEMOLITION WASTE – A RESOURCE OF FUTURE

P K Singh, Addl DG (WR-II), Bhopal
Dr K M Soni, Addl DG (TD) CPWD, New Delhi

Construction and Demolition (C&D) waste at present is being considered as a waste but in future, it is going to be resource material which will find place in many civil engineering applications in building construction ranging from filling to plaster, masonry to cement concrete and bricks to tiles and in road construction from sub base to WBM. Therefore, research in quality assurance, applications and awareness among stakeholders is essential at this stage as large demolition of old structures which have outlived their life will start soon all over the country.

Simultaneously, academic institutions, engineering organizations and organizations involved in making codes and standards are to come out with testing standards, guidelines for the use and codes and specifications so that everyone can use products of C&D waste with confidence.

Private entrepreneurs and businessmen have to install C&D waste recycling plants not only due to profit making concept but also as a part of their corporate social responsibility. Real estate developers having large financial turnover and land with them should also come forward to install such recycling plants in the country in addition to the Urban Local Bodies (ULBs) who are already in the process of doing so.

Ministry of Environment, Forests and Climate Change (MoEF&CC), Government of India has already notified "Construction and Demolition Waste Management Rules, 2016" for management of C&D waste vide GSR 317 (E) dated 29th March 2016 in which C&D wastes generated by an individual, organization or authority are covered. In the Rules, various government organizations have also been made responsible for promotion and use of C&D waste also as a resource material. Based on these Rules, Central Pollution Control Board (CPCB), Government of India has also brought out guidelines in March 2017 for curtailment of pollution due to C&D waste generation, handling and processing. Thus right type of C&D waste recycling plants would be required producing no or minimum pollution.

C&D Waste Management

C&D waste means the waste comprising of building materials, debris and rubble resulting from construction, re-modelling/renovation, repair and demolition of any civil engineering structure. It is estimated that 30-50 kg per sqm of C&D waste comes from new construction and repair while 300-500 kg per sqm from demolition hence most of C&D waste comes due to redevelopment activities. Soil, sand and gravel constitute approx 35% and, brick, masonry & concrete constitute approx 55% of C&D waste in India.

Segregation is first step in the process as mixing of C&D waste with Municipal Solid Waste, it cannot be put up to use. Spreading of C&D waste along road sides or in Municipal bins as is

the common practice, leads to debris lying on the roads, footpaths and streets and the same is not taken away by the sweepers who carry out manual sweeping. Such waste flies due to wind and also due to traffic movement, leading to unhygienic conditions and air pollution. Thus, segregation right at the place where it is generated is essential. This may be required at individual level, worker level, contractor level and at municipal level apart from the "Bulk generators" defined in C&D Waste Management Rules.

For reuse, the country has to switch over to "Deconstruction techniques" in place of "Demolition". Deconstruction is defined as planned way of taking out reusable materials from the structure before demolition. In fact, deconstruction uses scientific dismantling where reusable materials are taken out and reused. In redevelopment activities, government and ULBs may in future impose condition for some percentage of materials to be reused in new construction for minimization of C&D waste. This can also be done by the architects and consultants either by direct use or even with some modification in various architectural, non structural and even structural applications.

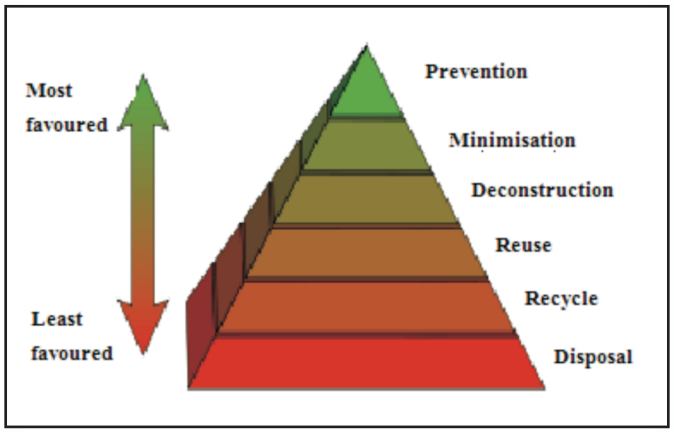


Fig. 1: C&D waste management pyramid

C&D waste management hierarchy pyramid is shown in Fig.1.Though hundred percent prevention is not feasible, governments and local bodies have to prevent generation of C&D waste by stopping construction of non engineered and unsafe structures which have short life requiring frequent repair and renovation and demolition before its prescribed life. Engineers, contractors and builders have to adopt quality concept in construction and repair to avoid generation of C&D waste. Engineers and contractors should use small instruments and equipment for drilling and chase cutting to avoid braking of walls, masonry work and concrete for example, drilling should only be resorted for passing pipes, chase cutting by cutters should be done or slits left before construction, trenchless technology adopted over road cutting. Such measures not only save time, lead to quality work but also generate less C&D waste, avoid air pollution and ultimately are economical. What is required is the change of mindset of contractors and engineers in adopting such measures in reduction of C&D waste generation.

Recycling of some waste will be essential even after reuse of some materials. Government

has already issued guidelines for the implementation required in all the cities for re-cycling of C&D waste. Recycling plants may be stationary plants, semi stationary or portable. Wet plants do not generate air pollution hence in cities or towns where air pollution is already a problem, such plants will be required. Bulk generators can themselves install plants however for small contractors and individuals, ULBs will have to provide some space or collect C&D waste even on payment basis so that it goes at right place i.e. at recycling plants and is not dumped at unwanted places. On site recycling for large reconstruction projects will have to be encouraged.

The country is witnessing large infrastructure development in all the sectors. Prime Minister has already given a call for "Housing for All by 2022" hence large amount of C&D waste is going to be generated by way of new construction and demolition of existing structures. Also, per capita income of common person is increasing hence renovation and refurbishing will continue with enhanced standards of living. Thus, there is a large scope of recycling plants in the country.

Recycled materials include sand, aggregates, and soil/mud. Aggregates may be from bricks or stones and concrete. Recycled sand and aggregate can be used to manufacture various products like tiles, paver blocks, kerb stones and concrete blocks. As availability of natural sand all over the country has become scarce due to ban on sand mining in many places and environmental concerns, sooner or later, recycled sand will be used in mortar and concrete.

Two types of aggregates are obtained from recycling plants- Recycled Concrete (RC) aggregates and Recycled Aggregates (RA). Recycled concrete aggregates are obtained from concrete hence they are hard having higher strength than RA. Such aggregates can be termed as of one type i.e. only of natural stones. These are used in manufacturing concrete products as mentioned earlier hence plant owners have no difficulty in using them and prefer to sell the products rather than the material. When the aggregates are of mixed type, they are termed as Recycled Aggregates (RA) since they contains soft aggregates from bricks and their strength is less hence are used in applications where large loading is not expected. Products of such aggregates are not in demand at present hence plant owners are worried about use of such aggregates. At present these are used in road applications, particularly in filling, in future it is likely that such aggregates are used in non structural applications of the buildings, manufacturing of roofing tiles, decorative tiles, pots, and similar products.



Fig. 2: Products from plant of ILFS Environmental Infrastructure & Services Ltd

In the last mud or soil is available. Since this mud also has fine grinded materials, it appears to be a better soil than the clay used in manufacturing bricks though a research can be done on the same. Therefore, bricks can be manufactured from this and even it can be used in horticultural applications. Further, it has scope of a better quality material if mixed with some additives improving properties and getting converted into very useful materials for various applications. Even today, it is not a problem for the plant owners.

Thus almost all the materials obtained from the plants are usable and nothing is left for the duping yards saving costly land, and the environment.

In future, there will be different types of materials to be recycled like ceramics, glass, plastics and products made from such materials. Therefore, recycling facilities and use of products from such products is to be looked into in advance.

Initiatives by Government Organizations

Though efforts have been made by the governments in this direction but "The C&D waste Management Rules, 2016" will have large impact on the implementation. Engineering and research institutions must include C&D waste in their topics as this is for the benefit of the society and simple research may prove highly beneficial. The Bureau of Indian Standards (BIS) and Indian Roads Congress have to prepare codes for the application of C&D waste recycled products as early as possible without any subjectivity so that field engineers, architects and builders use them with confidence.

CPWD has also included such products in DSR. At present the strength reported of the blocks is M10 which are manufactured with simple process of concreting. Like AAC blocks have came after the research by adding flyash, with additives through autoclaved process, research is required in case of Recycled aggregates (RA) and Recycled concrete aggregates (RC) so that C&D blocks are used for all the applications without restrictions and with confidence. RAs have large scope of use in sub bases of roads and highways while RCs in cement concrete applications. Since, recycled aggregates have cement paste adhered to aggregates, research has to be made whether small quantity of cement can be added to equivalent strength as that with natural aggregates.

Local bodies and state governments are also serious in implementation of policies of C&D management rules. They are finding out all the possibilities for encouragement in use of C&D waste products by providing incentives to private and public plants, mandatory use of recycled products, concessions for a bidder of the Rules and guidelines, and penal actions for defaulters.

Concluding Remarks

C&D waste needs proper management plan where all the stakeholders are to make their contribution as their social responsibility though large responsibility has been entrusted to bulk generators in "Construction and Demolition Waste Management Rules, 2016". Also, to

make "Swachh Bharat Mission" successful and enhance the image of country in hygiene, recycling of C&D waste and use of recycled products have to be incorporated in engineering practices. Governments, ULBs, engineering departments, private entrepreneurs, contractors, builders, research organizations and institutions, NGOS and individuals are to change their mindset about C&D waste as a waste material and but to consider it as a "Resource" material.

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BRIEF C&D WASTE MANAGEMENT RULES 2016

Dr. Amardeep Raju Scientist 'D', MoEF&CC, New Delhi

Ministry of Environment, Forest and Climate Change, Government of India has notified C&D waste management rules 2016 which are a major step towards segregation, re-use and recycle C&D waste in the country. The duties and responsibilities of various authorities, waste generators and individuals have also been defined in the Rules. These are given below in brief.

Government of India
Ministry of Environment, Forest and Climate Change
(HSM Division)

Construction and Demolition (C&D) Waste Management Rules, 2016

1.0 Background

1.1 The Ministry of Environment, Forest and Climate Change notified the Construction and Demolition (C&D) Waste Management Rules, 2016 for the regulation of waste generated from construction, re-modeling, repair and demolition of any civil structure and make a way forward to reuse, recycle such waste in gainful manner.

2.0 Need for the Regulation

2.1 India's construction sector is forecast to grow at 7-8 per cent each year over the next decade. It is estimated waste generation during construction is 40 to 60 kg/sqm. Similarly, waste generation during renovation / repair work is estimated to be 40 to 50 kg/sqm. The highest contribution to waste generation is due to demolition of buildings. Demolition of Pucca and Semi-Pucca buildings, on an average generates 500 & 300 kg/ sqm. of waste respectively. The C&D waste has potential for reuse in many applications. As per the information, the reuse of this waste is negligible in the country and the waste is being dumped indiscriminately in low-lying areas, river beds etc. and causing problems.

2.2 C&D debris, in general, is non-hazardous, uncontaminated material resulting from construction, remodelling, repair, or demolition of utilities, structures, and roads. However, its indiscriminate dumping is resulting in to filling up of landfills, destroying the property of top soil. In addition, illegal dumping of C&D debris can result in future health risks, decreased property values, and cleanup costs. It is observed from a source apportionment study under taken by Central Pollution Control Board that the construction activities and construction or demolition waste contribute to dust particles in ambient air and it is one of the major source of particulate matter especially in cities.

2.3 In order to address the issue of management of C&D waste, the Ministry has notified C&D Waste Management Rules, 2016. These rules envisage proper management and reduction of the amount of C&D waste going to environment and also conserve resources by the way of

its recycling and preserve the environment.

3.0 Salient features of C&D Waste Management Rules, 2016

3.1 Application: The rules shall apply to everyone who generates C&D waste, individual or organization or authority.

3.2 Duties of waste Generators:

Every waste generator shall be responsible for collection, segregation of concrete, soil and others and storage of C&D waste generated separately, deposit at collection centre so made by the local body or handover it to the authorized processing facilities, ensure that there is no littering or deposition so as to prevent obstruction to the traffic or the public or drains.

Waste generators who generate more than 20 tons or more in one day or 300 tons per project in a month shall submit waste management plan and get appropriate approvals from the local authority before starting construction or demolition or remodeling work, segregate the waste into four streams such as concrete, soil, steel, wood and plastics, bricks and mortar, keep the concerned authorities informed regarding the relevant activities from the planning stage to the implementation stage and this should be on project to project basis.

Waste generators shall pay relevant charges for collection, transportation, processing and disposal as notified by the concerned authorities;

3.3 Duties of Service providers and Contractors:

The service providers shall prepare within six months from the date of notification of these rules, a comprehensive waste management plan covering segregation, storage, collection, reuse, recycling, transportation and disposal of construction and demolition waste generated within their jurisdiction,

The service providers shall remove all construction and demolition waste in consultation with the concerned local authority on their own or through any agency.

Local Authority shall be responsible for proper management of construction and demolition waste within its jurisdiction including placing appropriate containers for collection of waste, removal at regular intervals, transportation to appropriate sites for processing and disposal.

3.4 Duties of State Government and Local Authorities:

The Secretary in-charge of development in the State Government or Union Territory administration shall prepare their policy with respect to management of construction and demolition of waste within one year from date of final notification of these rules.

The concerned department in the State Government dealing with land shall be responsible for providing suitable sites for setting up of the storage, processing and recycling facilities for construction and demolition waste.

The Town and Country Planning Department shall incorporate the site in the approved land use plan so that there is no disturbance to the processing facility on a long term basis.

Procurement of materials made from construction and demolition waste shall be made mandatory to a certain percentage (say 10-20%) in municipal and Government contracts subject to strict quality control.

Local Authority (LA) shall seek detailed plan or undertaking as applicable, from generator of C&D waste and sanction the waste management plan; seek assistance from concerned authorities for safe disposal of C&D waste contaminated with industrial hazardous or toxic material or nuclear waste if any;

LA shall give appropriate incentives to generator for salvaging, processing and or recycling preferably in-situ;

3.5 Duties of CPCB, SPCB / PCC:

The CPCB shall prepare operational guidelines related to environmental management of C&D waste. SPCB shall grant authorization to C&D waste processing facility and monitor the implementation of these rules by the concerned local bodies and the competent authorities and the annual report shall be sent to the CPCB.

3.6 Standards for products of C&D waste:

The BIS need to prepare code of practices and standards for use of recycled materials and products of C&D waste in respect of construction activities. Indian Roads Congress shall be responsible to the standards and practices pertaining to use of recycled materials and products of C&D waste in roads construction.

3.7 Duties of Central Ministries:

The Ministry of Urban Development, and the Ministry of Rural Development, Ministry of Panchayat Raj, shall be responsible for facilitating local bodies in compliance of these rules; The MOEFCC shall be responsible for reviewing implementation of these rules as and when required.

3.8 Facility for processing/recycling facility:

The operator of the facility shall apply in Form I for authorization from SPCB / PCC. The processing/recycling site shall be away from habitation clusters, forest areas, water bodies, monuments, National Parks, Wetlands and places of important cultural, historical or religious interest. A buffer zone of no development shall be maintained around solid waste processing and disposal facility, exceeding five Tones per day of installed capacity.

3.9 Timeline for implementation of provisions of these rules for management of C&D waste management:

(a) one year and six months from the date of its notification for million plus cities based on

2011 census of India; (b) two years from the date of its notification for 0.5 to 1 million cities based on 2011 census of India; (c) three years from the date of its notification for other cities (<0.5 million populations) based on 2011 census of India;

4.0 Expected outcome

These rules envisage prevention of indiscriminate disposal of C&D Waste and make a way forward to reuse, recycle such waste in gainful manner

Duties of waste generators, service providers would envisage people's participation (Jan Bhagidari) in scientific management of C&D waste and would be a helping hand to Clean India Mission of the Government (Swachh Bharat Abhiyan). The successful implementations of these rules will ensure availability of the segregated waste, which in turn will help in improving the recycling efficiency of wet waste and other organic waste.

Duties of State Government and Local authorities including collection of charge from large waste generators [above 20 TPD], will put in place the Institutional framework, administrative and other logistic supports for C&D waste management and also ensure Sustainability of Waste Management System for C&D Waste

Bringing code of practices and standards for use of recycled materials and products of construction and demolition waste in respect of construction activities by BIS, Indian Roads Congress will ensure the authenticity of products made from the C&D waste and create confident among the stakeholders on the utilization of such products.

MAKING C&D WASTE A RESOURCE: DELHI SHOWS THE WAY

Deepak Agarwal, IL & FS

As per CPCB Guidelines on Environmental Management of C&D Wastes issued in March 2017, 25-30 million MT of C&D Waste is generated annually in India out of which only 5% is processed. C&D Waste is estimated to account for approximately 25-30% of total Solid Waste generated.

