RECYCLING AND REUSE OF CONSTRUCTION AND DEMOLITION WASTE: A SERIOUS ISSUE

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Abstract-As we know that the world's two most populated countries, China and India. The current population of India is about 1362 million as Thursday, January 31, 2019, 36% of the world's population. And the population density in India is 460 per km2 (1192 people per m2).Therefore growth rate of population causes the scarcity of land area and environmental degradation. So it required newly constructed house, demolished the old structures, new infrastructure projects by government day by day. Lack of good aggregates is important problem in construction industry. Therefore this paper focuses to comparing the properties of Recycled aggregates and Natural aggregates and gives the interests to Recycled C&D waste and their uses in the construction activities as the resembling strength of natural aggregates

Keywords— **Natural Aggregates, Recycled Aggregates, C&D waste, concrete engineering properties, physical testing of RA', Environmental impacts, case study, Solid waste management,**

Abbreviation: C & D: Construction and Demolition; MT: Million Tones; CPCB: Central Pollution Control Board; TPD: Tones per Day; MSW: Municipal Solid Waste;

INTRODUCTION: Why Resource Efficiency?

Natural resources are critical for every society, but due to rapid economic and population growth, concerns about resource depletion have become acute in the last few decades. Resource supply constraints and price shocks can not only produce potentially severe economic and social consequences. In addition, resource extraction, utilization and disposal also typically impose significant environmental burdens, including land degradation, biodiversity loss, as well as air and water pollution. Moreover, resource extraction and utilization are extremely energy intensive, thereby utilizing a large amount of fossil fuels which even today, remain the main source of energy. This implies a strong correlation between resource use and greenhouse gas (GHG) emissions, which is a matter of urgent global concern. Many industrial countries have adopted resource efficiency as a priority in their policy agendas and the G7 countries have committed to resource efficiency in the protocol of their 2015 meeting1. Germany, in particular, has developed and notified a national resource efficiency programmer called ProgRess2 which is updated every 4 years. Learning from such best practices, it is important for India to initiate discussion on resource use and to identify priority areas for action, given its national context. In a resource constrained world, India cannot afford to ignore this issue as it can potentially jeopardize its development plans. Additionally, the enormous social benefits that can accrue from reduced environmental burdens should not be overlooked. Further, GHG emissions reductions resulting from resource efficiency measures will help India to meet its climate change commitments under the Paris global accords, 2015.

Context of Resource Efficiency in India: Resource efficiency is particularly relevant for India since its economy is going through a period of rapid transformation due to several interlinked factors described below:

a) **Growing population and increasing urbanization**: At 1.25 billion, India has the second highest population in the world. Projections show that India will overtake China to become the most populous country by 2030 and its population will keep growing past 20503. Like many other emerging countries, India is witnessing rapid urbanization. However, India has a relatively lower share of urban population (31% in 2010), and is currently experiencing a much faster rate of urbanization. By 2050, a majority of India's population is expected to live in cities4. In absolute terms, 590 million people will be living in cities by 2030; such an unprecedented scale of urbanization will require huge investments in housing and infrastructure.

b) **Rising income and growing middle class**: India has enjoyed one of the fastest economic growth rates over the past decade and is now the 4th largest economy in the world. While per capita income is still low by international standards, it has increased by a remarkable 400% since 19915. The Indian middle class has doubled in size between 2001 and 2010. In terms of middle class consumption, India is currently 12th in the world, but it is expected that by 2050 India will have the world's largest share of middle class consumption.

c) **Expanding industrial and service-related production:** Although the agricultural sector is still dominant in terms of employment, the industrial and service sectors are increasingly contributing higher shares to employment and Gross Domestic Product (GDP). The service sector in particular, contributed 58% of GDP in 20117. These sectors are resource intensive, owing to industrial production and higher consumption patterns due to a rise in disposable incomes.

