Use of C&D Waste in Road Construction: A critical review

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Abstract. Sustainable development pickup its importance as population of world is increasing day by day. Demand and supply of natural resource in construction of road is facing great challenge for world pavement industry. Parallel to this, there was big challenge to dispose construction and demolition(C&D) waste according to environmental and economic growth of society. This paper focused on review of literature in use of C&D waste in road construction and on suitable alternative materials, better performance of road as well as the gap in the existing knowledge in construction. Some practical problem, suitability of C&D waste as road aggregate is also discussed.

1. Introduction: Construction and demolition (C&D) wastes are formed throughout demolition of buildings, highways pavement, bridges, etc. It comprises generally of idle and non-biodegradable materials. One of the major forms of C&D wastes is cement-concrete waste. A bulk of aggregates material is required for bituminous concrete pavements. For rapid infrastructure development, causing a shortage of natural resource like aggregate as it consumed fast. Also, on the opposite side, there is an origin of solid wastes in the form of demolished structures found in the construction industry. So, there is a challenge to dispose solid wastes like Cement concrete as it being a non-biodegradable material. Generally, demolished concrete ends up in landfills. Concrete disposal has been a major environmental challenge with new environmental regulations and limited space available for it. Today, science and technology has a responsibility of updating new trends which are both economical and eco-friendly. To obtain recycled aggregate (RA) old demolished concrete structures can be recycled. Recycled aggregates obtained from demolished building waste material can be effectively utilized for sub-base and base layer road projects constructions.

2. Utilization of C&D waste – Global scenario
World Scenario, Waste arising from construction and demolition constitute leading streams in many countries (Murty et al. 2012). It has been estimated that approximately 180 million of C & D wastes are created throughout the year in the European Union. Germany is the leading producer of C & D waste with 77 million tons followed by United Kingdom with 30 million tons. Hong Kong and Taiwan have decided to support C&D waste application in firsthand concrete. About 18 millions of waste is produced in China each year. This material was reprocessed in land recovery (Rao et al. 2007). Singapore, another land constrained country, recycles 98 per cent of its C&D waste. The effective recycling rate in Korea is 36 per cent. Some member countries of Europe utilises 20 per cent of their national consumption from recycled material. In the pavement sector, recycled aggregates have used from Reclaimed Asphalitic Pavements (RAP) in hot mix asphalt (HMA) since 1980. This has generally been used by various state transport agencies in the United States.
Indian scenario: construction industries in India produces about 12 millions of waste per annum (Murty et al. 2012) where, 70% of the construction industry in India not aware of recycling techniques (TIFAC).

3. Major components and properties of C&D Waste

This category of waste is complex due to the different types of building materials being used but in general may comprise the following materials. Typical composition of C&D waste is presented in Figure 1 and Table 1.

![Figure 1: Use of C&D Waste](image)

![Figure 2: Typical composition of C&D waste (TIFAC, 2001)](image)

| Table 1 Composition of typical C&D waste |
|------------------------------------------|
| Components                  | Zhu et al. (2012) | Pérez et al. (2012) | Gómez-Mejíjde et al. (2015) | Gómez-Mejíjde et al. (2016) |
| Concrete and mortar          | 71.200            | 72.500              | 70.000                        | 69.800                        |
Natural aggregates/stones & - & 21.500 & 25.000 & 25.100 \\
Brick & 26.160 & - & - & - \\
Masonry materials & - & - & 0.370 & 0.340 \\
Ceramics & 2.30 & 1.00 & - & 0.219 \\
Miscellaneous bituminous & - & 4.00 & - & - \\
Concrete with metal particles & - & - & 1.1210 & 1.100 \\
Concrete with textile fibers & - & - & 0.1460 & 0.1460 \\
Gypsum plaster & - & - & 0.1030 & 0.1030 \\
Other materials & <0.4 & 1 & <0.100 & <0.100 \\

The major forms of C&D waste are cement-concrete waste. For bituminous concrete pavements bulk amount of aggregate is required. Due to rapid infrastructure development natural aggregate is consumed first and causes shortage of natural resources and there is a group of solid wastes generated form of demolished structures. So, there is a challenge to dispose non-biodegradable material C&D waste. Limited space available for concrete disposal has been a major environmental challenge for economical and eco-friendly standpoints. Recycled aggregate (RA) is obtained from old demolished concrete structure. Recycled aggregates obtained from demolished building waste material can be effectively utilized for base and sub-base construction of road projects.