Ministry of Urban Development (MoUD) vide its circular dated 28th June, 2012 stated that all cities with population of over 1 million shall set up C&D Waste recycling facilities.

As per the recent IIT Kanpur study on air pollution and GHG emissions in Delhi, PM (PM10 + PM2.5) emissions on account of C&D waste is 6.5 tons/day or 2,372 tons/year in Delhi.

Delhi is estimated to generate approx. 5000 MT of C&D Waste on daily basis. Technology Information, Forecasting and Assessment Council's (TIFAC) has developed some estimation on C&D waste generation which recognizes that the generation is project specific as follows:

a. Range 40-60 Kg per sqm of new construction,

b. Range 40-50 Kg per sqm of building repair,

c. Range 300-500 Kg per sqm for demolition of buildings.

Recycling and Reuse of C&D waste has important implication on natural resources and environment. Partial replacement of building materials by use of C&D waste would help in reduction of sand mining from river beds or cutting of rocks and excavation of fertile soil from agriculture land. Industrialized countries have system in place for recycling of construction and demolition debris and even in-situ recycling of black top roads.

Urbanization is Shaping New Trends

With rapid infrastructure development & redevelopment projects being undertaken by NBCC & CPWD in Delhi, the quantum of C&D waste is ever increasing in Delhi. The management of C&D waste is of major concern due to the shortage of disposal sites and increase in transportation/disposal costs. The disposal of C&D waste at designated sites is a cause for environmental degradation and air pollution. The management of C&D waste mitigates substantially the shortage of dumping sites and increased transportation/disposal costs as well.

Opportunities for C&D Waste Management

Due to boom in infrastructure sector and redevelopment projects undertaken in Delhi, there is rise in demand for construction materials. Also the increasing price of natural construction materials has created the demand for C&D recycled produce. The following opportunities will give boom C&D Waste Management:

(a) Housing for All Mission envisages Construction of 20 million Houses in Urban Areas and 30 million in Rural Areas by 2022

(b) BharatMala Plan envisages Construction of ~34,800 kms of Highways by 2022

(c) Redevelopment Projects to create a separate set of Demand, which can be most suitably addressed on a Captive Basis

(d) Along with Demand the Price of Construction Material also is rising.

(e) Construction Cost risen by approx. INR 50 per sqm (w.r.t. FY17) led by Cement.

Regulatory Framework

The management of C&D Waste in India is regulated by the Construction & Demolition Waste Management Rules 2016, published in the Gazette of India, Part-II, Section-3, Sub-section (ii) Ministry of Environment, Forest and Climate Change.

These rules mandate every waste generator be responsible for collection, segregation of concrete, soil and others and storage of construction and demolition waste generated, ensuring it does not get mixed with other waste. Waste generators who generate 20 tons or more in one day or 300 tons per project in a month shall have to pay for the processing and disposal of construction and demolition waste generated by them, apart from the payment for storage, collection and transportation.

C&D Waste Management Rules, 2016 also stipulate that procurement of materials made from recycling of C&D waste shall be made mandatory to a certain percentage 10-20% in municipal & Government contracts.

IS 383: 2016 Indian Standard "COARSE AND FINE AGGREGATE FOR CONCRETE – SPECIFICATION" (Third Revision) covers the requirements for aggregates, crushed or uncrushed, derived from natural sources, such as river terraces and riverbeds, glacial deposits, rocks, boulders and gravels, and manufactured aggregates produced from other than natural sources, for use in the production of concrete for normal structural purposes including mass concrete works.

Apart from above, Delhi has paved a way for utilization of C&D waste products in the following manner:

1) Central Public Works Department (CPWD)

- CPWD OM No.155/SE(TES)/C&DWaste/2018/256-H dated 23.05.2018 mentions the utilization of C&D recycled products
- CPWD OM No. 155/SE(TES)/C&DWaste/2018/290-H dated 13.06.2018 suggests inclusion of suitable clauses & items of recycled products in the tenders documents
- CPWD vide OM No. 133/SE(TAS)/CS-DSR-2016/147-E dated 02.11.2018 included C&D

Recycled Produce namely Precast Solid Cement Concrete Blocks & Paver Blocks in DSR-2016 of SH:26(New Technologies & Materials) and issued correction slip No. 17 Delhi Schedule of Rates 2016.

2) Department of Urban Development, Delhi

- Order No. 7(84)/AD/LB/2016/5782-5805 dated 06.07.2016 issued by the Department of Urban Development, GNCTD mandates use of C&D recycled materials & products in civil works.

3) Public Works Department, Delhi (PWD)

- PWD, GNCTD O.M No. CE/Work/2018/3883/CDWM dated 14.06.2018 says that PWD can utilize 100% recycled materials in non-structural members, PCC and road works, like replacement of footpath, tiles, kerb stones &other repair &maintenance in building works, recycled sand for filling under floors

4) East Delhi Municipal Corporation (EDMC)

- EDMC Office Order No. CA/F&G/2018/104 mandates use of minimum 2% recycled products in case of building works and minimum 10% recycled products in case of road works.

5) DDA O.M vide F.No: 73(192)2015/Circular/CE/QAC/DDA/177 dated 12/6/18 also mandates use of recycled aggregate, screened soil, manufactured sand etc in their projects.

6) NBCC Circular No. CE/2018:939a dated 01.08.2018

IL&FS Environmental Infrastructure & Services Ltd. (IEISL) has pioneered the concept of C&D Waste Management by setting up first C&D Recycling facility in the country at Burari. On the basis of success of Burari C&D recycling facility, Ministry of Environment, Forest & Climate Change (MoEF&CC) notified C&D Waste Management Rules in 2016.

IEISL is currently operating the following C&D Waste Management Projects in Delhi:

(I) 2000 TPD C&D Facility at Burari under North Delhi Municipal Corporation

(ii) 500 TPD C&D Facility at Shastri park under East Delhi Municipal Corporation

(iii) 300 TPD C&D Facility at Mundka with Delhi Metro Rail Corporation.

C&D Waste Processing Facility at Burari

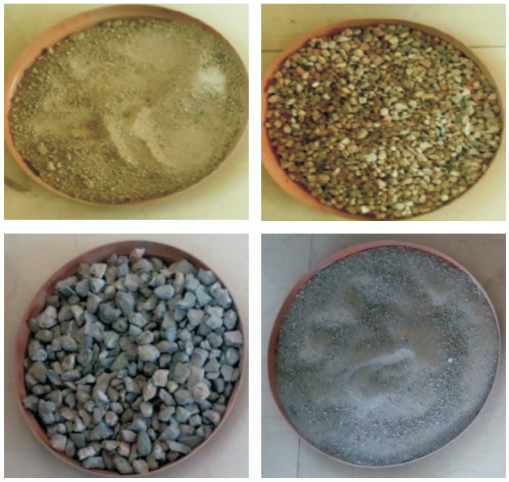


C&D Waste Processing Facility at Shastri Park



Recyclable/Reuse material from C&D waste

The following material can potentially be recovered from C&D Waste through a customized process of mechanical screening and re-sizing.



Application of C&D Materials

Description of Item	Specification	Size	Application
Good Earth	Produced in the process of filtration & pressing of slurry. Slurry is generated during the washing of C&D waste.	< 75 micron	Filling in low lying areas
Screened Soil	Produced during the screening of C&D waste. It consists of Soil & Aggregate	< 26.5 mm	Back filling, Road construction & Filling of ramp portion of the flyovers
Recycled Aggregate (RA)/ Brick Sub-base(BSB)/ Granular Sub-base (GSB)	Produced by Crushing & Washing of Brick Aggregate,Stone Aggregate, Tiles etc.	4.75 mm to 26.5/53mm & 11mm - 53mm	Lean Concrete (M10, M7.5, M5 grade). & PCC Work
Manufactured Sand	Produced by crushing & washing of C&D waste. It is a fine mixture of Stone & Brick Aggregates. All the properties are same as river sand except little more water absorption capacity.	75 micron - 5 mm	Brickwork& PCC Work
Recycled Concrete Aggregate (RCA)/ Stone Dust	Produced by crushing concrete based C&D waste only. Consists of Stone Aggregate & Cement Mortar Aggregate.	RCA- 5mm to 20 mm Stone Dust - < 5 mm	Upto 25% in Plain Concrete Upto 20% In RCC& 100% in Lean Concrete. (As per IS:383)

Delhi has witnessed the successful usage of C&D Recycled Produce in the following projects:

(a) Delhi Development Authority has already built a 4 km long, 100 m. wide stretch of road at Bakarwala, Delhi using recycled C&D materials of size less than 150 mm. The total quantum of the recycled material used for road stands to 3 lakh MT

(b) The Central Public Works Department is currently implementing a project for the new Supreme Court building at Pragati Maidan, Delhi, and already utilized around 18.6 lakh concrete bricks made from recycled C&D materials.

© Delhi State Industrial and Infrastructure Development Corporation (DSIIDC) has already used 1,29,324 MT of screened soil for development of unauthorized colonies in Delhi.

Measures Suggested For Sustainable C&D Waste Management

The following measures are suggested;

(i) Segregation of C&D Waste at Source.

(ii) Off-take of C&D Recycled Produce on regular basis for New Construction and Repair & Maintenance activities including Roads by the Government Departments to enable 100% processing of incoming C&D waste as per C&D Waste Management Rules, 2016.ules, 2016.

(iii) Mandate Redevelopment Projects to set up in-situ C&D Waste Recycling Facility having project cost more than 500 Crores.

(iv) City Development Plans/Master Plans to allocate Land for C&D Projects

(v) Inclusion of all the C&D Recycled Produce in Delhi Schedule of Rates (DSR), 2018 by the CPWD such as Recycled Aggregate, Recycled Concrete Aggregate, Manufactured Sand, Screened Soil, Stone Dust etc.

(vi) Amendment of BIS IS: 383 to allow 100% usage of RCA in Plain Concrete application from the existing limit of 25%.

(vii) Enhanced R&D to Expand Standards, Inclusion of C&D Products and Materials in Building Guidelines.

(viii) Application of Information, Communication & Technology (ICT) in C&D Projects.

(ix) Citizens using C&D products in construction of new houses shall be given rebate in house tax & shall also be allowed additional Floor Service Area (FSA).

(x) Inclusion of C&D Projects under Clean Development Mechanism (CDM).

(xi) Reduction of GST on C&D value added products from present applicable rate of 18% to 5%.

All C&D Products shall be covered under single HSN code for the purpose of applying GST.

NEED OF PROMOTING THE USE OF C&D WASTE IN INDIA

Rajeev Singhal, Chief Engineer, CPWD, New Delhi

Abstract

There is an increasing focus on management of Construction and Demolition (C&D) waste in India in view of the threat it poses to the environment as well as its connection with the sustainability of the construction industry. This paper examines the enormity of the problem and the ways to manage this waste with focus on promoting the use of C&D waste as a part of the Waste Management Plan.

Keywords

Construction, demolition, waste, recycling

Introduction

The waste materials generated from construction, renovation and demolition of buildings, roads and bridges is referred to as C&D waste. It primarily comprises of concrete, brickbats, asphalt, plastic, silt and grit etc. The primary source of generation is the construction industry. C&D waste as a distinct waste different from Municipal Solid Wastes (MSW) is also a relatively new phenomenon in India.

Quantifying the extent of C&D Waste

There are no systematically authentic figures of the C&D waste generated in India and different organizations have given their own estimates. This is because for a long time, C&D waste was not being considered a serious problem and there was no regulatory mechanism to quantify and regulate it. However it is estimated that the country generates more than 175 million tons of C&D waste annually.

There is a huge demand for houses and commercial built up infrastructure for the vast population of the country and as per the Mc Kinsey Global Institute Report of 2010[1], it is expected that 700 to 900 million square meters of residential and commercial area will have to be built in the country every year. It is also estimated that 60-70% of building stock in the country is yet to come up. This indicates that we are going to face the challenge of managing large quantities of C&D waste in the coming years.

In spite of the serious environmental challenge posed by C&D waste, not much work was done on management of C&D waste in India for long and rules existed only for management for Municipal Solid Wastes. The enormity of the problem was realized in the past 15-20 years and serious efforts to manage the C&D waste were then started.

Many countries estimate the quantity of C&D waste as a percentage of the municipal solid wastes (MSW) produced by them. As per a Report of the Committee to Evolve Road Map on Management of Wastes in India under Ministry of Environment and Forests[2], it was

reported that in the year 2008, MSW in India may be around 0.573 million metric tonne (MMT) per day. This implies that MSW in India will be about 210 million tonnes per year. For a population of 1.2 billion, this works out to about 175 kg per capita per year, which is much lower than the World Bank estimate of up to 1000 kg per capita per year for Asian countries (2000 estimate).

As per this report of 2000 of MoEF, India generated 10-12 million tonnes of C&D waste annually. However considering that C&D waste may be around one third of the MSW, quantities now may be alarming. There is thus, a wide gap in the estimates of C&D waste generation in India.

A comparison of data from other countries given in Table below can give an idea of the quantum of C&D waste in India.

International scenario in C&D waste generation:

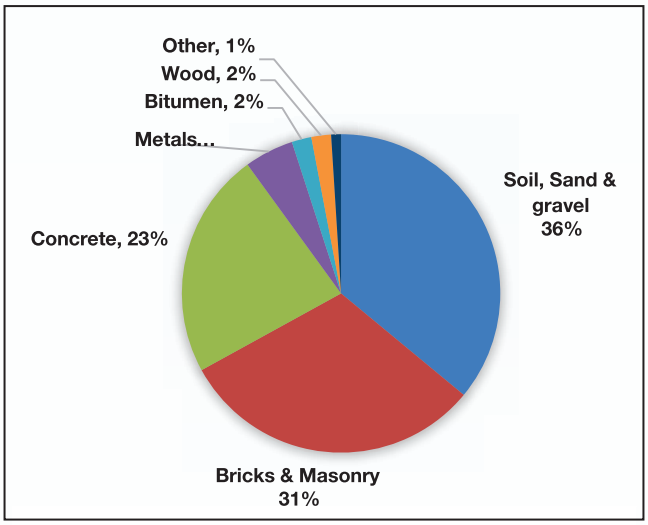
Country	C&D waste (Million Tonnes per year)	Year
Germany	223	2003
China	200	2005
Japan	85	2000
	77	2012
Australia	19	2008 - 2009
South Korea	61.7	2013

The figures for China and Germany are comparable and much higher than the figures for India. The figures for Japan and South Korea are comparable with the figures for India. With much higher waste, these countries have been able to manage the C&D waste better than India.

Composition of C&D Waste in India

The typical C&D waste from residential or commercial building works consists of concrete, brickbats, tiles, wood, plastics and soil etc. C&D waste from road and infrastructure consists of concrete, boulders, soil, asphalt etc.

Table below along with the pie-chart presents the results of Technology Information, Forecasting and Assessment Council (TIFAC) estimates of C&D waste composition in India. In addition, MCD survey findings and assessment carried out in 2005 by IL&FS Ecosmart are also shown in the Table.



Typical Composition of Indian C&D waste

C&D waste composition as per various estimates

C&D waste composition %	As per TIFAC	As per MCD survey, 2004	As per IL & FS Eco smart Survey 2005
Soil/Sand, Gravel	36.0	43.0	31.5
Bitumen	2.0	-	-
Metals	5.0	-	0.4
Masonry/Bricks	31.0	15.0	59.0
Concrete	23.0	35.0	-
Wood	2.0	-	1.5
Other	1.0	7.0	7.6
Total	**100.0**	**100.0**	**100.0**

Problems created by C&D Waste

Storage space requirements: As per estimates of TIFAC estimate [3], 40 to 60 kg waste is generated per sqm of new construction. This thumb rule indicates that we may be generating about 35 to 45 million tonnes of C&D waste per year from new construction itself. This shall fill up an area of 1 km x 1 km by 20m every year. In addition to this, C&D waste is also generated from renovation works, demolition (which generate around 425 kg of waste per sqm of building area), road and flyover works. Required space to dump such enormous quantities of waste is not available.

Pollution: C&D waste may not be hazardous in nature but still is a source of pollution of the soil and underground water as various chemical compounds are leached into the soil as the rain falls over it. There are chances that C&D waste may get mixed up with hazardous substances which make the entire waste as toxic. It is also observed that unscrupulous elements dump this waste in water bodies to escape carrying to longer distances thereby polluting the water bodies.

Wastage of natural resources: If the C&D waste is not recycled for new construction, the natural resources will get depleted at a much higher rate to sustain new construction. Even at this time, there is a shortage of natural sand and stone aggregates required in large quantities for construction. This has created problems of illegal mining of sand from rivers and also illegal cutting of mountains for natural aggregates which has created environmental problems.