d) **Per capita consumption of materials in India**: is still low compared to the rest of the world; at 4.2 tones, it was less than half the global average in 2009. However, due to the large population size, India's total resource consumption is quite high, and is expected to increase rapidly, given the trends described above. Between 1980 and 2009, India's total material consumption increased by 184%, making it the world's 3rd largest consumer of materials, accounting for 7.1% of global material consumption. If current trends continue, India's material requirements are projected to be 15 billion tones by 2030 and 25 billion tones by 2050, with the biggest increases in the shares of fossil fuels, metals and minerals. Extraction per area in India, which could be used as a rough estimate of environmental pressure, is already the highest in the world9, at 1,579 tones/km2 land area, compared to the global average of 454 tones/ km2.

NATURAL AGGREGATES: Natural aggregates, which consist of crushed stone and sand and gravel, are among the most abundant natural resources and a major basic raw material used by construction, agriculture, and industries employing complex chemical and metallurgical processes. Despite the low value of the basic products, natural aggregates are a major contributor to and an indicator of the economic wellbeing of the Nation. Aggregates have an amazing variety of uses. Imagine our lives without roads, bridges, streets, bricks, concrete, wallboard, and roofing tiles or without paint, glass, plastics, and medicine. Every small town or big city and every road connecting them were built and are maintained with aggregates. More than 90 percent of asphalt pavements and 80 percent of concrete are aggregates. Paint, paper, plastics, and glass also require sand, gravel, or crushed stone as a constituent. When ground into powder, limestone is used as an important mineral supplement in agriculture, medicine, and household products. Aggregates are also being used more and more to protect our environment. Soil erosion-control programs, water purification, and reduction of sulfur dioxide emissions generated by electric power plants are just a few examples of such uses. One way to understand and appreciate better the importance of the aggregates industries is to look at their production in the context of all mining. On the basis of either weight or volume, aggregates accounted for more than two-thirds of about 3.3 billion metric tons of nonfuel minerals produced in the United States in 1996.

WHAT IS C&D WASTE: Construction and demolition (C&D) waste is generated from construction, renovation, repair, and demolition of houses, large building structures, roads, bridges, piers, and dams. C&D waste is made up of wood, steel, concrete, gypsum, masonry, plaster, metal, and asphalt. C&D waste is notable because it can contain hazardous materials such as asbestos and lead. Estimates vary, but a commonly accepted estimate is that between 15% and 20% of municipal solid waste comes from construction and demolition projects.

Landfills: accepting C&D waste has limited capacity. Many have already closed or are scheduled to close. Currently, most of the C&D waste generated in Connecticut is disposed of in out-of-state landfills and only an estimated 7% of this is *reported* recycled. These figures are only reflective of the waste which passes through Connecticut permitted solid waste facilities and reported to the DEEP. The 7% reported recycled rate does not include most of the clean fill generated and reused or recycled, scrap metal recycled from construction projects, materials directly hauled from a job site to an out-of-state recycling end market, or materials reused on site.

Type of Waste	**Legal Classification In Connecticut**	**Examples**
Land clearing debris	Bulky waste	Tree stumps, tree tops
Demolition waste (from buildings)	Bulky waste	Concrete, wood, brick, plaster, roofing materials, wallboard, metals, carpeting, insulation
Construction waste (from buildings)	Municipal solid waste	Pallets, wood scraps, wallboard, siding and roofing scraps, packaging, carpeting. Foam padding, insulation
Highway construction and demolition waste	Bulky waste, municipal solid waste	Asphalt, concrete, steel, related construction and demolition wastes, utility poles, railroad ties, brick, block, rock
Oversized MSW	Municipal Solid Waste	Furniture, furnishings, carpeting, rugs

