TREATMENT AND RECYCLING OF CONSTRUCTION AND DEMOLITION WASTE – A COLLABORATING INITIATIVE BETWEEN INDIA AND NORWAY

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ABSTRACT

Several successful demonstration projects have been conducted the past 20 years in order to verify the practical, technical and environmental applicability of recycled aggregates. Furthermore, recycled aggregates are included for use in nearly all of the European (EN) aggregate standards, though at varying implementation level. A new Indo-Norwegian project has been initiated between Central Public Works Department and SINTEF where the aim is to increase the treatment and recycling capacity for construction and demolition wastes in India. The project will strive to implement international best practice, perform various capacity building activities and conduct pilot demonstrations. It will focus on the production of recycled aggregates from C&D waste with a documented stable quality applied in both bound and unbound user applications (e.g. concrete production and road construction).

1.0 Introduction

Proper handling, storage and treatment of non-hazardous and hazardous wastes are crucial in order to protect the fresh water resources (rivers, wetlands and ground water) and prevent degradation of productive land due to disposal of industrial and domestic wastes. Furthermore, insufficient management of industrial, municipal and construction and demolition waste (C&D waste) is the major cause of soil pollution and is a serious challenge in terms of magnitude and required resources.

Furthermore, C&D waste is one of the biggest waste streams in most countries. It contains wood, plastic and paper rejects, ceramics, mortar, concrete etc. 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, in many cases reduce the cost of transportation, minimize the waste sent to landfills and even re-absorb CO_2 from the air through increased carbonation. In Europe, more than 500 million tons are generated annually and approximately the same amounts are estimated to be generated in India according to a recent study (Satpathy et al., 2016), many times higher than the more common estimate of 25-30 million tons. The recycling levels in Europe varies in the range from less than 20% to more than 90% material recovery. However, some countries in Europe have been the forerunners on C&D waste recycling (e.g. the Netherlands) and significant efforts on research have been made. Proper handling, treatment and utilisation of C&D waste will therefore have significant impact on resource optimization/conservation and environment, in particular in urban areas, where space is limited.

This paper describes the new Indo-Norwegian project between Central Public Works Department and SINTEF. In addition, it gives examples of best practice for C&D waste.

2.0 Material fractions in C&D waste

C&D waste is usually defined as the waste generated from construction, renovation, reconstruction and demolition. Although the material fractions in C&D waste varies, depending greatly on the construction technique, type of building, age and materials employed etc., typical main fractions are concrete, bricks, gypsum, wood, glass, metals, paper, plastic, solvents, asphalt, asbestos and excavated soil. The concrete and masonry part is typically 30-50% by mass of the total C&D waste volume generated.

Different types of C&D waste are shown in Fig-1. Concrete waste derived from homogenous constructions that have been prepared for demolition, are shown in Fig-1a and Fig-1b. The source material is good quality concrete in both cases, which can be recycled into good quality recycled aggregates. The processing and recycling in these types of demolition projects could potentially be performed on-site with a mobile recycling facility (e.g. crushing, sieving and magnetic separation equipment). When the C&D waste are more heterogeneous as shown in Fig-1c and Fig-1d, the recycling process may demand several processing steps (e.g. primary sorting before feeding, separation of light materials, washing procedure, flocculation to enhance sedimentation of fines etc.).

Fig-1: Different C&D waste from a) Office building in Mumbai b) Reconstruction of Amar Mahal flyover in Mumbai c) feedstock material to Burari recycling facility in Delhi d) mixed waste at collection site in Delhi

2.1 User scenarios

When C&D waste are processed into recycled aggregates the user scenarios can be roughly divided into bound and unbound applications. In general, recycled aggregates are mostly applied in unbound applications due to the less stringent criteria than in bound applications. However, the focus in for example the European Union is to increase the share of higher-value recycling of

C&D waste. Potentially, a range of user scenarios exist for recycled aggregates for both bound and unbound applications. The most common user applications are:

- Road construction
- Landscaping and covering masses
- Ready-mix concrete
- Concrete products
- Other mineral building products

2.2 Implementation in European standards

Recycled aggregates are in general included for use in almost all existing European (EN) standards. Table 1 shows the standards for bound and unbound applications. It is emphasized that the implementation level is varying among these standards. A higher implementation level has been reached in EN 12620 and EN 13242, where additional properties or increased test frequencies for production of recycled aggregates are specified, compared to the remaining standards in Table 1 where recycled aggregates are mentioned with little or no specifications (Ng and Engelsen, 2017).