Way Forward and Solutions

The construction industry cannot grow at the desired pace unless it becomes sustainable and environment friendly. It is in the interest of construction industry itself that they take steps to effectively manage C&D waste. In a nutshell, the C&D waste has to be treated as a resource for reuse in new constructions.

Deconstruction instead of demolition

Demolition activities are the largest C&D waste producers, generating around 425 kg of waste per sqm of area. If the buildings are taken down in a planned manner (deconstruction), many components like wooden frames, door shutters, steel, glass, bricks etc. shall become available for re-use. This will not only reduce waste but also make available materials for further use in construction of the new building. There is a need to prepare guidelines for "deconstruction" of buildings of various types like RCC structures, Bricks masonry Structures, Mixed construction etc. so that the construction agencies can follow them. Many

techniques have been developed by various agencies for deconstruction which can be referred to. Some interesting case studies have been presented in a paper titled "Mechanizing Demolition for better Development" [4].

Segregation at source

The C&D waste must be separated at the site of work itself into (a) soil, (b) concrete, (c) steel, (d) wood & plastics and (d) bricks & mortar. This is also mandated by the "Construction and demolition waste management Rules, 2016" [5]. This shall ensure that the materials are easily treated at the recycling plant. Effective monitoring system has to be developed so that the concerned civic agencies can monitor that waste being segregated at source and impose penalties if required.

System for collection, transportation and recycling of C&D waste

The Government/local bodies need to establish more recycling facilities and develop an effective system to collect and transport the waste to these facilities. The Municipal Corporation of Delhi has collaborated with IL&FS Environmental Infrastructure & Services Ltd. (IEISL) which has established C&D waste recycling plant at Burari in Delhi. The plant receives 500 tonnes of C&D waste everyday (TPD) from three zones of Delhi. The material is recycled into aggregates, pavement blocks, kerb stones and concrete blocks and the products are being sold in the market. The waste after recycling is filled at the same site. Such

collaborations are needed to establish more and more recycling facilities in Public Private Partnership.

Use of Recycled material in Construction and Road works

The C&D waste material has the potential to be used as filled up material for embankments. This can be done with additional precautions of protecting the sides of such embankments with earth cover.

Crushed C&D material also has potential to be used in sub - base construction because it has good strength (CBR value) and it also drains well. Proper care to ensure grading as per MORTH guidelines can be taken as grading of C&D material is not as per the requirement. CRRI has taken up a feasibility study for widening @ 4m on both sides of 150m length on of an existing road in North Delhi. Sub base, 150 mm thick, was constructed with crushed C&D waste conforming to MORTH specifications for GSB. Over GSB, 150mm thick base course of crushed C&D waste was laid which was stabilized with 5% cement admixture. 75mm thick Base course with WBM followed with 50mm DBM and 25mm BC was provided over it. Performance was monitored for 2 years and found satisfactory[6].



Recycled Sand



Recycled Aggregates

The Recycled Concrete Aggregates (RCA) can be used in concrete works. However, there are problems of (a) higher porosity of the RCA due to mortar sticking to it, (b) the RCA are likely to be alkali reactive due to alkali content in the adhering mortar, (c) greater non uniformity in quality as the RCA may be sourced from different construction and demolition sites. Studies have indicated that 20-30% replacement of natural aggregates can be done with RCA without significant effect on strength of concrete [7].



Paver blocks from recycled aggregate



Cement Concrete blocks from recycled aggregate

Conclusions

Management of C&D waste is the biggest challenge being faced by the construction industry in terms of environmental risks it poses. The ways of dealing with this challenge have been elaborated in this paper. There is a need for more research on applications for recycled C&D waste and development of Standards so that they can be used extensively. Municipal corporations have to be proactive in developing system for monitoring the disposal of C&D waste and public has be sensitized to the seriousness of this challenge.

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INITIATIVES OF CPWD FOR UTILIZATION OF C&D WASTE, FLYASH AND TECHNICAL TEXTILES IN CONSTRUCTION WORKS

Kunwar Chandresh & Lakshmi Kumari, Executive Engineers, CPWD, New Delhi

Sustainable development is the future for all and government of India has been coming out with guidelines, policies, rules and regulations to achieve the goal of sustainable development. Central Pubic Works Division (CPWD) is the premier organization of government of India both in construction works as well as in policy making and their implementation in the construction works. CPWD has published "Guidelines for Sustainable Habitat" in 2014 which included guidelines on Reuse & Recycling of Construction & Demolition Waste.

CPWD has issued circulars and instructions to utilize fly ash, C&D waste and technical textiles in construction works throughout India in order to achieve the goal of sustainable development. Consistent endeavor of CPWD has caused the meaningful outcome to utilize fly ash, C&D waste and technical textiles in construction works as desired. But the task is not complete and still the department is trying to sensitize the construction sector about its benefits to maximize their use. This article discusses in detail about various initiatives of CPWD along with few case studies.

Initiative on Utilization of C&D Waste in Construction Works

On 24.11.2015 the Government of NCT of Delhi has issued an advisory on "use of Recycled Construction waste projects in Delhi"

Initiative on C&D waste upon the advisory issued by Govt. of NCT of Delhi, CPWD has issued an Office Memorandum to all concerned for implementation in CPWD works. The salient features of use of C&D waste as per the above advisory are as follows:

(i) The recycled products should be encouraged to be used to the maximum possible extent to reduce the negative environment impact due to dumping of C&D waste on roads, ridge side of river Yamuna etc. and to save precious urban space required for its dumping.

(ii) To ensure the quality and durability of recycled products, the agencies must adopt prescribed construction practices like using clear water for making concrete mix of recycled products. Therefore, all the C&D waste processing plants shall use clean water or install a R.O. plant of required capacity for treating the water to be used for production of different recycled products.

(iii) The recycled products may be used in non-sensitive structures like kerb stone, paver tiles in footpath, silt/earth for filling in plinth/embankment, use of bricks in non-load bearing partition walls, boundary walls, toe walls, recycled aggregates in RCC kitchen shelf, almirah shelf etc.

(iv) Regarding the quality of the recycled products, the user department must test the quality

of recycled products as per product specifications before accepting the same.

(v) Large quantity of recycled earth is extracted, during processing of C&D waste; the same may be used by the Govt. Agencies for filling in plinth f buildings and embankment of roads.

(vi) The technology of milling and reusing the bituminous material recovered by milling of existing bituminous pavement layers should be encouraged so as to avoid raising of road levels and to save the natural resources like stone aggregate. The Government agencies dealing in the construction of roads must consider these aspects and use these technologies for milling and recycling of existing bituminous layer before taking up re-carpeting of existing roads.

(vii) In all big redevelopment projects of the Government, costing more than Rs.500 crores, there may be a provision for installation of a C&D waste processing plant, of appropriate capacity, at the site itself to recycle C&D waste generated during the construction and also to use the recycled products in the same project to maximum possible extent.

(viii) The maximum Retail Price (MRP) of various recycled products may be at par with Delhi Schedule Rate (DSR) +prevailing cost index at any particular time. The recycled products manufacturing agency may sell their products at lower rate than the MRPs to capture more market.

Through an office memorandum (OM) dated 07.03.2016 CPWD has introduced changes in the CPWD specification (Civil) 2009 Vol. I whereby the existing provision of specification of stone aggregate in Para 4.1.1.1 was modified to include the specification of RCA (Recycled concrete aggregate) or RA (Recycled aggregate) which is described as follows:-

4.1.1.1 (a) Stone aggregate:- It shall consist of naturally occurring (uncrushed, crushed or broken) stones and manufactured from other than natural sources, by processing materials using thermal or other processes such as separation, washing, crushing and scrubbing. Manufactured coarse aggregate may be recycled concrete aggregate or recycled aggregate as given in hereunder. It shall be hard, strong, dense, durable, clear and free from veins; and free from injurious amounts of disintegrated pieces, alkali, free lime, vegetable matter and other deleterious substances as well as adherent coating. It shall be roughly cubical in shape. Flaky and elongated pieces shall be avoided. It shall conform to IS: 383 unless otherwise specified.

New Para introduced 4.1.1.1 (e) Recycled aggregate and Recycle Concrete Aggregate:- Use of construction and demolition (C&D) waste for manufacture of aggregates is a step towards effective management and utilization of this waste. This however, requires necessary care while producing aggregates to ensure their efficacy in their use as part of concrete. These aggregates may be of two types namely Recycled Aggregate and Recycled Concrete Aggregate. RA is made from C&D waste which may comprise concrete, brick, tiles, stone, etc. and RCA is derived from concrete after requisite processing. Recycled concrete

aggregate contain not only the original aggregate, but also hydrated cement paste adhering to its surface. This paste reduces the specific gravity and increases the porosity compared to similar virgin aggregates. Higher porosity of RCA leads to a higher absorption. Recycled aggregate will typically have higher absorption and lower specific gravity than natural aggregate. The concrete rubble has to be properly processed including scrubbing remove the adhered hydrated cement as much as possible.

The broad steps involved in the manufacture of aggregates from C&D waste may be:

I. Receipt and inspection of C&D waste at the plant.

ii. Weighing of waste.

iii. Mechanical and manual segregation and resizing this may involve segregation of various types of wastes such as bricks, stones, concrete, steel, tiles etc.

iv. Dry and wet processing.

Table 4.5 on grade of concrete was also modified with the footnote that the manufactured aggregate shall be permitted with their extent of utilization as percent of total mass of fine or coarse aggregate as the case may be as indicated in table 4.5 A against each, for use in plain, reinforce concrete and lean concrete. Manufactured aggregate shall not be permitted for use in pre-stress concrete.

The above changes in specification was made by incorporating IS : 383-2016 on the use of RA and RCA produced from other than the natural resources for using in plain and reinforced concrete.

Through a corrigendum issued on 22.03.2016 the percentage of C&D waste material in concrete works has been increased in order to ensure maximum utilization. The percentage of coarse aggregate and fine aggregate for the lean concrete of less than M-15 grade concrete has been increased to upto 100%.

Govt. NCT of Delhi through a gazette notification F. No. 13(183)/SWM-NP/MB/UD/2016-17/P.F-Vol.II/4595 dated 03.11.2017 under state policy and solid Waste Management Strategy for Delhi, has categorically mentioned about the role of major sport functionary departments/authorities wherein it was stated that The CPWD has a number of residential colonies in Delhi where it must ensure co-ordination with the ULBs and remove C&D waste from their colonies. Subsequently, CPWD has circulated the copy of gazette notification as mentioned above for necessary action in CPWD.

CPWD through OM No. 155/SE (TAS)/C&D Waste/2018/256 H dated 23.05.2018 circulated the information that Construction & Demolition (C&D) Waste management processing facilities are available in the NCT of Delhi at Burari, Shastri Park and Mundka with a combined capacity of more than 2500 MT/ day for effective management of such waste. It was further stated in the same OM that Ministry of Environment, Forest and Climate Change has notified

C&D Waste Management Rules 2016 and circulated vide no. DG/CON/Misc./04 dated 23.01.2017 for necessary action by the field units. With a view to ensure maximum utilization of C&D waste in the construction activities it is decided suitable clauses and items of recycled products may be incorporated in the contract documents by the NIT approving authority.

Product manufactured from C&D recycled waste can be used in the works subject to quality control and meeting relevant standards and specifications. An indicative list of applications is as follows:-

(I) Screened soil for filling applications in road work and under floors.

(ii) Recycled aggregates of size upto 150mm for sub-base applications in road work.

(iii) Manufactured sand in plaster.

(iv) Concrete blocks, kerb stones, paver blocks in open areas and footpath etc.

Subsequent to OM dated 23.05.2018 a corrigendum was issued vide letter no. 155/SE (TAS)/C&D Waste/2018/290 H dated 13.06.2018 that suitable clauses and items of recycled products shall be incorporated in the contract document by the NIT approving authority to ensure 10 to 20% mandatory use of recycled material and products for all CPWD projects in NCT of Delhi. A meeting was called on 10.08.2018 at Nirman Bhawan, New Delhi in which all the Chief Engineer/CPM's of CPWD of NCT of Delhi were requested to participate and provide updates about the use of C&D waste and to provide information about the number of NITs/ tenders/works under their zone having the provision of mandatory use of C&D waste recycled products.

On 01.08.2018 through an OM 155/SE (TAS)/C&D Waste/2018/363 H CPWD has introduced new online construction and demolition waste management reporting system through PIMS login for all the concerned field officers. The field officers in CPWD need to submit Annual Construction and Demolition Waste Management as per Govt. guidelines. Therefore, new Online Construction and Demolition Wasted Management Reporting System has been developed in-house by the e-Governance Unit to facilities the field EEs to submit these reports online through PIMS login. There is provision to submit Nil report. The module includes the following:-

I. Name of work.

II. Description of Waste Items

III. Quantity Generated upto 31st March.

IV. Quantity Recycled upto 31st March.

- Non-structural concrete aggregate

- Manufactured sand
- RMC
- Paving Block
- GSB
- Other, if any

V. Quantity used up to 31st March.

VI. Quantity disposed by land fills up to 31st March.

VII. Comments.

The online reports are monitored by DDG (Works), CPWD.

The CPWD has included items in DSR for block masonry from blocks of C&D in construction works through OM dated 02.11.2018 sub head 26 of DSR 2016 included new items for precast solid cement concrete blocks and paver block made of C&D waste. CPWD is regularly monitoring the progress in utilizing C&D waste in construction project and trying to sensitize the field officers to maximize its use.

CPWD through its Office memorandum dated 07.03.2016 has issued amendments to Delhi schedule of rates (hereinafter mentioned as DSR) 2014 wherein the items of DSR where possibly the C&D waste could be used were amended to include the C&D waste and those are specified in the items. The same items were incorporated in the next DSR 2016. The rates of those items were kept unchanged to promote the use if the C&D waste following the advisory of Government of NCT of Delhi. However, zonal Chief Engineers were authorized to decide rates as per availability and site conditions of coarse aggregates derived from RCA (Recycled concrete aggregate derived from concrete after requisite processing) or RA (Made from C&D waste may comprise concrete, bricks, tiles, stones etc).

CPWD has also issued instructions for use of products of C&D waste in Delhi. CPWD and National Building Construction Company have also recommended use of recycled C&D wastes in their construction activities if the construction waste is available within 100 km from construction site.

CPWD and SINTEF signed an MoU on 25.02.2016 with the objective of cooperating on all aspects of recycling of C&D waste for an institutional and technical assistance programme on "Treatment and utilisation of construction and demolition waste in India" on capacity building and technical support. The Ministry of Foreign Affairs (MFA) of Norway have entered into an agreement with SINTEF allocating a grant to be used exclusively to finance the programme during 2017-21. The goal of the programme is to increase the utilisation level of recovered C&D waste in the building and construction sector in India by increasing the treatment and recycling capacity. Target groups are CPWD, ULBs and other institutions and

academia including industry and waste management companies.

CPWD has used the blocks manufactured from C&D waste in Supreme Court additional office complex, New Delhi, produced from Burari plant, Delhi. These blocks were used in external walls, toilet walls and lift well walls after required tests and when the company was able to produce them of desired compressive strength of 10 MPa, they were used in the project. The size of the blocks used was 400x200x100mm and in total 17.50 lakh blocks were used.

Initiative on Utilization of Fly ash in Construction Works

CPWD has been utilizing fly ash in various construction materials like fly ash bricks PPC cement, AAC Block apart from filling of low lying areas and in the construction of road and flyover embankments.

CPWD is strictly following the directions of Ministry of Environments and Forest vide notification no. S.O. 763 (E) dated 14.09.1999 amended vide notification no. 979 (E) dated 27.08.2003 and further amended vide notification no. 2804 (E) dated 03.11.2009 regarding utilization of fly ash and fly ash based products in construction activities within 100 Kms of coal or lignite based thermal power plants and OM dated 12.12.2014 issued by CPWD it was directed to all the Chief Engineer/CPM/Project Manager to ensure that the provisions of the MOEF notification are complied strictly.

CPWD monitors the utilization of fly ash in construction materials, particularly PPC cement and fly ash brick, regularly and issues instructions to its field units to report the uses.

Initiative on Utilization of C&D Waste in Construction Works

In CPWD technical textile in various applications like improvement of roads, retaining walls, approaches of flyovers and slop stabilization. CPWD has proposed use of technical textile in its Border Road Projects and OM no. 155/SE (TAS)/C&D Waste/2018/447 H dated 22.10.2018 was issued vide which application of technical textile items in DSR 2016 was listed along with list of Geo Synthetic Manufacturers and list of major manufacturers of composites a separate list was given for major manufacturers of build textiles.

Conclusions

CPWD is taking lead in augmentation of the utilization of the C&D waste, fly ash and technical textile in the construction works and regularly monitoring its progress also. CPWD is firm in its approach towards sustainable development goals of government of India. CPWD has achieved a satisfactory result through its endeavor and in future also it would be pushing for the same.

