Civil construction wastes and influence of recycling on their properties: a review

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Abstract. Failures in the management and planning processes for waste disposal have caused serious urban and environmental problems leading to costly and inadequate management in cities. The lack of areas for waste deposition resulting from the occupation and valorisations of urban areas, the high social costs in waste management, troubles of public sanitation and environmental contamination are some of these problems. With technology suitable for the joint use of recycled construction waste as coarse aggregate, it is intended to reduce the extraction of sand and gravel, and also to reduce the volume of waste landfills. In this manuscript, a review of the bibliography on construction waste and its potential for application in the construction industry is presented.

1. Introduction
According to Gulghane & Khandve, 2015, the construction waste is defined as: “Waste from construction, renovation, repair and demolition of civil construction works, and that resulting from the preparation and excavation of land, such as bricks, ceramic blocks, concrete in general, soils, rocks, metals, resins, glues, paints, wood and plywood, ceilings, mortar, plaster, tiles, asphalt pavement, glass, plastics, pipes, electrical wiring etc., commonly called rubble works, wick or shrapnel” [1].

Construction waste is classified into four classes: A, B, C and D. Class A refers to reusable or recyclable waste such as construction aggregates, demolition, paving reforms and repairs, infrastructure works, earthworks, buildings (bricks, mortar, concrete, ceramics), etc. Class B refers to recyclable waste for other destinations, such as: plastic, paper, cardboard, metals, glass, wood, plaster, etc. Class C refers to waste for which no economically viable technologies or applications have been developed to enable recycling/recovery. Finally, Class D refers to hazardous wastes from the construction process, such as paints, solvents, oils, and also wastes from demolitions, renovations and repairs to radiological clinics, industrial facilities and others, as well as tiles and other objects and materials containing asbestos or other products harmful to health [2]. According to Yahya&Boussabaine(2006), some civil construction wastes were analyzed, and they presented contamination; such contamination may affect the quality of the product composed of the waste and might also present environmental risks, that is, the civil construction waste cannot always be classified as an inert waste [3].

In USA, approximately 570 million tons of construction waste were collected in 2017, this total corresponds to a generation of around 1700 kg/habitant/year [1]. About 40% of the total mass of solid waste collected in developing countries, such as Brazil, in 2011 is waste from construction. This amount corresponds to more than 30 million tons of...
civil construction waste. In Brazil, only 1% of this waste is recycled, in the Netherlands this percentage reaches 90% [4]. In the city of São Carlos, the rate of civil construction waste per capita generation is high, according to Córdoba (2019), about 3 kg / inhab.day were generated. Thus, for each ton of household waste, 4 tons of construction waste were generated in the municipality of São Carlos [5]. The generation of civil construction waste in the municipality has been growing significantly [6], in the survey carried out by Neto & da Costa (2003), the average generation of civil construction waste was 1.93 kg / inhab.day, that is, there was an increase in generation of about 55% in the period from 2003 to 2019. From the 1990s, the generation of construction waste grew significantly, consequently, there was a growth in companies and autonomous collectors of such waste [7]. The civil construction waste is generated basically during three phases of a construction, they are: construction phase (construction site), maintenance and renovation phase and the demolition of the building. The most varied types of materials that make up the civil construction waste are generated, such as: ceramic, metallic, organic and soil materials [8]. According to Letcher & Vallero (2019), in order to make a diagnosis of the generation of construction waste, it is necessary to consider professionals and / or companies related to: 1) Executors of reforms, extensions and demolitions - an activity that most of the time is not formalized with the approval of plants and request for permits; 2) Builders of new, single-story or multi-story buildings - with construction areas over 300 m², whose activities are almost always formalized; and 3) Builders of new residences, both larger ones, generally formalized, and small peripheral residences, almost always self-built and informal [9]. Figure 1 shows the civil construction wastes generated in some Iraqi cities due to wars.

![Figure 1. Civil construction wastes generated in some Iraqi cities due to wars.](image)

The activities related to reforms, expansions and demolitions are responsible for the generation of about 50% of the total civil generated in Europe [10]. There are several types of materials used in a work, so it can be said that the composition of construction waste is quite variable. Another factor that can be highlighted refers to the different types of works, for example, an excavation work, it will generate the soil with main waste, already a residential demolition work, it will generate waste of concrete, mortar,
bricks, blocks, etc. Different construction techniques and materials are used in the world, for example, in the United States and Japan, wood is a widely used material, in Latin America and Middle East, buildings are generally made up of concrete, mortar, bricks ceramics, concrete blocks, etc. Thus, the composition of construction waste generated in different countries is quite variable [11-13]. The types of civil construction wastes and influence of recycling on their mechanical properties are presented in this review paper.