Table 1 EN standards which include the use of recycled aggregates

User application	EN standard
Concrete production	EN 12620
Lightweight aggregates for concrete, mortar and grout	EN 13055-1
Lightweight aggregates for bituminous mixtures and surface treatments	EN 13055-2
Mortar	EN 13139
Track ballast	EN 13450
Road construction and civil engineering	EN 13242

Regarding aggregates for concrete, the factory production control is specified in annex H in EN 12620. Regarding the raw material input control for recycled aggregate production, the following should be identified:

- Nature of raw materials
- Source and place of origin
- Supplier and transporting agent

In general, the properties of recycled aggregates should be the same as for the natural aggregates for the same intended use. However, some additional properties are required to be documented and with a higher test frequencies.

3.0 Examples of full-scale demonstration projects

Fig-2 shows full-scale demonstration projects (bound use) where recycled coarse aggregates have been used in a concrete retaining wall and in the foundation, columns and the basement walls in a high school building. The concrete contained 100% and 37% recycled coarse aggregate fraction, respectively (Tangen et al., 2007; Lahus et al., 2002). In Fig-3 scrap of reinforced concrete elements were recycled into particle sizes of 0/100 mm and 20/120 mm and used as sub-base material in highway E6 Melhus. According to the results from this project, recycled crushed concrete material should perform excellent as unbound sub-base layer in roads, even with high traffic levels (Aurstad et al., 2006).

FWD measurements (bearing capacity) on the road 1½ year after construction have

shown substantial increase in stiffness on the crushed concrete sections, especially on the section with 0-100 mm material. This is probably due to renewed hydration of unreacted cement and physical bonds in compacted binder fines. Concrete E-moduli in the order of 800-900 MPa was obtained by back calculations for 0/100 mm. Furthermore, laser measurements on the road 1½ year after construction revealed satisfying surface conditions (IRI = 0.5-1.0).

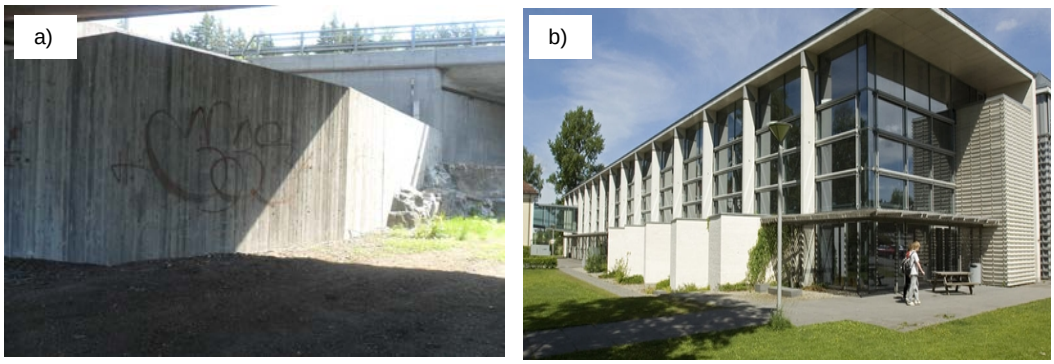

Fig-2: a) Concrete retaining wall with recycled coarse aggregate content of 780 kg/m^3 (Highway E6, 20 km south of Oslo, Norway) b) Concrete foundations, columns and basement walls with recycled aggregate content of 269 kg/m^3 (Sorumsand High School, Norway)

Fig-3: a) Hollow core reinforced concrete waste was used to produce recycled aggregates b) Cushing and sieving to particle sizes of 0/100 mm and 20/100 mm c) Paving and compaction of sub-base material after sprinkling d) Finished test section of the highway E6 Melhus (Aurstad et al., 2005)

Environmental properties of recycled aggregates are important to assess in order to prevent any harmful impact on soil and groundwater. Hence, the leaching of harmful chemical substances has been measured in a full-scale demonstration project over a period of more than 10 years, see Fig-4. The materials applied at the field site were recycled concrete aggregate (RCA) and foam glass aggregate (FGA). The RCA originated from a demolished section of the highway E6 (25 km south of Oslo), which was constructed with concrete pavement in the beginning of 1980. The demolished concrete was crushed and fractionized into a grain size of 20-120 mm and applied in test segments of the road sub-base in the entrance lane to the north-bound lane of E6 Taraldrud. A simplified risk assessment showed that the released quantities of trace elements did not exceed the pre-defined acceptance criteria for groundwater and fresh water (Engelsen et al., 2017; Engelsen et al., 2012).