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C&D WASTE RECYCLING FOR CONVERTING INTO RESOURCE

Sanjay Singh, Vice President – CDE Asia Ltd. Kolkata

Construction and demolition (C&D) waste is the debris which is generated from the construction, repair, renovation and demolition of civil structures.

All over the world, the useful materials from C&D waste are segregated and reused with little or no processing. The rest of the material can be recycled and gainfully utilized for manufacturing building materials such as aggregates, sand and components such as bricks, blocks etc. The concept is not new and being practiced world over. However in India, it is time to orient our approach to treat this as a resource.

The traditional disposal mechanism from C&D waste in India is land fill has been a great cause of concern from environmental point of view in urban areas. Authentic data for C&D waste generation quantity is not available. As per one estimate, C&D waste generated in India is about 175 million Tons which is bound to increase with government's ambitious scheme in housing and infrastructure sectors. Therefore, it calls for a concerted effort to efficiently utilize this waste with know-how already available in the market.

With above scenario in sight, Govt. has notified rules for Management of Construction and Demolition Waste 2016 under which every corporation has to install C&D waste recycling units in its area within a scheduled plan. Few developments are listed below -

- Mandatory to setup recycling plant within a time frame.
- Generators of waste are required to pay notified collection and processing fees.
- Imposed heavy penalty on illegal dumping of C&D Waste.
- Waste disposal plan to be made before sanction of building plans
- Use of recycled C&D waste - 20% to 100%. IS-383 standard code revised.

For processing of C&D Waste CDE is globally known as number one company in this field. More than 50 waste processing plants are operating throughout world which include two successful plants in Delhi, India. Other locations where CDE plants are under execution in India are- Thane, Surat, Delhi, Agra, Hyderabad, Pimpri etc. Globally CDE's plants are processing 6 million tons of C&D waste every year.

Success of the CDE Plants' can be attributed to the followings;

- It is environment friendly as it does not cause any sound, water or dust pollution.
- Light weight contaminants are removed because of which products such as aggregate and sand are usable in construction.
- Adhered fines from the aggregates are removed by its patent machine Rotomax, which

makes the aggregate comparable to virgin material.

- Ultra-fines from the sand are removed accurately making it suitable for construction purpose.
- 90 – 95% water is recycled back into the system, making water requirement as minimal.

With compliance of C&D Waste Management rule 2016, the following gainful impact can be visualized;

Impact to Corporation;

- Compliance of waste management Rules 2016
- Sustainable path to become Smart City
- Savings of large land banks (perpetual loss)
- Savings of cost of managing unclaimed waste (its transport)
- Carbon credits for minimizing greenhouse effect
- Generation of employment with no additional cost.

Impact to Citizens;

- Cleaner and healthier city
- Ease of waste disposal
- Collection of waste from door step
- Availability of low cost building materials within city limits.
- River saved from illegal C&D waste dumping/River mining.

In nut shell, it can be concluded that C&D waste should now be considered a valuable resource and no longer a waste.

RECYCLING CONCRETE FROM CONSTRUCTION AND DEMOLITION (C&D) WASTE INTO RECYCLED CONCRETE MATERIALS (RCM)

Abhijeet N Gowde, AGM, Godrej Construction

India has seen a considerable growth in the number of infrastructure projects in the recent years. Today, India ranks among the top 10 countries in the world generating the highest amount of municipal solid waste. The unfortunate part of the story is that a huge chunk of waste goes untreated. The issue of dumping C&D waste into landfills has been one of the key reasons why the Court had to intervene and prevent Municipal Corporation of Greater Mumbai (MCGM) from providing approvals for building construction for several months in Mumbai City.

Environmentally sustainable practices are integrated in the manufacturing processes and value chain across businesses at Godrej. Our efforts to achieve our sustainability goals include a range of initiatives from energy efficiency and water conservation at our manufacturing sites, to promoting IGBC/LEED-certified green buildings. Keeping this in mind Godrej Construction in line with the commitment that Godrej Group has towards building a greener India through its good & green initiative has ventured into manufacturing Recycled Concrete Materials (RCM) for construction activities. It is one of the first organised private players in India who have invested in state of the art machinery that recycles concrete debris into Recycled Concrete products such as Blocks and Pavers at Vikhroli, Mumbai. This plant manufactures products with the minimum ecological footprint. These products meet the codal requirements and match the strength of concrete manufactured using virgin stone aggregates from quarries. The RCM plant recycles concrete in a controlled environment. The right amount and mix of materials contribute to resource conservation and minimal wastage.

The manufacturing facility is capable of producing blocks and pavers of varying shapes, sizes and colour options (for pavers) at a full capacity of 170 cubic metres a day.

It is capable of manufacturing 36000 blocks per day that include:

- TUFF Solid Recycled Blocks
- TUFF Hollow Recycled Blocks that are light weight
- TUFF Insulated Recycled Blocks with thermal insulation properties
- TUFF Flyash Recycled Blocks

And about 54000 pavers per day that include:

- TUFF Zigzag
- TUFF Trihex
- TUFF Euphrates

- TUFF Colorado
- TUFF I Section pavers

Not only concrete debris is recycled, TUFF Recycled Concrete Materials product range is itself 100 percent recyclable and Green Pro certified. Such initiatives help to promote the circular economy by easing the increasing demand for natural resources and also help the society by reducing the need for dumping of construction and demolition waste into landfills.

Besides, Godrej Construction offers a wide range of construction materials which include specially engineered Ready Mix Concrete, TUFF range of AAC blocks & Pavers, Ready Mix Plaster and Mortar etc.

USP of TUFF Recycled Concrete Material Products:

TUFF recycled concrete blocks are superior in many ways. They are weather-proof owing to their low water-absorbing quality. They are quite versatile in their usage application and are three times stronger than conventional clay bricks. Unlike clay bricks, these have minimal wastage during transportation, usage and handling. Thus it helps in saving time and cost. TUFF recycled concrete pavers last longer than standard concrete or asphalt. Flexible in structure, they are suited to seismic hot zones because they adapt to distortion. Maintaining and repairing pavers is cost-effective and efficient; only the units that are damaged need to be replaced.

Environmental benefits of using Recycled Concrete Materials

- Water: Recycling one ton of cement could save more than 5000 litres of water.
- Carbon Footprint: Recycling one ton of cement could save more than 900 kg of Co2.

Others benefits include;

- Landfill Issue: It offers a way to reduce landfill waste and landfill space
- Circular Economy: Using recycled material reduces the need for mining for virgin raw materials.

Godrej Construction has received the 'Green Pro' certificate from Indian Green Building Council (IGBC) for TUFF Recycled Concrete Blocks & Pavers making them very beneficial for use in Green building constructions. These products can help secure more points for a higher Green Building rating.

Today, even the stone aggregates market is highly volatile and facing a lot of shortage due to government ban because of undue pressure on quarries resulting in intermittent stoppages of work due to non-availability of aggregates. All such events directly/ indirectly eventually result in pressure on the timelines and cost of the project.

The use of Recycled Concrete Materials would also help reduce the pressure on quarries to

generate more stone aggregates and natural river sand. It would help reduce the increased demand and related strain for natural resources, thus reducing further degradation of the environment. This would also help reduce dumping of concrete construction waste into landfills.

The company is also exploring the possibility of using Recycled Concrete Materials for Accropods, Tetrapods, street furniture, Garden Furniture and other non-structural concrete elements which could avoid large scale use of virgin natural materials.

Godrej Construction has urged builders, construction teams and design practitioners who are committed to reducing the negative impact of construction activities on the environment to divert construction and demolition (C&D) materials from being disposed into the dumping grounds. Instead, consider the usage of Recycled Concrete Materials to the maximum extent possible. The company is extremely happy to state that our TUFF range of Recycled Concrete Material Products are getting wide acceptance from many leading environmentally conscious players in the industry.



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www.godrejconstruction.com

construction@godrej.com

USE OF TECHNICAL TEXTILES IN CIVIL ENGINEERING

Dr K M Soni, Addl DG (TD) CPWD, New Delhi
Manu Amitabh, CE(CSQ), CPWD, New Delhi

Technical textiles are defined as textile materials and products manufactured primarily for their technical performance and functional properties rather than aesthetics or decorative functions. Thus the textiles like apparels or furnishings are not technical textiles.

Technical textiles are used in many applications nowadays and growth of such textiles is higher than the growth of apparels. Annual growth of all types of technical textiles is about 20% (17% - 23%) in the country. Government of India is already giving a lot of emphasis on its growth and providing technical support to the industry. Textile Commissioner, government of India has been given the task of growth of the industry by the Ministry of Textiles.

Classification of Technical Textiles

Technical textiles are classified as Agrotech, Buildtech, Clothtech, Geotech, Hometech, Indutech, Meditech, Mobiltech, Oekotech, Packtech, Protech, and Sporttech. These are described briefly in the following.

Agrotech

As the name indicates, agrotech means agro + tech i.e. technical textiles used for agricultural applications which include horticulture, fisheries and forestry also. Examples of agrotech are shade nets, mulch mats, crop covers, fishing nets, anti hail nets, bird protection nets etc.



Shed net



Mulch mat

Agrotech textiles are used in farming, animal husbandry and horticulture to control the hazardous influences of environmental and climactic factors on crop production and cattle breeding, regulate nutrient level intake of plants, and assist in process and post harvest operations. Fishing industry has been using agrotech extensively though their use is increasing substantially in other fields also. Their use will also result in increasing agriculture yield. In this sector, manufacturers of shade nets are Garware Wall Ropes, CTM Agrotextiles Limited, Rishi Techtex Limited, Tuflex (Netlon India Limited) and Neo Corp International Limited, of mulch mats as Unimin, Fiberweb India, Shivam Polymers, Climax Synthetics Pvt. Limited, Creative polymers Pvt. Limited and Essen Multipack Limited, of anti-hail nets and

bird protection nets as Tuflex, Kwality Nets and Garware Wall Ropes, of crop covers as Unimin India Limited, Fiberweb India Limited, KK Non-woven and KT Exports, and fish nets as Garware Wall Ropes, Hinafil India Pvt Limited, and SRF Polymers Limited.

As seen above, such technical textiles are not generally used in civil engineering applications though to a very limited extent, they are used in horticulture applications.

Buildtech

Buildtech are the technical textiles used in construction of buildings/structures. They are used in many applications for temporary as well as permanent structures including in roads, bridges, dams, and tunnels. Temporary structures include tents, marquees and awnings. Architectural membranes are used nowadays in many permanent structures including stadiums. Other products include hoardings and signage, cotton canvas tarpaulins, HDPE tarpaulins, awnings and canopies, scaffolding nets, floor and wall coverings etc.

India's buildtech segment was expected to grow at a rate of 17% to US$ 541 Million by 2016-17 as per estimates of the Working Group on Textiles and Jute Industry, Ministry of Textiles, Government of India. Key manufacturers of buildtech in India are; for architectural membranes as Entremonde Polycoaters Limited, for canvas tarpaulin substrate as Gokak mills, Bharat Textiles and SRF Limited, for HDPE tarpaulin as Gujarat Raffia and Gujarat Craft, awnings and canopy by SRF and Entremonde Polycoaters, for floor and wall coverings as Uniproducts and Birla Corporation and for scaffolding nets as Rishi Techtex Limited and Kwality Nets.



Architectural membranes



Scaffolding net

The Buildtech are used in civil engineering applications directly through agreement items as well through contract conditions. Architectural membranes, canopies, awnings, signage and floor coverings are used through agreement items on architectural and structural requirements while scaffolding nets, safety nets, tarpaulins and signage are generally used through contract conditions.

Clothtech

Clothtech are the technical textiles used for specific functional applications in garments and shoes largely hidden. These include interlinks in shirts, sewing threads, shoe laces, labels, hooks and loop fasteners (Velcro), umbrella cloth etc. Key Indian manufacturers in the segment include for shoe laces as Neelam Shoe Lace Industry (Delhi) and Indian Shoe Lace (Agra), for interlinings as Bombay Dyeing, Ruby Mills, Ashima Syntex and Talreja Textiles, for nonwoven interlining fabric as Supreme Nonwovens Pvt. Limited, KK Nonwovens India and Freudenberg Nonwovens India Pvt. Limited, for zip fasteners as YKK India Private Limited, Tex Corp. Limited, and Zip Industries Limited, for elastic narrow fabrics as Spica Elastic Private Limited and Sky Industries, for hook and loop tape fasteners as Sky Industries Limited and Siddartha Filaments Private Limited, and for sewing threads as Madura Coats, Mahavir Spinning Mills (Vardhman Threads) and Precot Meridian.

Such technical textiles though used by almost everyone are not used in civil engineering applications.

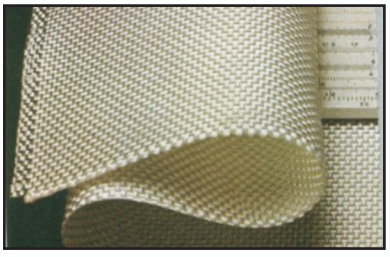
Geotech

Geotech are the technical textiles used with soil to perform various functions primarily separation, reinforcement, confinement, filtration, drainage, and protection. Geotech or geo-technical textiles are used in roads and pavements, slope stabilization, embankment protection, tunnels, rail-track bed stabilization, ground stabilization, filtration and drainage, soil erosion control, and in landfill and waste management.

Geotech products include geotextiles, geogrids, geonets, geopipes, geocells, geomembranes, geocomposites, prefabricated vertical drains, geo-gabions, geotubes etc. With the growing emphasis on biodegradable products, natural materials like jute and coir have also attracted significant interest as temporary products under this category.



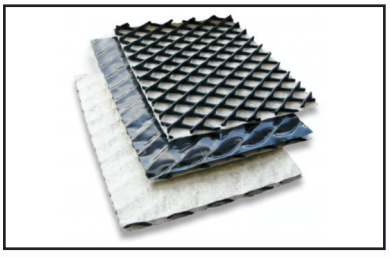
Geogrids



Woven geotextiles



Non woven geotextiles



Geocomposites

The Indian geotech segment was estimated to grow at a rate of 22% to US$ 201 Million by 2016-17 as per estimates of the Working Group on Textiles and Jute Industry, Ministry of Textiles, Government of India. Key Indian manufacturers in the segment include Strata Geosystems, Garware Wall Ropes, SRF, Techfab India, Skaps, Terram, Maccaferri, Kusumgar, Neo Corp International Limited, Shri Ambica Polymer Private Limited, Shri Jagdamba Polymers Limited, International Packaging Product Pvt. Limited, Texel Industries Limited, Aadi Plastic Industries Pvt. Limited, Supreme Nonwoven, Charminar Nonwoven etc.

The Bombay Textile Research Association (BTRA) is recognized as a Centre of Excellence (COE) for Geotech by the Ministry of Textiles, Government of India. The association has established a new geotech laboratory with testing facilities to test geotextiles, geomembranes, geocomposites, gabions, geosynthetic clay liners, geogrids, and prefabricated vertical drain etc. and is also providing training to users and entrepreneurs in geotech as well as in other technical textiles.

Geotech are normally used only in civil engineering applications. They are gaining popularity due to functional and durability characteristics as they do not get corroded. In civil engineering applications, they are in use for a long time now and thus codes and specifications of the materials are also available. CPWD has also included some of the items in Delhi Schedule of Rates (DSR).

Hometech

These are the technical textiles used for home or household applications such as blinds, filter products used in vacuum cleaners, furniture products, stuffed toys, fibrefill, mosquito nets, carpet backing cloth, mattresses and pillow components. Hometech products are made of both natural and synthetic fibres. Key Indian manufacturers in the segment include for fibre-fill as Reliance Industries Limited, Ganesh Polytex, Arora Fibres limited, Alliance Fibres and Nirmal fibres Private limited, for carpet backing cloth as Ludlow Jute, Birla Corporation and Gloster Jute, for stuffed toys as Hanung Toys & Textiles Limited, for blinds as Hunter Douglas, Mac Décor Limited, Aerolux India Private Limited and Viesta, for mattresses and pillows as Kurlon Limited and Sleepwell, for flock fabrics as The Rishabh Velveleen Limited, Girdhar & Company, Sangam Group of Companies, Chiripal Group of Companies and Niranjan Deco Flocks and for PU coated fabrics as Jasch Group, NELCO, and Aman Leather.

Though hometech finds place almost in every home in the form of mattresses, pillows, blinds, furniture products and toys etc, their direct applications in civil engineering applications is not there.

Indutech

Indutech are the technical textiles used in industrial or manufacturing sector. These technical textiles include conveyor belts, driving belts, cigarette filters and rods, decatising cloth, bolting cloth, absorption glass mats, glass battery separators, ropes and cordages, composites, filtration products, seals, gaskets, and brushes used in industrial applications.