WHAT IS RECYCLED GGREGATES: Concrete recycling gains importance because it protects natural resources and eliminates the need for disposal by using the readily available concrete as an aggregate source for new concrete or other application According to a 2004 FHWA study, 38 states recycle concrete as an aggregate base; 11 recycle it into new Portland cement concrete. The states that do use recycled concrete aggregate (RCA) in new concrete report that concrete with RCA performs equal to concrete with natural aggregates. Recycling of concrete is a relatively simple process. It involves breaking, removing, and crushing existing concrete into a material with a specified size and quality. See ACI 555 (2001) for more information on processing old concrete into recycled concrete aggregates. The quality of concrete with RCA is very dependent on the quality of the recycled material used. Reinforcing steel and other embedded items, if any, must be removed, and care must be taken to prevent contamination by other materials that can be troublesome, such as asphalt, soil and clay balls, chlorides, glass, gypsum board, sealants, paper, plaster, wood, and roofing materials.

APPLICATIONS

In general, applications without any processing include:

- many types of general bulk fills
- bank protection
- base or fill for drainage structures
- road construction
- noise barriers and embankments

After removal of contaminants through selective demolition, screening, and /or air separation and size reduction in a crusher to aggregate sizes, crushed concrete can be used as: new concrete for pavements, shoulders, median barriers, sidewalks, curbs and gutters, and bridge foundations structural grade concrete soil-cement pavement bases lean-concrete or econo-crete bases and bituminous concrete.

2. Case Studies:

This study considers case studies from two different sources, so that the suitability for recycled waste materials can be determined easily.. For case study 1, a ten-year-old single storey building (Fig 1(a)) was considered, from which demolished structural elements, such as beams and columns, with known engineering properties of compressive strength, etc., were obtained. For case study 2, randomly chosen demolished structural elements obtained from a municipal dumpsite were considered without any prior knowledge about the engineering properties of the concrete waste (Figure 1(b))

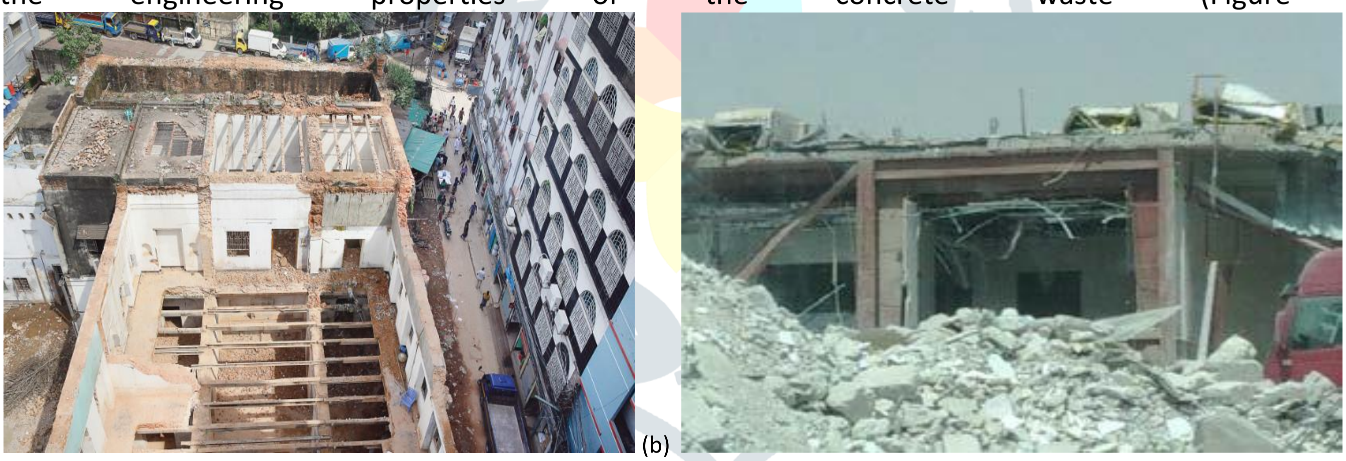
(b)

Fig. 1 (a): Ten-year-old concrete structure of a single story building; (b) Random concrete waste from construction and demolition.