2. Problems of civil construction waste

The construction and related fields represent one of the sectors of the economy that continues to develop despite the global recession [14, 15]. According to Nistorescu & Ploscaru, (2010), and Yuan et al. (2019) the civil construction sector recorded an average annual growth rate of approximately 5.0%. However, as of 2012, there has been a slowdown in activities, due, among other reasons, to the reduction in economic activity in the world [16, 17]. Today the sector is taking advantage of the good results accumulated in recent years, which have been acting as buffers in the face of the impacts they present due to the retraction of the national economy. The construction system consumes, on average, 50% of the mineral resources produced throughout the planet; highlighting cement, lime and aggregates as the products from these mining activities most applied in the civil construction production cycle [18]. Aggregates and coarse are often used for making concrete. The most widely used construction material is concrete, commonly composed of a mixture of Portland cement with sand, gravel and water [19]. In many countries, the ratio of concrete consumption to steel consumption is ten to one. There is no material more consumed by man in such quantity, with the exception of water. Raw materials are used in making concrete, including coarse and fine aggregates, which are not renewable metals goods. It is of great importance to look for different resources (such as wastes) which will substitute, as a minimum partially, the aggregates incorporated into the concrete [20]. The waste has a decreased cost with respect to the natural fine aggregate, in this manner decreasing the total price of produced concrete, besides being favorable for the ecosystem, its use in the formulating of concrete or other purpose. These days the focusing on the preservation of our ecosystem is a real fact. The extraction of natural sand is being strictly controlled and is often restrained by the bodies responsible for monitoring the environment. For this reason, several alternatives have been sought to replace natural aggregates, using for this purpose the incorporation of some industrial residues in the manufacture of concrete and also mortars. The use of civil construction waste crushing residue replacing, at least in part, the fine aggregate used in making the concrete, is considered a successful alternative. According to Zhu et al (2015), civil construction waste powder is already used in several countries, including the Asian and South American countries [21]. Liu et al. (2015), state that in several European countries, in the United States and in South Africa, civil construction waste powder is used on a large scale [22]. According to Yan & Ye (2012), in China, the use of solid powder happened recently, based on technical studies carried out by Xiangfan Power Plants, which showed technical, environmental and economic advantages [23]. This author states that other studies were deepened by engineers at different plant when the ecological building was built in Xiangyang Hubei, China resulting in the use of civil construction waste powder in concrete after waste mortars were crushed. Today, in European countries, 98% of civil construction waste is already being used in the production of normal and high strength concrete [23]. A study conducted by YAN et al (2015), civil construction waste powder is used by some concrete companies, as part of the fine aggregate, in the production of conventional concretes, and is also used in asphalt plants for the production of petroleum asphalt cement [24]. Within the construction activity, one of the aspects of greatest concern is the volume of services generated by the construction of new works and the demolition and remodeling of old structures, which is not yet in use and is considered a serious environmental problem associated with the construction sector. All this development of the construction has led to the introduction of new technologies, with an exaggerated increase and some planning, these works are still producing huge wastes in our cities [25]. The residues have been defined as something other than the absolute minimum amount of energy, material resources, equipment and manpower required to add value to the recycling product. In general, all the construction activities produce costs, in direct or
indirect pattern. The progress of these products is restrictedly considered as wastes based on agricultural values. A lot of beneficial materials as well as harmful wastes are produced from the construction, renovation, repair and demolition of technical structures, such as residential and commercial buildings, wagons, puentes, etc [26-28]. The composition of civil construction waste varies for different activities and structures [1]. The civil construction waste at large contains heavy and voluminous materials, such as concrete, wood (for buildings), asphalt (for roofs and roof tiles), and it (the main component of drywall), metals, tiles, glass, plastics, constructions components recovered (doors, windows and plumbing accessories), land and rocks [29, 30]. Environmental problems have been considered a serious situation in the construction activity. Waste management is pushing the most with the alarm signal advancing the industry of what is happening. Reuse, optimization, recycling and minimization of waste must be considered as alternatives and methods for recovering generated waste, however, the process of these processes is something that is still on the way. There is approach to a model for recycling civil construction waste materials from the design of different projects with determined life cycle estimation. This environmental problem translates into costs the cause of environmental degradation which, for many countries, exceeds 1% of GDP per year, due to the increase in the frequency of natural disasters and the degradation of the areas due to the change in the surroundings, and the deterioration of health due to air pollution and water, in urban areas, where more than 50% of the world's population lives [31-33]. According to an investigation carried out by many researchers and civil engineering workers, it has been mentioned that the current construction and the cycling its wastes consume an important amount of natural resources and energy. The buildings use around 60% of the materials that are extracted from the planet. Also, much of the construction materials that are used require high energy and natural resource and energy consumption for their transformation and recycling: cooked ceramics, steel, aluminum, etc.. Bearing in mind by the many published works, there is a concern for responsible work by the different actors who are within the construction sector to minimize environmental impacts within the sustainable development concept [34-36].