Key Indian manufacturers in this segment include for decatising wrappers as Bombay Dyeing, JKT Fabrics and Noor Textiles, for bolting cloth as Bombay Bolting Centre, Surat Bolting and Khanna Bolting, for battery separators as Daramic Products and AGM separators, for backing cloth for coated abrasives as Madura textiles and Keetex Textile, for conveyor belts as Phoenix Yule, MRF and SempertransNirlon, for drive belts as Fenner India, Pix transmissions, Nirlon Limited and L. G. Balakrishnan & Bros Limited, and for glass fibre fabric as UP Twiga Fibres, Montex Fibre Glass, Satyaluxmi International and SRM International.

These technical textiles have industrial applications.

Meditech

Meditech are the technical textiles used in medical and hygiene care. These products include wipes, baby and adult diapers, adult sanitary and incontinence products as well as medical and surgical products such as operating gowns, operating drapes, sterilization packs, dressings, sutures and orthopaedic pads. Key Indian manufacturers in the segment include for baby diapers as Unimin India Limited and Fiberweb Pvt. Limited, for sanitary napkins as Procter and Gamble, Johnson and Johnson and Kimberley Clark Lever, for surgical disposables as Thea-Tex Healthcare Pvt. Limited, Mediklin Healthcare Limited and Sivshree Medittex India Pvt Limited, for surgical sutures as Johnson and Johnson, Centennial Surgical Suture Limited and Futura Surgicare Pvt. Limited, for surgical dressing material as Johnson and Johnson India, Lavino Kapoor, and Dr. Sabharwal Laboratories, for artificial vascular grafts as TTK Healthcare in collaboration with Sri Chitra Tirunal and for artificial tendon (mesh) as TTK Healthcare in collaboration with Sri Chitra Tirunal.

Such technical textiles do not have civil engineering applications.

Mobiltech

These are the technical textiles used in automobile applications including in cars, buses, trains, ships and aircrafts. Mobiltech products can be broadly classified into two categories as visible components and concealed components. Visible components include seat upholstery, carpets, seat belts, headliners, etc. Concealed components include noise vibration and harness components, tyre cords, liners, composite reinforcements for automotive bodies, civil and military aircraft bodies, wings and engine components etc. Key Indian manufacturers in the segment include for seat belts as IFB Autoliv India, Abhishek Auto Industries, Bond Safety Belt and Rane TRW, for seat covers as Faze Three Limited, Shamken Multifab and Bhilwara Melba Limited, for automotive interior carpets as Uniproducts India, Bajaj Carpets, Hitkari Fibres and Supreme Non-wovens, for headliner fabrics as Uniproducts (I) Limited and Supreme Non-woven Pvt Limited, for insulation felts as Uniproducts India and Supreme Treves Pvt. Limited, for nylon tyre cord fabric as SRF and Century Enka and for airline disposables as Chaitanya fibres and JMDI Group.

These technical textiles are used in automobile applications hence also in machinery and

equipment used in civil engineering applications.

Oekotech

Oekotech means eco+tech and thus are the technical textiles used for ecological or environmental functions such as geo-membranes, geo-composites and clay liners used for waste and hazardous waste management. Though oekotech are classified separately but they are also sometimes combined with other technical textiles like indutech, geotech, agrotech and indutech. They overlap with indutech for filtration media, geotech for erosion protection, insulation and containment of toxic waste and agrotech for minimizing water loss from the land and reducing the need for use of herbicides by providing mulch to plants. The products under Oekotech segment can include geomembranes, geosynthetic clay liners from geotech segment, and air and water filters from indutech segment etc.

These are largely used in barrier applications where leakages are to be prevented likely to pollute the environment like ground water or even can be used for avoiding leakages due to storage required.

Packtech

These are the technical textiles used for packing applications such as woven sacks, leno bags, jute hessian sacks, soft luggage products, tea bags etc. Traditionally cotton, flax and jute were used for bags and sacks but now polypropylene is being used increasingly. For packing various civil engineering products including cement, such technical textiles are used. Key Indian manufacturers in the segment include Texplast Industries, Tulsyan NEC and Rishi Techtex for Raffia, VIP industries Universal Luggage for soft luggage, and Cheviot Co Limited and Gloster Jute Mills Limited for Jute hessian and sacks. Packtech are used indirectly through bags used in various applications for construction materials but they are not directly used.

Protech

Protech are the technical textiles used for protection or safety from hazardous conditions like bullet proof jackets, nuclear, biological and chemical (NBC)suits, high altitude clothing, and fire retardant clothing. Key Indian manufacturers in the segment include Tata Advanced Material Limited and Anjani Technoplast for bullet proof jackets, Rajasthan Weaving and Spinning Mills Limited and Jaya Shree Textile for chemical coated fire retardant fabrics, Trevira from Reliance Netherlands B.V. and Rajasthan Weaving and Spinning Mills Limited for inherent fire retardant fabric, Tara Lohia Pvt. Limited and Mallcom India Limited for fire/flame retardant apparel, The Ordnance Factory for NBC suits, Reflectosafe and Intech Safety Private Limited for high visibility clothing, Northstar Safety Products Pvt. Limited (Chandigarh), Intech (Kolkata) and Jyotech Engineering Co. Pvt. Limited for chemical protection clothing, Ordnance Factory Board and Entermonde Polycoaters for high altitude clothing, and Mallcom India Limited, Rajda Industries and Exports Pvt. Limited for industrial gloves.

Such technical textiles do not have civil engineering applications though they may be required in some safety clothing required for the workers in particular situation.

Sporttech

As the name indicates, these are the technical textiles used for sports applications such as artificial turf, parachute fabrics, ballooning fabrics, sail cloth, sleeping bags, sport nets, swimwear, sports shoes, sports composites like footballs, volleyballs, basketballs etc. Key Indian manufacturers in the segment include for sports composites as Sanspareils Greenlands Pvt Limited, Soccer International Pvt Limited and Mayor International Limited, for parachute fabrics as Kusumgar Associates (Mumbai), Oriental synthetics and Rayon Mills Pvt. Limited (Mumbai), for ballooning fabrics as Bandhu Aerospace Private Limited, for sleeping bags as Standard Gram Udyog Sansthan, Kanpur Tent Factory and Mahalaxmi Textile Industries, for sport nets as Garware Wall Ropes and Kwality Nets, for shoe components manufacturers as Reebok, Adidas, Nike, Bata, Liberty, Lakhani and Relaxo, and for tent fabrics as M Kumar Udyog, Madhur Enterprises Pvt. Limited (Kanpur) and Tirupati Taxco Product Pvt. Limited.

They are used for sports facilities and thus for specific requirements of sport turfs sometimes may be required.

Standards and Specifications

Bureau of Indian Standards (BIS) has already brought out standards and specifications on most of the materials and applications of technical textiles. Therefore, they can be used for various applications with confidence.

Various departments like Central Public Works Department and state PWDs have already started bringing out the items of geotech in their Schedule of Rates. IRC has also published standards and guidelines for use of geotech in road works. CPWD has already issued OMs for their use and also included Geotech in DSR. The following items are included in the DSR;

1. Supplying & laying of bi-axial extruded high modulus polypropylene geogrid conforming to MORTH Specifications for base/sub-base reinforcement having minimum tensile strength 15kN/m in the longitudinal and transverse direction, with 5kN/m and 7kN/m tensile strength at 2% and 5% strain respectively in the longitudinal and transverse direction, junction efficiency not less than 95% and with 38mm X 38mm mesh opening.

2. Supplying & laying of bi-axial extruded high modulus polypropylene geogrid conforming to MORTH Specifications for base/sub-base reinforcement having minimum tensile strength 20kN/m in the longitudinal and transverse direction, with 7kN/m and 14kN/m tensile strength at 2% and 5% strain respectively in the longitudinal and transverse direction, junction efficiency not less than 95% and with 38mm X 38mm mesh opening.

3. Supplying & laying of bi-axial extruded high modulus polypropylene geogrid conforming to MORTH SPECIFICATION for base/sub-base reinforcement having minimum tensile

strength 30kN/m in the longitudinal and transverse direction, with 10.5 kN/m and 21kN/m tensile strength at 2% and 5% strain respectively in the longitudinal and transverse direction, junction efficiency not less than 95% and with 38mm X 38mm mesh opening.

4. Supplying & laying of bi-axial extruded high modulus polypropylene geogrid for base/sub-base reinforcement having minimum tensile strength 40kN/m in the longitudinal and transverse direction, with 14kN/m and 28kN/m tensile strength at 2% and 5% strain respectively in the longitudinal and transverse direction, junction efficiency not less than 95% and with 38mm X 38mm mesh opening.

5. Supplying and laying high strength flexible geogrids (HSFG) as soil reinforcement / basal reinforcement as per MORTH 3100 and IRC 113, made of high tenacity polyester core with polyethylene coating with minimum Long Term Design Strength (LTDS) of more than 50% of ultimate tensile strength at 30 degree Celsius corresponding to 12% strain.

    i. Ultimate tensile strength- 100 kN/m sqm
    ii. Ultimate tensile strength- 150 kN/m sqm
    iii. Ultimate tensile strength- 200 kN/m sqm
    iv. Ultimate tensile strength- 250 kN/m sqm
    v. Ultimate tensile strength- 300 kN/m sqm
    vi. Ultimate tensile strength- 350 kN/m sqm
    vii. Ultimate tensile strength- 400 kN/m sqm
    viii. Ultimate tensile strength- 500 kN/m sqm
    ix. Ultimate tensile strength- 600 kN/m sqm
    x. Ultimate tensile strength- 700 kN/m sqm
    xi. Ultimate tensile strength- 800 kN/m sqm
    xii. Ultimate tensile strength- 900 kN/m sqm
    xiii. Ultimate tensile strength- 1000 kN/m sqm
    xiv. Ultimate tensile strength- 1100 kN/m sqm
    xv. Ultimate tensile strength- 1200 kN/m sqm

6. Supplying & laying of drainage composite for use behind walls, between two different fills, alongside drains of road, below concrete lining of canals etc. Geocomposite for planar drainage, realized by thermo bonding a draining core in extruded monofilaments with two filtering nonwoven geotextiles that may also be working as separation or protecting layers. The draining three dimensional core will have a “W” configuration as

longitudinal parallel channels. Minimum thickness to be 7.2mm, with two filtering UV stabilized polypropylene nonwoven geotextile of minimum thickness of 0.75mm characteristic opening size (O90) of 110 micron and tensile strength of 8.0 kN/m that will be working as separation or protecting layer, geocomposite having in plane flow capacity of 2.1 L / (m.s) at hydraulic gradient of 1.0 & 20 kPa pressure and tensile strength of 18 kN/m , with mass per unit area of 740 gsm, supplied in the form of roll for easy transportation to site of work as per detailed specification all complete as per directions of Engineer in charge.

7. Supplying & laying of drainage composite for use behind walls, between two different fills, alongside drains of road, below concrete lining of canals etc. having thermobonding a draining core – HDPE geonet comprises of two sets of parallel overlayed ribs integrally connected to have a rhomboidal shape with a polyethylene film and a nonwoven geotextile having mass per unit area 130 gsm and tensile strength of 8.0 kN/m that will be working as separation or protecting layer, geocomposite having in plane flow capacity of 0.7 L / (m.s) at hydraulic gradient of 1.0 & 20 kPa pressure and tensile strength of 13.5 kN/m , with mass per unit area of 830 gsm, at easily accessible location including top and bottom, with all leads and lifts, manpower and machinery, materials, labour etc. Complete and as directed by Engineer -in - Charge.

Technical Textiles in Civil Engineering applications

Any civil engineering structure requires large number of building materials, electrical installations, fire protection measures and horticulture works. Civil engineering structures include buildings, roads, railway structures, bridges, flyovers, irrigation structures, dams, flood protection works, soil retaining structures, stadia and even nuclear structures. Therefore, large numbers of technical textiles are directly or indirectly used in civil engineering structures.

Market size of technical textiles is ever increasing hence Government of India has already brought out various schemes to encourage use of technical textiles and also manufacture of such products in the country.

Use of geotech has already replaced conventional RCC in retaining walls, embankments, approaches to bridges, flyovers etc. Further geotech has also found useful applications in environmental applications, ground stabilization and ground improvement, gabions, slope stabilization, road works, and drainage and filtration applications. From 2010-11 to 2015-16, use of geotech increased to more than double in terms of cost and thus use of technical textiles will increase in the country manifolds in coming time.

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APPLICATIONS OF GEO-COMPOSITE DRAINS FOR CAPILLARY CUT-OFF AND HORIZONTAL SUB-SURFACE DRAINAGE IN HIGH ALTITUDE ROADS IN UTTARAKHAND

D.Roychowdhury, Chief Engineer, CPWD

Geosynthetics include Geotextiles, Geogrids, Geocomposites, Geonets, Geofoams, Geodrains and Geomembranes. Thus, these are one of the types of Technical Textiles, normally called as Geotech. Geosynthetics have found their way into the design and construction of road infrastructure in a big way in the recent years. Each type of geosynthetic material has its specific use under specific or different situations. Amongst these, geotextiles have been the most widely used form, especially in the road infrastructure sector. Geotextiles were originally intended to be an alternative to granular filters used in erosion control works, and as such are also known as filter fabrics – though now they find use in many other applications.

The engineering properties of the geotextiles depend on the polymer used for its manufacture, the type of fiber and the fabric style. Polypropylene, Polyester, Polyethylene and Polyamide (nylon) are the types of polymers used for making geotextiles for majority of applications. The polymers are used in the form of fibers (monofilament, multifilament, staple fiber, slit-film monofilament and slit-film multifilament) which are woven into yarns. The yarn strength, elongation at failure and Young's modulus depends on the type of fibers and their manufacturing process. Subsequently, the yarn is converted to fabric, which can be woven, non-woven or knitted. Again the processes have immense impact on the engineering properties of the finished fabric. In the case of geocomposites, different types of geosynthetic materials are put together to achieve a specific set of properties and use.

Geotextiles find four distinct uses in geotechnical engineering applications according to the function;

i) Separation of dissimilar materials placed contiguously to avoid intermixing

ii) Reinforcement (or other load bearing materials like flyash, slag, etc.)

iii) Filtration, where the water flows across the textile and works to retain the fines

iv) Drainage, where the water flows within the geotextile (in-plane) In most cases, the geotextile performs more than one function. Thus, the textile is to be designed for each application separately considering the engineering requirements.

More about Geocomposites

Geocomposites are manufactured as a combination of any two or more synthetics materials like geotextiles, geogrids, geonets, geomembranes, etc. in laminated or composite form to achieve desired engineering properties. One of the popular and extensively used geocomposite is a drainage geocomposite, which is formed by combining a geotextile with a

geonet, or polymeric mesh or cuspated sheets and yield much higher flow properties than even very thick geotextiles.

In the present context, essentially the capillary break and drainage function of the geocomposite material is being discussed. The drainage function can be achieved by using plain geotextiles for low volumes of flow water. For higher water flow conditions, different types of drainage geocomposites can be used. Drainage geocomposites essentially consist of a drainage core of high in-plane flow capacity sandwiched between geotextiles on one or both sides. The drainage core is usually HDPE geonet or mesh with high void ratio, whereas the geotextile provides separation, filtration, some drainage and capillary break actions. The capillary break is provided by draining out the capillary water through the drainage core. The selection of geocomposites depends on site specific soil and moisture conditions, availability and cost considerations.

Drainage geocomposites are used in three common applications;

a) Prefabricated Vertical Drains (PVD, also called wick drains or band drains), which are used for consolidation of Soft clays by draining out ground water. Coupled with surcharging, they expedite consolidation of otherwise slow draining soils.

b) Sheet Drains are planar composites with a drainage core and geotextiles on both sides and often works as a capillary break along with drainage function. Sheet drains are designed based on the hydraulic head available and the compressive stresses (cross-plane) that tend to reduce the flow capacity.

c) Highway Edge Drains which accumulates the water from the granular sub-base and carries it to a preferred outlet. The geocomposite edge drain is typically installed between the GSB/CRM crust and the shoulder.

Flow performance of geo-composites deteriorates over the time due to;

i) Elastic deformation of the adjacent geotextile intruding into the drainage core space

ii) Creep deformation of the drainage core itself and / or creep deformation of the adjacent geotextile intruding into the drainage core space

iii) Chemical clogging of the geotextile and / or drainage core

iv) Biological clogging of the geotextile and / or drainage core

Usually manufacturers provide reduction factors for different range of products and different application areas so as to provide allowable flow rate to be used in design. The short term flow rate is determined from short term tests as per relevant codes.

Why Horizontal Drainage Requirements?

It is well known that ingress of water into the pavement crust is one of the major causes of distress in flexible pavements. Water in the asphalt surface leads to loss of tensile strength,

stripping of bitumen from aggregate, and in reduction of stiffness modulus of the order of 30%. Moisture in the unbounded base and sub-base layers leads to loss of stiffness of around 50%, thereby causing large deformation under load in flexible pavements. It causes erosion of fine aggregates/soil, erosion of shoulders, and eventually ruts and pot-holes (IRC SP 42-2014). Research has also shown that if the structural section remains saturated even 10% of the time, the life of the pavement may reduce upto 50%.