3. Experimental Program:

3.1 Specimen Preparation and Aggregate Engineering Properties:

An experimental program was conducted in order to compare the engineering properties of aggregate obtained from reclaimed concrete waste from different sources: construction and demolition (C&D) concrete waste with and without some prior information, lab-tested concrete waste from a commercial ready-mix company with known engineering properties, and regular aggregate from the market. After processing the concrete waste into gravel with a crusher, the amount of reclaimed material from the waste was calculated; the reclaimed gravel was then processed through an abrasion machine (Figure 2). It was found that from 100 kg of demolished concrete waste, 30 kg of quality recycled aggregate can be obtained.

Tests related to aggregate, such as sieve analysis, resistance to degradation of coarse aggregate by impact in the Los Angeles machine, relative density (specific gravity), absorption, bulk density (unit weight) and voids in aggregate, were conducted in order to investigate the engineering properties. The lab samples were fabricated based on a **30 MPa** mix-design with the various recycled aggregate waste, along with control samples fabricated with aggregate from the market. Finally, compressive strength, tensile strength, and flexural strength tests, along with some non-destructive tests (NDT), such as plus velocity and Schmidt hammer, were conducted. Correlations between results obtained from the various tests were calculated in this experimental program.

Fig 2: Processing construction debris into gravel.

3.1.1. Bulk Density (Unit Weight) and Voids

Based on the specifications of ASTM C29/C29M – 09, the results obtained show that the bulk densities of the Lab-tested concrete waste and C&D concrete waste were higher than the control sample, whereas the number of voids was less (see Table 1). This is due to the angularity of the aggregates, since a crusher machine was used to create a uniform aggregate size of **20 mm**. The size, shape, and arrangement of the voids affect important engineering properties, such as compressive strength.

3.1.2 Relative Density (Specific Gravity), Absorption, and Resistance to Degradation

According to ASTM C127 for specific gravity and absorption test, the nominal maximum size (**12.5 mm**) was Used. The results show that the specific gravity increases as the absorption decreases (see Table 1).

Table 1: Physical Properties of aggregate from different sources

Physical properties	C&D concrete waste		Lab-tested concrete waste	Control sample
	Case 1	Case 2		
Volume of Cylinder (m3)	0.0053	0.0053	0.0053	0.0053
Unit weight (kg/m3)	1089.53	1120.58	1168.23	1162.42
Voids (%) -	24.8	25.5	23.78	22.5
Bulk specific gravity (SD) -	2.19	2.118	2.276	2.289
Apparent specific gravity -	1.92	1.827	1.982	1.831
Water Absorption (%) -	3.42	1.68	2.56	1.73
Loss by abrasion and impact (%)	31%	28%	24.34%	25%

The specific gravity of the crushed recycled aggregate was lower than that of the otherwise identical regular aggregate, which is usually around 2.2 to 2.5 in the saturated surface-dry (SSD) condition. Due to the cement mortar attached to the particles, the absorption of recycled aggregate is much higher than that of the similar virgin aggregate, which is typically 2% to 6% for coarse aggregate; the results are suitable and fall within an acceptable range. A possible reason for the high absorption rate of the lab-tested and the C&D waste is a higher water-cement ratio used in the mix; when the water evaporates, it leaves behind voids that occupy space in the concrete.

4. Results:

4.1 Compressive Strength (ASTM C109/C109M – 13)

Three concrete specimens were prepared with the aggregate from each of the different sources: C&D concrete waste, lab-tested concrete waste, and regular aggregate from the market, which was used to prepare the control samples. All specimens were designed with a compressive strength of **30 MPa**. The compressive strength of each specimen (see Table 2) was tested according to ASTM C109/C109M – 13, at 7, 14, and 28 days. The results indicate that, at 28 days, the control samples exceeded the design strength of 30 MPa, and have the highest strength; the specimens made from lab-tested waste aggregate and C&D waste aggregate from Case 1, which was taken from beams and columns, achieved the design strength, whereas the specimens made from aggregate from Case 2, taken from random concrete waste, was slightly below the design strength.