The great increase in the generation of solid urban waste, made authorities, researchers and society concerned with the management and proper final disposal of this waste [37]. It can be said that most of the solid urban waste refer to civil construction waste; thus, the inadequate handling and final disposal of this material results in great damage to the environment. Class A civil construction waste must be reused or recycled in the form of aggregates or sent to a Class A waste landfill to reserve material for future use [38]. Civil construction waste is disposed, in most cases, in inappropriate places, such as: vacant land and watercourse margins, thus causing serious environmental problems. The incorrect disposal of waste can also lead to health problems caused by the proliferation of harmful vectors. There are several points of clandestine disposal of construction waste in the municipality of many cities. it is possible to observe a vacant lot where construction waste, household and bulky waste are discarded. The scenario of management of construction waste in most municipalities is worrying, it is expected that many changes will be made in order to improve the management and final disposal of these materials, a since they have the potential to be applied in various ways in the construction industry [39, 40].

3. Recycling of civil construction waste

Recycling plants started to be implemented in many European and America cities in the 90's. Private companies and city halls have recently started to invest in civil construction waste recycling plants, transforming this waste into materials as aggregates, for later application [41-43]. Demolition residues, in most cases, are not selected for recycling, thus, the recycled aggregate produced becomes mixed, containing various materials in its composition (concrete, ceramics, soil, etc.). In some civil construction waste recycling plants called class A, a visual sorting is performed to classify the waste as gray (cement-based waste) and red (ceramic waste, soil). Methodology to assess the potential for waste recycling was proposed to Recycling plants. This methodology has 3 principles:

1) Scientific Analysis: the characteristics and physicochemical properties of the residues must be evaluated so that it is possible to identify their possible applications;
2) Sustainability: economic and market aspects must be considered; and also the environmental and human risks;
3) Focus on the life cycle: the life cycle stages of recycled products must be considered by the sustainability analysis in order to guarantee the consistency and reliability of the studies [44-46].

Waste recycling is efficient when it basically addresses issues related to the performance and cost of the final product. Some of the measures proposed to encourage the practice of recycling civil construction waste are related to the formulation of systems that aim to standardize the quality for recycled aggregates and also the institutionalization of a system of certification of quality and guarantee [44-46].

4. Civil construction waste Recycling Plants

To implement a recycling plant, the municipality must have implemented waste management in addition to partnerships with builders and buckets to facilitate sorting and transporting materials to the plant. Another aspect to be highlighted refers to the market that must exist to absorb the material recycled by the plant; many city halls use recycled aggregates for paving and restoring streets [47, 48].

The purpose of setting the minimum requirements for the design was prepared with implementation and operation of recycling areas for civil construction waste classified in class A (construction aggregates, demolition, reforms and pavement repairs, infrastructure works, earth from earthworks, buildings). As for the implementation conditions, the criteria defined should be related to: Location; Isolation and Signaling; Accesses; Lighting and Energy; Protection of surface water; Preparation of the Operation Area; and The project to install an civil construction waste recycling plant must contain:
A-Descriptive memorial with information about the location, description of the implementation and operation, equipment used, safety equipment, operation plan, inspection and maintenance;
B-Basic project containing clashers, surface drainage devices, accesses, buildings, receiving places, sorting, temporary storage of non-recyclable waste, processing of waste and its equipment, storage of the generated products;
C-Responsibility and authorship of the project with the qualifications of the responsible entity and the professional responsible for the project.

The operating conditions according to [47, 48] include factors related to: 1) Receiving, sorting and processing of waste; 2) Training of workers and safety equipment; 3) Inspection and Maintenance Plan for the recycling area; 4) Procedures for control and registration of the operation; and 5) The value of implementing an civil construction waste recycling plant can vary widely.

5. Types of plants and processes for the processing of civil construction waste

A recycling area can be classified as fixed, semi-mobile or mobile. The classification is performed based on the installation characteristics. As the name implies, fixed installations have a definite location, their installation cost is higher and requires larger areas for installation and processing. The use of equipment with greater capacity improves the crushing process, removing impurities and sieving the materials, thus, for this type of installation, the products obtained can be more diversified and with better quality [49]. Semi-mobile facilities are used in places where medium-term projects will be carried out, such as hydroelectric dams and quarries for paving works. In this type of installation, the equipment is mounted on metallic structure bases and at low height to facilitate the assembly and maintenance of the system.