In hill roads on cutting side, the source of water can be from rainfall, snow melt, seepage of water, waterfalls, capillary rise of water from the soil sub-grade etc. Water enters the crust through cracked / rutted surface, joints and edges, pervious shoulders, and pervious/damaged side-drains etc. Surface drainage and sub-surface drainage are required for keeping the structural elements of the pavement in well drained conditions though the latter having been mostly neglected in practice. Sub-surface drainage requirement is in both vertical (behind retaining and breast walls) as well as horizontal (open graded granular sub-base). However, with the advent of geo-textiles and geo-composites, good quality vertical as well as horizontal subsurface drainage options are available.

In case of hill roads in the Himalayan region, many situations are seen where the phreatic line comes out of the cut slope surface, leading to seeping surfaces. This situation is more prolific in the summer seasons when the snow melts in the upper reaches and otherwise dry hillsides start seeping water. Since most areas of this region have soil boulder mix, vertical drains in the hillsides (IRC 34 – 2011) are generally not feasible due to presence of boulders.

The requirements of a good horizontal geocomposite drain are;

i) Sufficient stiffness to support traffic without significant deformation under dynamic loading

ii) Inflow capacity greater than infiltration from adjacent layers

iii) Sufficient transmissivity to rapidly drain the pavement section and prevent saturation of the base, and

iv) Sufficient air voids within the geocomposite to provide a capillary break.

Case Study: A Pilot in Uttarkashi Region of Himalayas

The Border Road Circle, CPWD, New Delhi, with all support of the Border Fencing Zone, New Delhi, has executed two small patches of approximately 20m road length with a properly designed horizontal geocomposite drain at a location where subsurface water was rising to the top of base course. The work was executed on the 10th of October 2017 under very cold conditions. After considering the available options in the market and very small working window available, the product MacDrain W-1071 was chosen for the particular site. It is a first of its kind application in hill roads in India. Some important site conditions and product specifications are as given below;

Road is through cutting in hard rock. The crust consists of 200mm Crusher Run Macadam,

60mm Dense Bituminous Macadam and 40mm Bituminous Concrete. The Geo-Composite Drain (GCD) has been placed over a sand bed of 100mm overlaid on rocky subgrade. The GCD has been laid in 3% slope and covered with 100mm sand bed before laying the CRM and compacting. The sand layers are provided to avoid construction damage by pointed rock pieces. The geo-composite consists of extruded monofilament UV stabilized PP core laid in longitudinal channels in the drainage direction, with two needle punched thermally bonded non-woven PP geotextiles on both sides. The GCD has a mass of 740 g/m2, thickness 7.2 mm at 2 kPa, in-plane flow capacity (main direction) of 2.10 litres/(m.sec) at 20kPa soft/soft contact and hydraulic gradient of 1.0. The geotextiles have a Characteristic opening size (O90) of 110 micron, static puncture resistance of 1400N and cross plane flux of 100 litres/(m2.s).

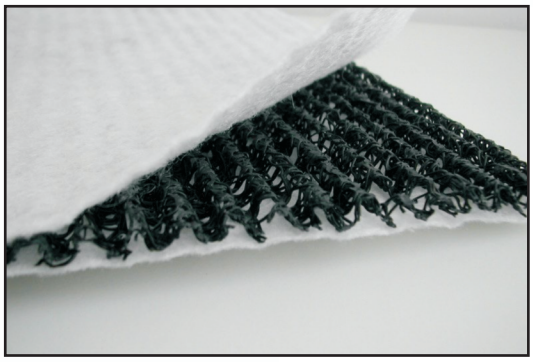


Fig. 1: Geocomposite MacDrain W-1071



Fig. 2: See page water visible on CRM surface before installation



Fig. 3: Geocomposite drain being rolled out for cutting



Fig. 4: GCD laid in slope and being covered by sand layer

The installation stretches are being monitored during the working season when the roads are in operation, to gauge the effectiveness of the horizontal sub-surface drainage system. In the snow melting season of 2018, no distress or water accumulation on pavement surface has been observed.

The Way Forward

During the design and execution of the pilot project, some issues were encountered which need further deliberations and resolution. Some of them are as given in the following;

- The present MoRTH specifications and IRC 34-2011 are at variance regarding the properties of geocomposites. The former specifies the mass per unit area of the core as

710g/m2 whereas the latter specifies the same mass per unit area for the full composite. Typically, relevant engineering properties should govern the selection of the material with the mass per unit area only provided for logistics etc.

- The properties of geocomposites given in Section 4 (Drainage) of IRC 34-2011 and Section 7 (Capillary Cut-off) are different. It is not clear as to why they are different and what are the considerations for arriving at the same?
- In case of a drainage geocomposite, the confining condition (hard-hard, or hard-soft or soft-soft) under which the geocomposite operates, influences the drainage properties, especially the long term design properties. The laboratory conditions are usually hard-hard whereas the site conditions are generally soft-soft. The Indian codes and specifications are entirely silent on this aspect.

There is a need to carry out more pilot projects for the stretches of different soils and for different types of geotextiles and geocomposites like PVDs, edge drains etc. by project units so as to gain confidence in the use of this new and very efficient material.

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Acknowledgements

The untiring efforts of Shri Vinay Sheel Saxena, Assistant Engineer (Civil) and Shri Net Ram, Junior Engineer (Civil) of Border Road Sub-Division, Harshil, Uttarakhand for getting the work executed in extremely cold and windy conditions at an altitude of about 14,000 feet is commendable and acknowledged. Shri Ankit Kachhal, Senior Engineer from M/s Maccaferri Environmental Solutions Pvt. Ltd. was present at site during installation and gave valuable inputs regarding handling, storage and installation of the product.

FLY ASH AS A RESOURCE MATERIAL

D. S. Panwar, Executive Engineer, CPWD, New Delhi

Abstract

Traditionally, ash (Fly ash and bottom ash) generated at coal/lignite based thermal power stations has been disposed off in ash ponds as waste material. Ash has now been recognized as a 'resource material' and 'useful commodity' capable of being utilized in most of the civil construction activities in an eco friendly manner. Fly ash has pozzolanic properties and has large number of applications in various construction activities.

Introduction

Fly ash is a fine powder that is a byproduct of burning pulverized coal in electric generation power plants. Fly ash is a pozzolan, a substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water, fly ash forms a compound similar to Portland cement. This makes fly ash suitable as a prime material in blended cement, mosaic tiles, and hollow blocks, among other building materials. When used in concrete mixes, fly ash improves the strength and segregation of the concrete and makes it easier to pump. Fly ash or flue ash, also known as pulverized fuel ash in the United Kingdom, is a coal combustion product that is composed of the particulates (fine particles of burned fuel) that are driven out of coal-fired boilers together with the flue gases. Ash that falls to the bottom of the boiler is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler, it is known as coal ash. Depending upon the source and composition of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (S_iO_2) (both amorphous and crystalline), aluminum oxide ($Al2O_3$) and calcium oxide (C_aO), the main mineral compounds in coal-bearing rock strata.

In the past, fly ash was generally released into the atmosphere, but air pollution control standards has now been made it mandatory that it should be captured prior to release to the atmosphere by fitting pollution control equipment. In the United States, fly ash is generally stored at coal power plants or placed in landfills. About 43% is recycled, often used as a pozzolan to produce hydraulic cement or hydraulic plaster and a replacement or partial replacement for Portland cement in concrete production. Pozzolans ensure the setting of concrete and plaster and provide concrete with more protection from wet conditions and chemical attack.

It is important to understand that natural resources are depleting day by day and the area available for land filling is also reducing at a good rate. Recycling also costs less than throwing away in almost all cases. It is therefore imperative to look for alternative methods that would lead to sustainable living. Utilizing C&D waste may or may not be the best possible solution for the problem, but it is certainly better than depleting natural resources.

Types/Class of Fly Ash

There are two common types of fly ash: Class F and Class C. Class F fly ash contains particles covered in a kind of melted glass. This greatly reduces the risk of expansion due to sulfate attack, which may occur in fertilized soils or near coastal areas. Class F is generally low-calcium and has carbon content less than 5 percent but sometimes as high as 10 percent.

Class C fly ash is also resistant to expansion from chemical attack. It has a higher percentage of calcium oxide than Class F and is more commonly used for structural concrete. Class C fly ash is typically composed of high-calcium fly ashes with a carbon content of less than 2 percent.

Currently, more than 50 percent of the concrete placed in the U.S. contains fly ash. Dosage rates vary depending on the type of fly ash and its reactivity level. Typically, Class F fly ash is used at dosages of 15 to 25 percent by mass of cementitious material, while Class C fly ash is used at dosages of 15 to 40 percent.

Important Areas of Ash Utilization

Fly ash can be used as prime material in many cement-based products, such as poured concrete, concrete block, and brick. One of the most common uses of fly ash is in Portland cement concrete pavement or PCC pavement. Road construction projects using PCC can use a great deal of concrete, and substituting fly ash provides significant economic benefits. Fly ash has also been used as embankment and mine fill, and it has increasingly gained acceptance by the Federal Highway Administration.

The rate of substitution of fly ash for Portland cement typically specified is 1 to 1 1/2 pounds of fly ash for 1 pound of cement. Accordingly, the amount of fine aggregate in the concrete mix must be reduced to accommodate the additional volume of the fly ash.

The important areas in which ash is being presently utilized are as under:

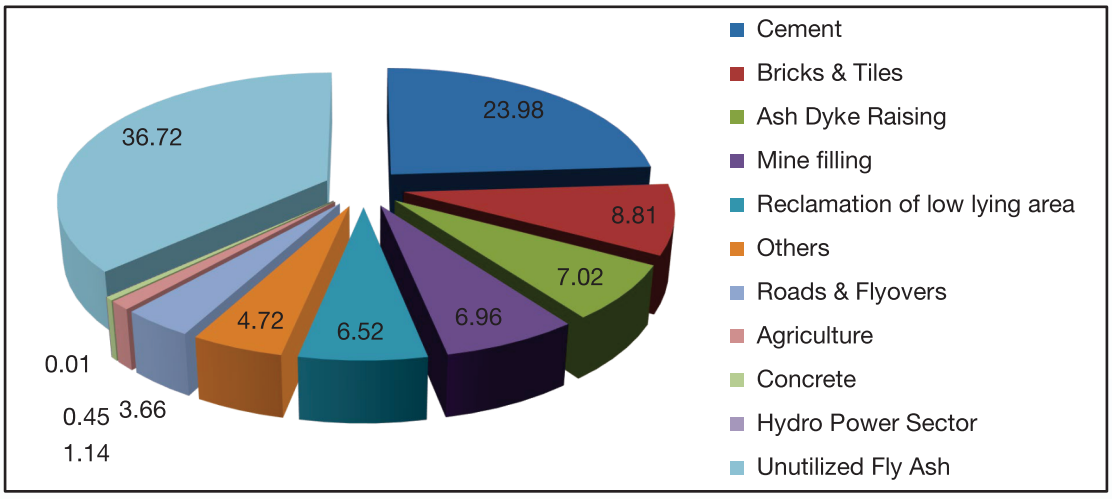
- In manufacturing of Portland Pozzolana cement
- As a part replacement of cement in concrete
- In making fly ash based building products like bricks, blocks, tiles, road blocks, kerb stones etc.
- In the construction of roads, flyovers, embankments, ash dykes etc.
- In construction of Roller Compacted Concrete Dams in Hydropower Sector
- In reclamation of low lying areas and raising of ground level
- Backfilling/stowing of mines
- In agriculture and waste-land development

Status of fly ash generation and its utilization

Description	Status in Year 2016-17
Nos. of Coal/Lignite based Thermal Power Stations from which data was received	155
Data received for an installed capacity(MW)	157377
Coal consumed(Million ton)	509.46
Ash content (%)	33.22
Fly Ash Generation (Million ton)	169.25
Fly Ash Utilization (Million ton)	107.10
Percentage Fly Ash Utilization	63.28%

Major Modes of Fly Ash Utilization

Sl. No.	Modes of utilization	Fly ash utilization in the Year 2016 - 17	
		Quantities(Million - ton)	Percentage (%)
1.	Cement	40.59	23.98
2.	Bricks & Tiles	14.91	8.81
3.	Ash Dyke Raising	111.89	7.02
4.	Mine filling	11.78	6.96
5.	Reclamation of low lying area	11.04	6.52
6.	Others	7.98	4.72
7.	Roads & Flyovers	6.19	3.66
8.	Agriculture	1.92	1.14
9.	Concrete	0.76	0.45
10.	Hydro Power Sector	0.02	0.01
11.	Unutilized Fly Ash	62.16	36.72



Environmental problems

Groundwater contamination

Since coal contains trace levels of trace elements (like e.g. arsenic, barium, beryllium, boron, cadmium, chromium, thallium, selenium, molybdenum and mercury), fly ash obtained after combustion of this coal contains enhanced concentrations of these elements, and therefore cause groundwater pollution.

Exposure concerns

Crystalline silica and lime along with toxic chemicals represent exposure risks to human health and the environment. Fly ash contains crystalline silica which is known to cause lung disease, in particular silicosis. Crystalline silica is listed by the IARC and US National Toxicology Program as a known human carcinogen.

Lime (CaO) reacts with water (H2O) to form calcium hydroxide [Ca(OH)2], giving fly ash a pH somewhere between 10 and 12, a medium to strong base. This can also cause lung damage if present in sufficient quantities.

Material Safety Data Sheets recommend a number of safety precautions be taken when handling or working with fly ash. These include wearing protective goggles, respirators and disposable clothing and avoiding agitating the fly ash in order to minimize the amount which becomes airborne.

The National Academy of Sciences noted in 2007 that "the presence of high contaminant levels in many CCR (coal combustion residue) leachates may create human health and ecological concerns".

Fly Ash Benefits

Fly ash can be a cost-effective substitute for Portland cement in many markets. Fly ash is also recognized as an environmentally friendly material because it is a by-product and has low embodied energy, the measure of how much energy is consumed in producing and shipping a building material. By contrast, Portland cement has a very high embodied energy because its production requires a great deal of heat. Fly ash requires less water than Portland Cement and is easier to use in cold weather. Other benefits include:

- Produces various set times
- Cold weather resistance
- High strength gains, depending on use
- Can be used as an admixture
- Considered a non-shrink material
- Produces dense concrete with a smooth surface and sharp detail

- Great workability
- Reduces crack problems, permeability, and bleeding
- Reduces heat of hydration
- Allows for a lower water-cement ratio for similar slumps when compared to no-fly-ash mixes
- Reduces CO_2 emissions

Fly Ash Drawbacks

Smaller builders and housing contractors may not be familiar with fly ash products, which can have different properties depending on where and how it was obtained. Additionally, fly ash applications may face resistance from traditional builders due to its tendency to effloresce along with concerns about freeze/thaw performance. Other concerns about using fly ash in concrete include:

- Slower strength gain
- Seasonal limitation
- Increased need for air-entraining admixtures
- Increase of salt scaling produced by higher proportions of fly ash

Case Study

Use at Additional Office Complex for the Supreme Court of India

The construction of Additional office Complex for the Supreme Court of India is being executed by CPWD at Gate no9, Pragati Maidan, New Delhi. The external load bearing walls have been constructed with the C&D block masonry M10 grade of block size 400x200x100 mm. The internal partition walls and panel walls have been made from AAC blocks as non load bearing walls in the construction of Additional Office Complex for the Supreme Court of India. Autoclaved Aerated Cement blocks masonry with 200mm thick AAC blocks and 2 nos. 6mm dia M.S. bars at every third course of masonry work has also been used to avoid cracks in the masonry.

Properties of AAC blocks

Size: 600x200x200 mm

Block Density: 572 Kg/m3

Compressive Strength: 4.8 N/mm2

Water absorption: 8 to 10%

Drying Shrinkage: 0.012%

Base price per piece (600x200x200 mm)=Rs.44.75/-

Present Rate of masonry per cum=Rs.5000 to 5200 per cum



Fig: AAC Blocks



Fig: Placement of bars

Requirement for improvement

- The holding capacity for anchor and hold fast for door window fittings is not good
- Jambs need to be made of some other materials like C&D waste blocks etc for holding the hold fast and anchors etc for durability.

- Vertical bands should also be provided for separating panels to avoid cracks in future.