Table 2 validates some of the infinite benefits of potential C&D waste among which include limited natural resources, shortage of raw materials, disposing of waste stores, and more justifiable environment on this planet.

| Benefit | Significance |
|---------|--------------|
| Protection of earth’s natural resources | • Fortification of usual resources for impending generation |
| Reduction of raw materials requirement | • Limited use of natural assets |
| Exclusion of different wastes | • Waste material uses |
| | • Conservatory gas discharge reduction |
| | • Water and Air pollution organized |
| Reduce waste disposal | • Transportation and landfilling cost control |
| Environment protection | • Climate change prevention |

4. Utilization of C&D waste in road sector
The main aim is to utilize C&D waste for designing an optimal road pavement which will serve satisfactorily both structurally and functionally. Some of studies have reported the various properties of road with C&D waste and some utilization of previous studies using C&D waste are discussed.
Table 3 shows physical and mechanical characteristic recycled concrete aggregate (RCA) when crushed (Gómez-Meijide and Pérez, 2014).

| Property                              | Pérez et al. (2012) | Gómez-Meijide et al. (2016) | Al-Bayati et al. (2018) |
|----------------------------------------|---------------------|-----------------------------|-------------------------|
| Flakiness index (%)                   | 34.00               | 4.50                        | -                       |
| Specific gravity (Bulk) (t/m³)        | 02.63               | 02.64                       | 02.295                  |
| Sand equivalent (%)                   | 67.00               | 77.00                       | -                       |
| Porosity (%)                          | -                   | -                           | 13.56                   |
| Los Angeles fragmentation (%)         | 34.00               | 38.00                       | -                       |
| Micro-Deval abrasion loss (%)         | -                   | -                           | 23.57                   |
| Absorption (%)                        | 6.10                | 7.0                         | 5.91                    |
| Specific gravity (Dry) (t/m³)         | -                   | 2.23                        | -                       |
| Crushed particles (%)                 | 100.00              | 89.00                       | 89.90                   |
| Adhered mortar (%)                    | -                   | -                           | 3.02                    |
| Flat & elongated (%)                  | -                   | -                           | 2.87                    |
| Crushing value test of Aggregate      | -                   | -                           | 27.42                   |
| Freezing & thawing                    | -                   | -                           | 18.03                   |

Mohsen (2018) studied about usability of C&D waste in base and sub-base layer of pavement and after various laboratory experiment concluded that C&D waste is used only in sub-base layers of pavements. Arulrajah et al. (2011) investigate about the use of aggregates (cement-preserved) in base and layers sub-base of roads and established that recycled aggregates (cement treated) can be used in sub-base layer construction of road and is a good alternative to usual materials. Arulrajah et al. (2019) conducted laboratory studies to evaluate various properties, characteristics and fatigue life and concluded that that 3% cement stabilized 5% polyethylene terephthalate + 95% recycled concrete aggregate and 5% polyethylene terephthalate + 95% crushed brick may be used for pavement bases and sub-bases construction. Gomez-Meijide et al. (2015) focused on the possibility of improving the environmental aspects of Cold Asphalt Mixtures by using recycled waste materials and found higher stiffness by using C&D waste as compared to natural aggregate. Barbudo et al. (2012) studied mechanical behavior of road using 27 types of recycled
material and 4 types of natural material and concluded that recycled aggregate can be used in road pavement as subbase layer material. Marco Bassani and Luca Tefa (2018) tried to gain a better understanding of the response of recycled un-separated construction. Melanie et al. (2020) showed that after compaction and testing bearing capacity is found slightly lower than as per the specifications. Recycled asphalt mixture play an significant role in pavement base for recycling solid wastes and minimizing engineering cost (Le Ding et al. 2020). It is also reported that the behavior asphalt concrete made with construction and demolition waste aggregates mainly depends on temperature and load cycle (Luis-Antonio Esparza et al. 2020). Mehrjardi et al. (2020) conducted a series of cyclic plate load tests to evaluate the effectiveness using geocell reinforcement on the bearing capacity of C&D waste materials. They showed the reduction in bearing capacity of C&D waste backfills by 20–40% than that of standard material. C&D waste can be used as a substitute for natural aggregates of EAM (Guilian et al. 2020). Amorim Beja et al. (2020) concluded that according to tested result it is confirmed that the stiffness of C&D waste material significantly increases over time it is good sub base alternative material for heavy traffic loads. Junhui Zhang et al.(2020) concluded that recycled C&D waste aggregates with proper grading and strict construction technologies perform well and the subgrade filled with recycled C&D waste has a smaller deformation than that of the soil subgrade.

5. Summery and Conclusion
This paper review the use of C&D waste in road sector regarding various fact and properties of C&D waste material with its effect after using as an alternative material in road construction. It will help for the future investigation improvement in this field. It has been found that the mechanical and stability performance of C&D waste is gaining consideration day by day for used as a construction material.

In India, use of C&D waste and its application in road is limited because less knowledge and research application. Thus, more attentive research requirements to be conducted in this area for the efficient use of C&D waste as an alternative material. In order to overcome this challenge, some methods is observed from above study like significant reduction in cost of roads as suggested by different researcher and Environment friendly outcome.

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