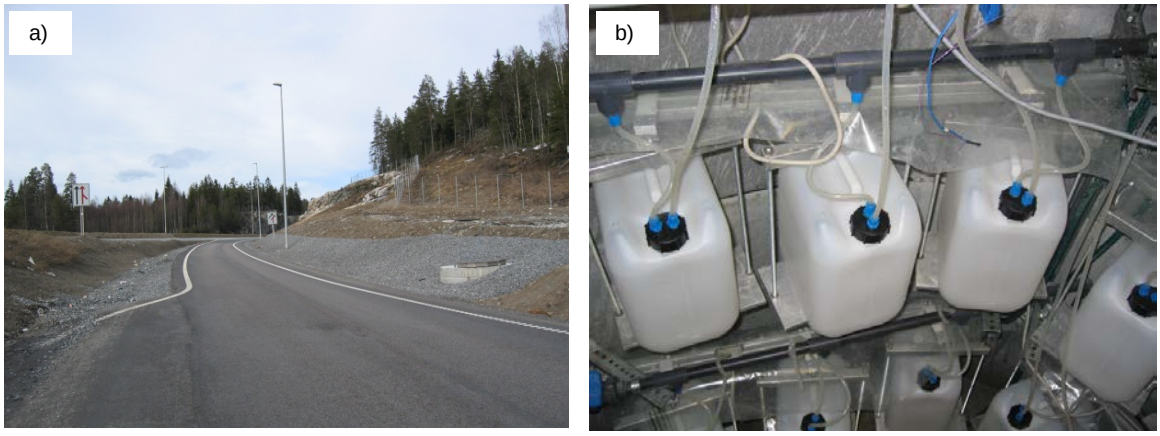

Fig-4: a) Recycled aggregates with particle size 20/120 mm applied in test segments of the road sub-base in the entrance lane to the north-bound lane of E6 Taraldrud b) Collection of the infiltration water from sub-base were conducted in separate sampling lines inside a collection well

4.0 Indo-Norwegian project

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. The MoU has been developed based on mutual interests, needs and competence, which have been identified through regular communication between the Ministry of Housing & Urban Affairs, CPWD, the Royal Norwegian Embassy in New Delhi and SINTEF for several years. The purpose with the MoU is to incept a 4-years institutional cooperation program between CPWD and SINTEF on capacity building and technical support on treatment and utilisation of construction and demolition waste in India. The Central Public Works Department (CPWD) is the premier construction agency of the Government of India and plays a pivotal role in the construction programme of Government projects. Its activities are spread throughout the length and breadth of the country. It also undertakes the projects of Autonomous Bodies and Public Sector Undertakings as Deposit Works.

4.1 Regulatory framework

Some of the main components of the general framework for managing C&D waste today is consisting of the following regulations, guidelines and supporting documents:

- Solid Waste Management Rules 2016 (MoEFCC, 2016);
- Construction and Demolition Waste Management Rules 2016 (MoEFCC, 2016);
- Management Manual on Municipal Solid Waste (MoH&UA, 2016);
- Manual on Municipal Solid Waste Management (MoH&UA, 2000);
- TAG Report on Municipal Solid Waste Management, (MoH&UA, 2005);
- National Mission on Sustainable Habitat (MoH&UA, 2010);
- National Environmental Policy, (MoEFCC, 2006);
- CPWD manual for sustainable habitat, (CPWD, 2014);
- Green Building Norms, (CPWD, 2012).

Solid Waste Management rules 2016 (MoFCC, 2016) gives reference to the C&D Waste Management Rules 2016 for storage, collection, transportation and disposal of C&D waste.

According to the Construction and Demolition Waste Management Rules 2016, waste generators, which generate more than 20 tons or more in one day or 300 tons per project in a month shall segregate the waste into four streams such as concrete, soil, steel, wood and plastics, bricks and mortar. The waste generator shall submit waste management plan and get appropriate approvals from the local authority before starting construction or demolition or re-modelling work. The waste generators shall pay for the processing and disposal of C&D waste generated, in addition to the payment for storage, collection and transportation. The rate shall be fixed by the concerned local authority or any other authority designated by the State Government. The rules specify the criteria for storage, processing or recycling facilities for construction and demolition waste and application of construction and demolition waste and its products. However, the specific guidelines and manuals for several user scenarios will need to be developed.