Conclusions

- Waste management is the most important in today's scenario. Reduce, Reuse and Recycle, is important for conservation of Energy, Economy, and Environment.
- Natural resources are depleting day by day so it is need of the hour to reuse the waste product and by product for sustainable.
- Annual Fly Ash utilization has remained about 60% of fly ash generated and therefore, it has become a matter of concern in view of its adverse environmental effect and its progressive accumulation may lead to situation when ash pond may not be in a position to accommodate fly ash further.
- The fly ash generation is increasing in such a proportion that it will not be possible for cement industry alone to utilize the same. New avenues of gainful utilization of fly ash have to be found and promoted.
- The use of clay bricks need to be banned completely and use of fly ash and other blocks made from waste product and by product to be used and to be made mandatory.
- Policy frame work on utilization of Fly Ash and Slag is to be made on priority.
- Utilization of fly ash in cement concrete is limited due to lack of required information to actual users like State/Central Govt construction department, builders, developers etc
- Guidelines must be issued and enforced for use of fly ash bricks and other construction materials made from fly ash.

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MANAGING C&D WASTE- MCD INITIATIVE

Vishv Ratan Bansal, Superintending Engineer (NDMC)
Sh. Arun Sharma Sr. Executive, IL & FS.

India is a rapidly growing economy leading to increased urbanization and industrialization. This requires large scale infrastructural development. The Pradhan Mantri Awas Yojna, which has set ambitious targets for dwelling units, has also given boost to construction industry. This has further resulted into increased demand of building materials. Studies indicate a shortage of aggregates to the extent of 55 billion cubic metre. Such shortfall between demand and supply leads to increased pressure on natural sources.

This surge in infrastructural development has also resulted into generation of large amount of construction and demolition waste. As per TIFAC (Technological information, Forecasting & Assessment council, Deptt. of Science and Technology, GoI), estimated waste generation during construction work is 40 to 60 kg/sq.m. Similarly, demolition of pucca/semi-pucca buildings generates an average of 300-500 Kg/sq.m. Additionally, large quantity of waste is generated from Infra projects e.g. roads, flyovers, bridges etc.

The study conducted by CPCB and NEERI in 2005, covering 59 cities, estimate the solid waste generation in India as 48 million tonnes per annum. However, Press Information of India report 2016 (PIB 2016) estimates this figure as 62 million tonnes/annum with an average annual growth rate of 4%. Construction and Demolition waste is taken to be 25% of it.

Till few years back, construction and demolition waste was mostly used to fill low-lying lands or more commonly, dumped in unauthorized manner on road sides or unused private/public land.

Swachh Bharat Abhiyan, launched on 2nd October 2014 envisages processing of 100% of solid waste generated in cities and towns by 2nd October 2019, which includes Construction and demolition waste.

Definition of C&D Waste

Experts give varied definitions of Construction and Demolition (C&D) waste. Some even prefer defining it separately however, with the enactment of C&D waste rules, 2016 by Govt. of India, there is an inclination to accept the definition of C&D waste given therein.

Construction and demolition (C&D) waste Management Rules, 2016 define the C&D waste as the "waste comprising of building materials, debris and rubble resulting from construction, re-modeling, repair and demolition of any Civil Structure."

Problems from C&D Waste

C&D waste is difficult to dispose of and due to its bulky nature, requires much space for disposal. Unauthorized contractors very often dump the C&D waste in low-lying areas and

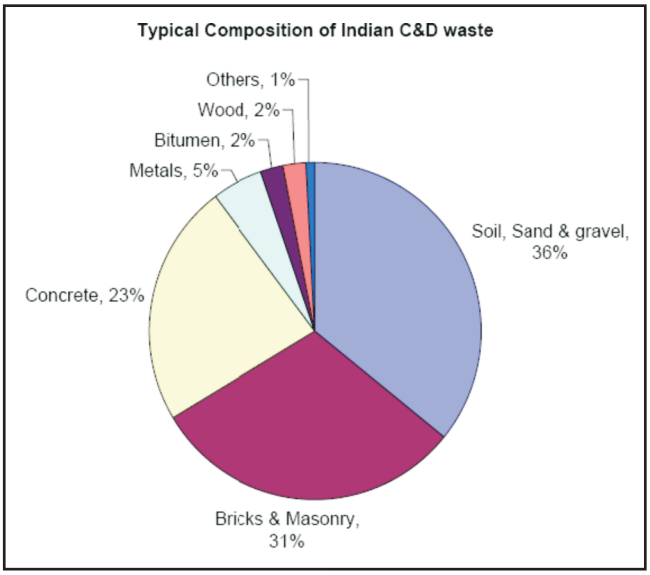
even water bodies, severing both, their area as well as depth. When dumped on roadside, it restricts the mobility of commuters as well.

As lot of dust is generated in both, construction and demolition activities, C&D waste is, thus, one of the major contributors of environmental pollution which is the cause of many health problems.

Composition of C&D waste

C&D materials often contain bulky, heavy materials, such as

- Bricks, rubble or other masonry materials
- Soils, trees, or any type of vegetation;
- Rock
- Wood (included painted, treated and coated wood and wood products)
- Land clearing debris
- Wall covering, plaster, dry wall
- Plumbing fixtures
- Non-hazardous insulation
- Glass
- Roofing, waterproofing material and other roof coverings
- Asphalt pavement
- Plastics, paper, gypsum boards, electrical wiring etc.



C&D waste majorly consists of 36% of sand/gravel, 31% of bricks, 23% of concrete and rest consisting of wood, metals etc.

C&D waste from individual households finds its way into nearby municipal bins and waste storage depots, making the municipal waste heavy, and degrading its quality for treatments such as composting or energy recovery.

Legal Framework

Till a couple of years back, there were no proper laws concerning management of C&D waste. C&D waste was briefly included in the "Municipal Solid Waste (management and handling) rules, 2000" but there were no details, except a brief mention in Schedule II of the rule for its separate collection. Now, Ministry of Environment, Forest and Climate Change, Govt. of India has notified the rules specifically for the management of C&D Waste. These

rules are titled "Construction and Demolition Waste management Rules, 2016" and extensively deal with the management of C&D Waste.

The major provisions of these rules, which are based on the principle of "polluter pays", are:

- Duties of various stakeholders i.e. waste generator, service provider, pollution controlling bodies, legislatives, Standards formulating authorities etc. clearly defined.
- Every waste generator shall be responsible for collection, segregation and storage of construction and demolition waste generated and deposit at collection center or handover it to the authorized processing facilities, besides ensuring that there is no littering.
- Large generators (generating 20 mT per day or 300 mT per project) shall pay relevant charges for collection, transportation, processing and disposal as notified by the concerned authorities:
- Makes it mandatory to use C&D recycled products in various civil works, ranging from 2% in building works to 10% in road works.
- Based on the population (based on 2011 census of India), Cities (starting from population of 0.5 milion) shall commission the processing and disposal facility in their jurisdiction within one-and-a-half years to three years from date of final notification of these rules.
- SPCB shall grant authorization to construction and demolition waste processing facility and shall also monitor the implementation of these rules by the concerned local bodies/authorities.
- Criteria of site selection for setting up of C&D waste plant also defined.
- Timeframe for implementation of these rules also specified.

Govt. of NCT of Delhi has also issued an advisory in this regard, mandating installation of on-site C&D waste processing plant in redevelopment projects costing more than 500 crores and directed the same to be included in all relevant civil works tenders for strict compliance.

MCD Initiative

Based on the then estimated C&D waste generation of about 2000 MT/day in Delhi, the unified Municipal Corporation of Delhi signed an agreement with IL&FS Environmental Infrastructure & Services Limited for a pilot project at Jahangirpuri (Burari) for Collection, Transportation and Processing of 500 MT/day of C&D waste. The project is based on PPP model (Public Private Partnership) and is the first successfully implemented project of its kind in the country.

Under the PPP agreement, the concessionaire was made available, for a period of 10 years, a plot of area 34,000 sq.m. for setting up the plant and 7.0 acres of adjoining land for storing the dumped C&D waste. The initial cost of setting up of the plant was Rs. 20 Cr. which comprises

of Rs.14.0Cr. As capital cost and Rs. 6.0 cr. as working capital. The plant uses hydro-cyclone technique which is a specialized separation mechanism to separate micro-fine particles from fine particles.

The capacity has subsequently been increased to 2000mTPD in 2012.

Buoyed by the success of this plant, another facility with capacity of 1500 mTPD has been planned by North DMC at Ranikhera in North-West Delhi.

Following the footsteps, East Delhi Municipal Corporation has also set up another facility for 500 mTPD in Shastri Nagar in Shahdara, Delhi. South Delhi Municipal Corporation has also taken up setting up similar facility in Bakkarwala with 500 mTD capacity.

Innovations

Earlier the entire C&D Waste used to be sent to Sanitary Land Fill (SLF) sites alongwith the Municipal Solid Waste (MSW), causing extra load on already over-flowing SLF Sites. With the implementation of this project, the C&D Waste is separated from MSW and re-cycled /re-used into useful building material. This, in turn, will help improve the life of such land fill sites.

This is first project of its kind in the country and selection of processing equipment as well as methodology adopted for processing has had to go a number of reiteration / improvements. Due to the hydrogenous nature of incoming C&D Waste, the production process as well as the technology adopted for re-cycling has had to be constantly fine-tuned and now, about 95% of incoming C&D waste is recovered.



Fig. 1: Project Site

Endeavour has been well appreciated by Ministry of Urban Development (MoUD).

Benefits

Reducing and recycling C&D materials conserves landfill space, reduces the environmental impact of producing new materials, creates jobs, and can reduce overall building project expenses through avoided purchase/disposal costs.

Scope of work for the Project

The scope of work for the project includes:

1. C&D waste collection: this includes collection from designated location, on-call C&D waste collection services and operational call center/ helpline
2. Transportation: This includes transportation of C&D waste from the designated collection points to the processing site, along with owning or hiring tricks for transportation.
3. Processing: this includes weighment; segregation of C&D waste; screening through grizzly and wet processing/ dry processing.
4. Selling Recycled Material: this includes use of recovered aggregates to produce variety of products including RMC (Ready Mix Concrete), brick dust and granular sub-base (which is sold as a building material), pavement block, kerb stone, concrete block, bricks etc.

C&D waste collection

A number of C&D waste collection points, 70 at present, are designated by North DMC, as per the concessionaire agreement where C&D waste is collected and later transported to the plant site, either by the department or by the concessionaire. These waste collection points are identified at convenient places so that it is easier for the collection and subsequent transportation of the C&D waste. Endeavour is also made to create awareness for identifying new areas where C&D waste is available, in consultation with representatives of the concessionaire.

Transportation

The concessionaire is required to lift and transport the C&D waste from the designated sites of three zones i.e. Karol Bagh, Sadar-Paharganj and City Zone. From rest of Delhi, the C&D waste has to be transported to the plant site by respective agencies. In case of transportation of C&D waste from the site to the plant by the concessionaire, the same is preferably done in the presence of representative deputed by the concerned MCD authorities/official. SLF Slip (Sanitary Landfill Slip) is generated in triplicate which is signed by JE and a copy is handed over to the driver of the vehicle

In addition to the collection and transportation done by IL&FS, other government agencies are also bringing the C&D waste to the plant for further processing.

On arrival of vehicle with C&D waste, quality of the waste is visually checked by Quality Control Supervisor (QCS). If quality is not acceptable as per Concession agreement, vehicle is sent back with a Rejection slip.

C&D Waste Processing

The activities of the C&D recycling plant shall be classified into the following sections:

- Weighment
- Manual Segregation
- Processing of C&D waste
- Quality Testing and storage
- Sales and dispatch

Weighment

- C&D waste being received at the plant site is weighed and weighment slip is generated in triplicate and one of it is handed over back to the concerned MCD official. Daily Report of C&D waste received is prepared by Weighbridge operator under the instructions of Plant In-charge and sent daily to various authorities at the plant as well as the EE in-charge from MCD.

Manual segregation

- First of all, Manual segregation of C&D waste is carried out.JCB is deployed to spread the unloaded waste in the incoming material storage area so that manual segregation is convenient. Workers segregate the Bricks and stones and keep it separately for further processing. Concrete Blocks and stones are processed to recover recycled cement aggregates for RMC and then used in the kerb stone, Tiles and Paver blocks etc. These high value concrete blocks are segregated manually and using the JCB and transferred to the Crusher for crushing and recovery of recycled cement aggregates.
- Whole and partly broken bricks from the waste are segregated manually and stored separately. Partly broken bricks can be sent to CDE-ASIA plant to recover aggregates which can be sold to the customer. The whole bricks so segregated are used for In-plant construction works.
- Manual Segregation of unwanted material like wood, plastic, cloth etc. is also done at feeding point. The collected MSW is sent to the Okhla facility for further processing.
- The left over silt-soil mixture is sold to customers as filler material.

Processing of C&D waste

- Collected C&D waste is first screened through a 60 mm grizzly to remove loose soil and

muck

- Over sized Screened material is collected in the hand sorting section where bricks and concrete are separated
- Segregated Bigger size concrete boulders as well as mixed concrete are broken with the help of rock breaker
- Further size reduction is done with the help of processing machines

There are two methods of processing of C&D waste, i.e. dry processing and wet processing.

Dry processing

The dry processing is done by Rubble Master Compact Recyclers. The Rubble Master Compact Recyclers are the compact class for C&D Processing and produce high quality cubic value grains from construction debris. The machine is capable of processing @ 50 tonnes per hour. It is a diesel operated machine with inbuilt system for spraying water to minimize the dust generation. With the help of this machine, hand segregated concrete is crushed and graded to produce Recycled concrete Aggregates (RCA) The machine has been appreciated by the residents for its dust suppression and noise reduction cover system. It is compact processing machine and can be easily transported from one place to another and can be made operational in short span of time.

Wet processing

The wet processing involves the following steps:

1. Feed reception: in this step the oversized materials are sized and removed. Also the undesirable materials like metals, plastics, rugs, woods are detected and removed. the mix is then feed into the hopper with an initial screen of 200mm to get the material of desired composition and size
2. Separation of Concrete and bricks: the concrete blocks of size over 200 mm are separated by hand and are stacked separately.
3. Size reduction using impact crusher: the size of the concrete blocks and mixed C&D is further reduced using crushers, to size as suitable for the end use.
4. Feeder Conveyor: the material is further feed into the hopper and the crushed material is then collected. The material is then fed to prograde/ rinsing station.
5. Screening: water is then added to improve the quality and to retrieve the fine particles. The material is then sent to the Log washer to separate light contaminants (i.e. Plastic and wood)

6. Washing & Contamination Removal: the aggregates are sized by rinsing and using screens of different sizes. The clean and dry aggregates are sized and stockpiled into bays.

7. Fines Recovery: the washed sand produced which is free from any silt is recovered. The size of the washed sand recovered is maintained at -3mm to +75 microns

8. Water Treatment: the -75 microns material is passed to the Aqua cycle thickener. Specifically chosen flocculent is added to it in controlled quantities. Condensed sludge is then formed. The clean water is recycled.

9. Waste Management: Filter Press squeezes water from sludge. Filter cakes of upto 80% dry solids are dropped into bay as final waste. This can be used for brick making/ pavement blocks/ CLC bricks etc.

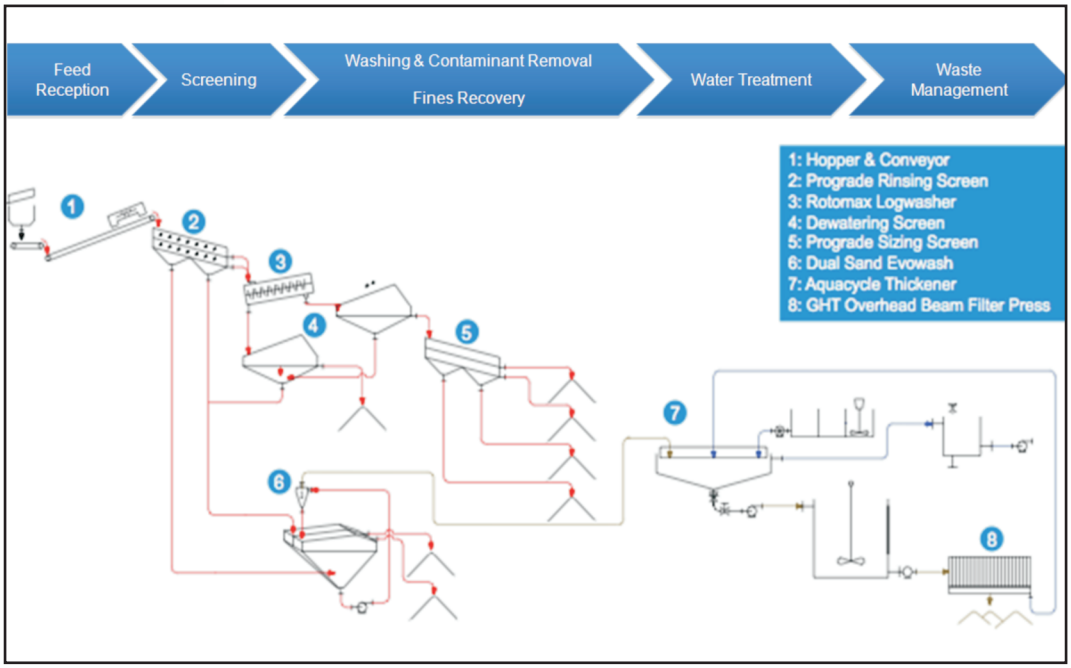


Fig. 2: Wet Processing of C&D waste

Products

From processing of brick-mix C&D waste, the products derived are i) recovered sand ii) recovered aggregate (brick mix), iii) recovered soil whereas form processing of concrete based C&D waste, the products derived are i) recovered concrete aggregate 10mm& 20 mm ii)recovered stone dust.