Table 2: Average Compressive strength (MPa) of three specimens for each aggregate source - ASTM C109/C109M – 13

Curing time (Days)	C&D concrete waste		Lab-tested concrete waste	Control sample
	Case 1	Case 2		
7	27.000	25.713	26.000	29.000
14	29.000	26.963	29.000	30.000
28	33.000	28.453	35.000	36.000

4.2 Tensile Strength (ATSM C496/C496M-11)

The split tensile strength test was used to compare concrete made with aggregate from lab-tested concrete Waste, construction and demolition (C&D) concrete waste, and regular aggregate from the market. Three specimens for each source were tested at 7, 14, and 28 days (see Table 3). The split tensile strength of the concrete specimens made with the market aggregate was generally higher than the strength of the specimens made with the lab-tested aggregate, especially at 28 days. Furthermore, the split tensile strength of the specimens made with the C&D concrete waste aggregate from Case 1 was also generally slightly higher than the strength of the specimens made with aggregate from **Case 2 at 28 days**.

Table 3: Average split tensile strength (MPa) of three specimens for each aggregate source - ATSM C496/C496M-11

Curing time (Days)	C&D concrete waste		Lab-tested concrete waste	Control sample
	Case 1	Case 2		
7	1.071	1.796	2.269	2.143
14	2.107	1.919	2.557	2.607
28	2.303	2.177	2.716	3.035

4.3 Flexural Strength (ASTM C78/C78M – 10)

The flexural strength test was employed to compare the strength of concrete made with aggregate from the various sources. Three specimens for each source were tested at 7, 14, and 28 days (see Table 4).

Table 4: Flexural strength (MPa) of three specimens for each aggregate source - ASTM C78/C78M – 10e1

Curing time (Days)	C&D concrete waste		Lab-tested concrete waste	Control sample
	Case 1	Case 2		
7	1.919	1.717	2.131	2.371
14	2.745	2.538	2.647	3.389
28	3.313	3.259	3.712	4.210

The flexural strength of the specimens for the market aggregate was higher overall than the specimens for all other aggregate sources; the lab-tested aggregate specimens had higher flexural strength values than the C&D aggregate. Between the C&D aggregate specimens, Case 1 had slightly higher flexural strength on average than the Case 2 specimens.

5. Conclusion:

An experimental program was designed to compare the engineering properties of aggregate from various Sources and emphasis on the recycling the C& D waste: lab-tested concrete waste from a commercial ready-mix company with known engineering properties, reclaimed construction and demolition (C&D) concrete waste with a little information from two different sites (case study 1 and case study 2), and regular aggregate from the market. Mechanical properties for case 1 (building) were compared with that of the control samples. The bulk density (unit weight) of the C&D waste for case 1 was higher than the market product, whereas the number of voids was less.

The specific gravity increased as the absorption decreased. The specific gravity of crushed recycled aggregate was lower than that of the otherwise identical virgin aggregate, which usually has values of about 2.2 to 2.5 in the saturated surface-dry (SSD) condition. The absorption value for the recycled aggregate was much higher than that of the similar virgin aggregate, most likely due to the cement mortar attached to the particles. For compressive strength, it was found that the control sample had the highest strength, with an average value of 41.6 MPa. The results also show that the average compressive strength of C&D concrete waste for case 1had the highest value of 34.3 MPa, which is nearest to the designed compressive strength of 35 MPa. It was noted for the C&D concrete waste that the increase in compressive strength of the concrete lead to an increase in flexural strength and split tensile strength, with high correlation values (R2= 0.9798 and R2= 0.997) for split tensile and flexural strength, respectively, while the correlation value between compressive strength and NDT was lower (R2= 0.8526 and R2=0.8459) for pulse velocity and Schmidt hammer, respectively.

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