The Management manual on municipal solid waste (MoH&UA, 2016) gives an overview of the technical aspects of processing and treatment of C&D waste, including site selection criteria, reuse/recycle potential, proposed use for processed C&D waste and environmental considerations.

The manual on municipal solid waste (MoH&UA, 2000) is describing C&D waste (chapter 4). However, the description is only given in general terms regarding characteristics, storage, collection and transport, recycling and reuse and disposal.

The TAG report (MoH&UA, 2005) is a comprehensive report of proven technologies for processing and disposal of solid waste. It was compiled by a technology advisory group set up by the Ministry of Urban Development. The report serves as guidance in solid waste management to ULBs. However, the technology regarding treatment and utilisation of C&D waste is not included.

The National Mission on Sustainable Habitat (MoH&UA, 2010) is a component of the National Action Plan for Climate Change. One of the main aspects the mission covers is recycling of material and urban waste management. Furthermore, developing technologies for recycling of construction waste is identified as one of the strategies and methodologies for mitigation. Developing standards and performing demonstration projects for C&D waste is specified as one of the complementary actions in the main components of the mission.

The National Environment Policy (MoEFCC, 2006) seeks to extend the coverage, and fill in gaps that still exist, in light of present knowledge and accumulated experience. It builds on the present national policies for environmental management. Strengthen the capacities of local bodies for segregation, recycling, and reuse of municipal solid wastes is one of the points in the action plan in the abatement strategy for soil pollution.

The CPWD Works manual is a Government of India publication (CPDW, 2012) prepared for the use by CPWD. The manual may also be used by other governmental departments, private bodies and individuals as Central Public Works Department plays a decisive role in the construction programme of Government projects. Besides being the construction agency of the Government, it performs a regulatory function in setting the pace and programs for the building industry in the country. The Green Building Norms are specified in the manual. According to these norms, all CPWD constructions shall undergo an internal certification following the GRIHA rating system of TERI (MoNRE and TERI, 2010). Regarding waste management, criteria are specified in terms of general commitments to minimize waste generation, streamline waste segregation, storage, and disposal, and promote resource recovery from waste.

The Indian environmental policy has clearly defined the actions and strategies in their policy documents as shown above. However, it can be seen that rules and guidelines, specific criteria and standards that specifically apply for the C&D waste category, are lacking. This includes guidelines and mandatory requirements to follow prior to construction, repair or demolition of a building or civil engineering works (e.g. removal of building components that contain dangerous substances), during demolition (e.g. minimum pre-sorting criteria), treatment and utilisation of the demolition waste (e.g. technical guidelines for the use of recycled product).

4.2 Main project activities

The project aims to integrate the best from international practice with requirements of international environmental standards and Indian conditions. Guidelines will be tested and evaluated in pilot demonstration activities in selected Indian provinces and cities.

The project activities will collect and prepare Indian baseline information as well as international information on best practice. This information will make the basis for the pilot demonstration activities. The outcome of the demonstration projects will be evaluated and the findings used to amend final guidelines. Capacity building and training will be cross cutting and overarching activities. The project will be implemented over a period of four years (2017-2020) and the tentative project schedule including the main activities are summarized in Table 2.

Table 2 Tentative project schedule

Main project activity	2017	2018	2019	2020
(1) Indian baseline information gathering				
(2) International best practice				
(3) Capacity building and training				
(4) Pilot demonstrations				
(5) Amendments to guidelines				

5.0 Conclusion

C&D waste is one of the biggest waste streams in most countries. It contains wood, plastic and paper rejects, ceramics, mortar, concrete etc. The heavy inorganic part (from concrete and masonry) could be processed and refined into recycled aggregates which can substitute natural aggregates in various amounts. A number of successful demonstrations have been conducted in order to verify the practical, technical and environmental applicability of recycled aggregates.

The Indian scenario is different from the scenarios encountered in many countries in Europe including challenges with source segregation, lack of space during demolition, lack of space for transfer stations offering simple segregation, and deficiency in treatment capacity for both mobile and stationary recycling facilities.

The purpose of the new Indo-Norwegian project is to implement a 4-years institutional cooperation program between CPWD and SINTEF on capacity building and technical support on treatment and utilisation of construction and demolition waste in India. The project intends to adapt the existing best practice to Indian conditions. The project has been developed based on mutual interests, needs and competence, which have been identified through regular communication between the Ministry of Housing & Urban Affairs, CPWD, the Royal Norwegian Embassy in New Delhi and SINTEF for several years.

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