The following products are made from the above recycled products: -

- Recycled Concrete Aggregates (RCA)

- Ready mixed concrete
- Brick pozzolana
- Pavement blocks and kerb stones, drain covers, and any other non-load bearing pre-cast product
- Coarse sand and silt
- Brick sub-base.

Mixed concrete and brick base is converted into granular sub-base which is used for making concrete blocks which meet the strength requirements of IS: 2183.

Strength specifications for the relevant products are strictly adhered to as specified in IS: 15658.





Products from RCA

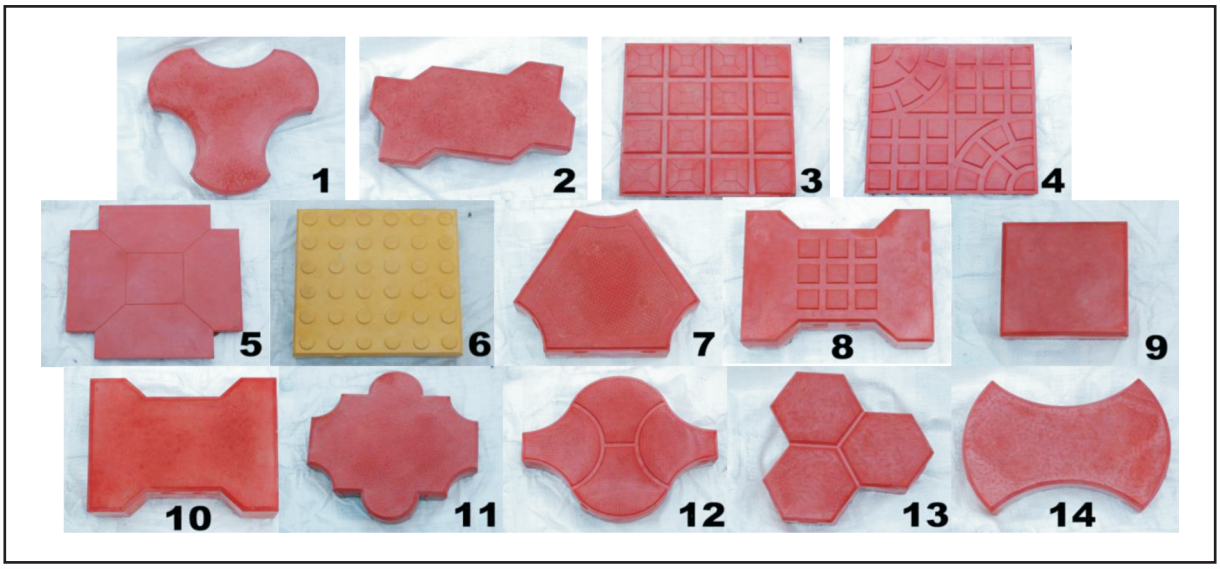


Fig. 3: Products form RCA

Quality Monitoring and Control Procedure

Quality control of the finished products is monitored as per the relevant BIS norms. For RMC, samples are collected from the each and every batch manufactured in the batching plant and tested in the testing lab on 7th, 14th and 28th day for its hardness. The following is the acceptable level of hardness for the RMC manufactured.

- For Kerbstones ----- 20 Kilo Newtons.
- For Tiles & pavers- 25 Kilo Newtons.

The aggregates are checked for contamination of other materials like bricks, plastics or any other unwanted foreign materials as also for any size variation.

Environmental Management

Ambient air quality monitoring

Ambient air quality is monitored at least every 2 months and readings recorded. Analysis of the particulate matter in the ambient air is monitored using the Gravimetric method. APM(10) sampler is installed permanently for the purpose.

Noise monitoring

Noise level inside the premises are measured and kept under the threshold level defined by DPCC.

- For Day time ----- 55 dB(A) Leq.
- For Night time-- 45 dB(A) Leq.

Noise level are monitored at least every 2 months and readings recorded.

Green belts

Green belts have been developed along the periphery of the facility wall. Regular maintenance and watering of plants are being carried out.

Safety Management

Safety and physical hazards

Safe operation of plant activities is only possible with the complete cooperation of all personnel participating in the operation. A safe work place means a workplace where every attempt is made, by all involved, to recognize and minimize hazards and to train each employee in the proper procedures to manage those hazards.

C&D Recycling operations will involve certain risks because of the potential for encounters with heavy equipment used in processing, transportation during collection, foreign materials contained in raw materials, noise, dust, fire, etc. Stringent safety norms as per the industry

standards are maintained at the plant site to mitigate the physical and health hazards.

Key Innovations Implemented

- Mechanical and Manual separation of concrete from mixed C&D waste.
- Processing of concrete and mixed C&D in batches,
- Size reduction of C&D by use of Impact crusher, as by use of Impact crusher better cleaning of aggregates is achieved (as compared to conventional jaw and cone crusher)
- Use of Vertical Shaft Impactor, to produce manufactured sand.
- Inter connection of process lines so that aggregates in usable sizes as per market demand can be made.
- Design mix of Ready Mix Concrete using 100% recycled concrete aggregates.
- Production of products like pavement Blocks, Pavement tiles, roof tiles
- With the implementation of the wet processing facility, a fraction of upto 95% is obtained from the C&D waste, whereas, earlier only 40% was obtained.
- The 5% remaining comprises of wood and other material, which is sent for RDF generation.
- Above 500 tonnes of C&D waste is being lifted and processed at this plant

Therefore, the facility is a zero waste plant.

Social / Environmental Impact of the Innovation

- Improvement in C&D Debris Management Situation in Delhi
- C&D Waste is being processed in Compliance with C&D waste management Rules 2016.
- Urban areas have huge Landfill sites where Municipal Solid Waste for years has been dumped. C&D waste also continue to go to these Landfill sites. By reuse of C&D waste, load on overflowing landfill sites is reduced
- City will be more cleaner
- Drain clogging is less
- C&D waste which is indiscriminately dumped throughout the city is processed and made products, which can be again used by the building Industry
- Professional and Scientifically Managed Projects
- Improving efficiency of Composting and Energy Efficiency processes
- Long-Term Sustainable Solution

- Constant endeavour for improvement through R&D
- Recycle and reuse of C&D Debris
- Gradual shift from illegal C&D debris dumping to legalized disposal system
- Phase wise transfer of C&D debris management cost to the generator / polluter.

Limitations

- Low awareness. Many in the construction industry are still not aware of the recycling techniques.
- On source separation is still not being done, degrading the quality of the C&D waste.
- Strength and various other characteristics of recycled materials and those of fresh materials vary, thereby limiting its use.
- Not enough data available to standardize the recycled materials.
- Standards for use of recycled material were not available till now.
- Format/template for EOI/RFP/NIT etc. is still not standardized.
- Problems are being faced in implementing C&D waste rules.
- Sales are at best moderate, making the sustainability of the project an issue.
- No rebate in taxation. Benefits of social cause project shall be extended to such projects to make it sustainable.

Initiatives Taken to Promote Recycled Products

- BIS has revised its code IS 383:2016 wherein recommendations have been made about the utilization of recycled course aggregates in plain concrete, reinforced concrete and lean concrete.
- 100% use as well as blending of recycled material is defined now in the relevant BIS codes.
- DSR also now provides for use of recycled products.
- All govt. departments mandated to incorporate a clause in their tender documents for use of recycled products.
- Many Govt. Departments have issued advisories that mandate 2% and 10% use of recycled products in building and road works respectively.
- With more and more facilities for processing of C&D waste being established, availability of adequate quantity of recycled material is ensured.

- North DMC has recently issued orders for procurement of C&D waste recycled products for departmental use in all 104 wards, initially for a period of one year.
- Advisory has been issued; making it mandatory for all big development projects of Govt. costing more than Rs. 500 Cr., to install C&D waste processing plant at the site itself and the recycled products so obtained shall be consumed in the project itself.

Conclusions

It is an initiative undertaken by the North Delhi Municipal Corporation to address to growing environmental concerns. The plant has till date processed about 370-380 mT of C&D waste, thus saving useful space at the landfill site besides helping in curbing environmental pollution. However, for the sustainability of the project, it is very important to maintain the balance between economical, environmental and social issues. There is a growing need for standardization of the recycled products including guidelines for fixing of their rates, encouragement for their use as well as to incentivize in terms of relaxed taxation rules for the recycled products to make them more competitive and increase their acceptability.

References

"Guidelines for utilization of C&D waste " by BMTPC

Concessionaire's agreement for Burari plant

Various circulars/advisories issued from time to time on use of C&D waste products.

'Use of waste material in construction'

TREATMENT AND UTILIZATION OF CONSTRUCTION AND DEMOLITION WASTE (C&D WASTE) – A STUDY TOUR TO NORWAY

O P Tripathi, Chief Engineer, CPWD, New Delhi

A delegation of senior CPWD officers went on study tour to Norway from 26th to 30th November 2018 getting firsthand knowledge on recycling and use of C&D waste in construction industry as a part of the ongoing Indo-Norwegian project cooperation between CPWD and SINTEF on "Treatment and Utilization of Construction and Demolition Waste (C&D Waste) in India". The aim of the study tour was to meet with concerned authorities, visit the recycling facilities and sites where recycled C&D waste used and to take part in trainings and workshops for capacity building.

Workshop at SINTEF Headquarters

One day technical workshop was held at SINTEF Headquarter at Oslo, Norway on 26th November 2018 in which various presentations were made on Energy Recovery and Management by Vice President, SINTEF, International Experience on C&D waste by Christain J. Engelsen, Senior Scientist, Waste Management activities in India and Myanmar by Palash Saha, Research Scientist, SINTEF, Minamata convention on Mercury by Monica S. Nodland, Scientist, SINTEF and research being carried out on Aluminium reinforcement in place of Steel bars by Harald Justnes, Chief Scientist, SINTEF. It revealed that waste management has become the top priority not only in developed countries but also in developing countries. Recycled C&D waste has been successfully used in many places. C&D waste recycled products also help in absorbance of CO_2 emissions. The research being carried out on substitute of steel reinforcement is to avoid corrosion to enhance the durability of RCC structures. Energy management is also one of the important topics of present research.

Following the presentation of above papers, a visit to SINTEF Nanotechnology Laboratory was also made having facility for testing of various C&D products having CO_2 absorbance determination and monitoring facilities.

Site Visit of C&D Waste Recycling Plant

Visit was made on 27th November 2018 to Stavanger city to visit Norway's modern integrated C&D waste recycling plant producing recycled aggregates, asphalt and concrete at Velde. During the visit, a presentation was made by the product manager and subsequently the plant site was visited by the team and all the facilities were seen in detail.

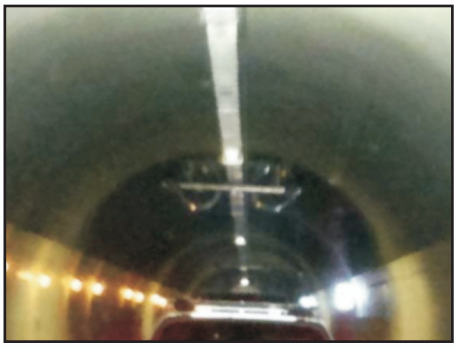
This wet recycling plant has a capacity of 300 TPH (Tonnes Per Hour) and is producing sand, coarse aggregates of different fractions and filter press material which is mostly mix of clay and silt. The aggregates are as good as natural materials on visual inspections. The plant is owned by a private entrepreneur and selling the recycled materials as a rate about 5% cheaper than the natural materials. Government has not so far given any mandate to use recycled materials. As Norway is a rich country, about 45% material is only sold. Filter press

material is not finding many users while recycled aggregates are also under stock. Plant authorities feel that road management authorities should encourage use of recycled aggregates in government works. The plant is in open and has washing facilities hence it is not operated during sub zero temperature.




Visit to Longest and Deepest tunnel

At Stavanger, another visit was made of the tunnel under construction which will be an alternate route to lone existing road. This tunnel will be about 14 km. long and 390 feet deep from MSL at the deepest point. This tunnel has been constructed in hard rock through blasting operations and has an inspection gallery in which services are also planned. At the entry of one of the place, the filter press material (compressed fine material basically silt and clay received from recycled C&D waste) has been used over concrete bed as it works as impervious layer and prevents water percolation. Thus, it is clear that filter press material can be used as impervious lining.




Visit to Recycling plant of Polluted Soil

A visit was made of recycling plant of polluted soil on 28th November. The soil having heavy metals and other hazardous pollutants are removed from the soil and C&D waste is recycled into non-polluted fine and coarse aggregates. The plant is housed in a building thus being indoor plant and can be run during sub zero temperature also. It has a water tank in addition to the facilities of recycling C&D waste facilities in which flocculants are added so that heavy metals are settled at the bottom and thereafter get segregated along with filter press material. This material is then sent to landfill where adequate precautions are taken to avoid leaching

to ground water which is hardly 20% of overall C&D waste. This plant was also capable of recycling C&D waste received from railway sleepers and other similar products.





A meeting was held with the Environment authorities who have C&D waste management rules and C&D hazardous waste management Rules. A C&D waste management plan has to be submitted by the waste generators. A developer who has to make new construction on vacant plot has to get soil tested for the soil hazardous pollutants. In case the soil has the pollutants more than the prescribed limits, the owner has to get them removed from the polluted soil or needs to replace it.

Visit to E-6 Highway south of Oslo

A site visit was made to E-6 highway south of Oslo where recycled aggregates (RA) have been used in sub base and in a RCC retaining wall. Both the structures are behaving very well and have shown no distress proving that recycled aggregates can be used successfully in such structures however in Norway, the recycled aggregates have mostly concrete aggregates.





Visit to Building with Recycled Aggregates (Sorumsand Videregaende School)

A visit was also made of the school in which in 2004, about 37% recycled aggregates were used as the replacement of natural aggregates used in basement slab, beams and columns in RCC. The structures are showing no distress showing again that recycled aggregates can be successfully used as partial replacement of natural aggregates even in RCC.





A meeting was held with Norwegian Government Property management and Building department Statsbygg. Statsbygg is the Norwegian Government's key advisor in construction and property affairs, similar to CPWD who carries out construction and maintenance of government's assets in Norway and also abroad. They are also concerned about recycling of C&D waste and hazardous waste and are taking various measures of energy conservation and energy efficiency in building construction. Another meeting was held with local authorities who are implementing the C&D waste and C&D hazardous management rules. The builders are required to submit their plan and are also responsible for abiding the Rules.

From the meetings and the discussions, it is clear that C&D waste products can be successfully used in engineering applications.

Recommendations

The following recommendations are made from the study tour;

(I) C&D waste recycled sand, aggregates and products manufactured from such waste can be successfully used in building construction.

(ii) In RCC, partial replacement of natural aggregates can be successfully made. A research has to be made and prior testing of recycled aggregates needs to be carried out.

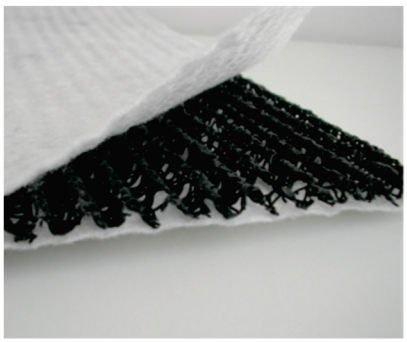
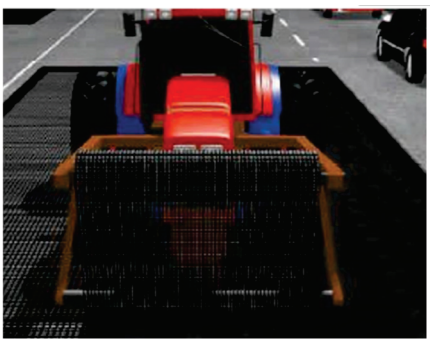
(iii) Cement paste gets stuck to the aggregates and thus it is advisable to use additional cement in order to gain sufficient strength.

(iv) Recycled aggregates can be successfully used in road sub base.

(v) Quality of the products manufactured from has to be ensured due to varied composition of C&D waste.

(vi) Along with the building plans, builders and architects must submit C&D waste management plan for the approval of the projects to the local bodies.

(vii) Before issue of Occupancy Certificate, the C&D waste management plan submitted at the time of Local body approval must be checked for the compliance.


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Government of India
Ministry of Housing and Urban Affairs
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