The advantage of this typology is the ease, speed and economy of assembly [50]. Mobile installations have advantages in terms of flexibility (they are easily relocated), installation and un-installation time is short, they are available in different sizes and operating systems. This type of installation is used in projects that require constant mobilization, such as road maintenance works. Although the quality of the material produced is inferior when compared to the fixed installations, it can be emphasized that the rates of transport of the materials were quite reduced. There are three types of processes for the processing of civil construction waste, they are called: first, second and third generation. In the first generation process, the removal of contaminants is carried out manually and ferrous materials are identified using a magnet, thus making the process simpler. In the case of the second generation process, the procedures for cleaning and sorting waste are more sophisticated. The third generation process relies
on the use of more advanced equipment aimed at eliminating the greatest possible amount of contaminants [51].

a) First Generation
It uses conventional crushing equipment, which can be classified as open or closed. In the case of the closed system, after sifting, the material that does not pass through the largest mesh sieve is returned to the crusher for further processing, whereas in the open system, the recycled material is processed only once and stored according to its granulometry.

b) Second Generation
In this system, the aggregates are classified after primary crushing by dry or wet, and the portion of material with a particle size of less than 10mm is discarded in order to reduce impurities. After disposal, secondary crushing and sifting are performed again. This procedure eliminates most of the organic impurities that exist in the civil construction waste.

c) Third Generation
In the third generation process, dry, wet and / or thermal procedures are carried out in order to eliminate virtually all secondary materials (impurities). Such procedures promote the obtaining of high quality aggregates, but recycling may become economically unfeasible. So that this type of process is not impracticable, it is necessary to reduce transport as much as possible, both from the source of waste until after recycling and application of the materials.

6. Equipments used in the civil construction waste recycling process

A civil construction waste recycling plant consists basically of the following equipment [52]:

- Vibrating feeder: equipment responsible for mechanically feeding the crusher uniformly and continuously.
- Crusher: it can be considered the most important equipment in a plant, since most of the properties of the aggregates produced are determined during the crushing of the material. There are several types of crushers on the market: jaw crusher, hammer crusher, cone crusher, among others.
- Conveyor belts: the belts transport the materials from the crushers to the storage location (aggregate pile), have an adjustable turning radius and are designed for horizontal and vertical applications.
- Vibrating screen: classifies the materials according to the granulometry, such classification occurs through two processes: stratification and separation. Through the vibratory movement, the smaller particles of the material tend to descend, while the larger ones move upwards, this process is called stratification. The separation is the process where the particles go to the sieve openings, if the particle size is smaller than the mesh, it will pass, otherwise it will be retained. Most plants use dry sieving with inclined vibrating sieves[52]. Potentialities of using recycled civil construction waste aggregates in civil construction

7. Potentialities of using recycled civil construction waste aggregates in civil construction

There are several possibilities for applying recycled aggregates from construction waste, such as: landfills, paving, and production of cement artifacts. However, it is known that in many developing countries, only 1% of construction waste is reused and / or recycled, in Netherland this percentage reaches 90% [52]. The construction waste has characteristics and physicochemical properties suitable for use as construction material. The main applications of this waste are in base and sub-base of pavements, landfills, aggregates for concrete and mortar and raw material for the manufacture of concrete block bricks or soil-cement. It is worth noting that knowledge of the physical properties of recycled aggregates is essential to define their mechanical strength and durability, and also of the concrete produced with such aggregates [53]. Rahal, (2007) analyzed the shear strength of recycled civil construction waste aggregates compared to the natural aggregate (crushed stone). The gravel showed greater resistance to shear than the recycled aggregate, but, when the recycled aggregate was incorporated as reinforcement of the soil, the breaking strength in some cases was 50% greater than the soil without reinforcement [54]. Santos et al., (2014) studied the potential for using civil construction
waste as a backfill material in reinforced soil structures and concluded that the civil construction waste showed good results, with low coefficients of variation, mechanical behavior and adequate resistance [55]. Yu & Shui, (2014) carried out a study on the use of recycled civil construction waste aggregates in concrete blocks. The blocks composed of residues presented resistance to compression greater than the reference control blocks (without the addition of recycled aggregates) within few weeks [56]. In a study conducted by Monish et al., (2013), civil construction residues were applied to replace coarse aggregate in concretes, several researchers investigated the behavior of civil construction waste in the production of cementitious matrices [57].

8. Use of civil construction waste as an aggregate in cementitious matrices

The recycled civil construction waste aggregate has characteristics that alter the properties of the concrete in the fresh and hardened state. In the fresh state of the concrete, the water absorption, shape and texture of the recycled aggregate are the main characteristics that affect workability. According to Rathoure, 2019, workability is the property that determines the effort required to manipulate a quantity of fresh concrete, with minimal loss of homogeneity. Workability is measured by consistency, the test most used to measure this property is the cone trunk slump test [53]. The civil construction waste aggregate presents greater water absorption due to its porosity, in the case of the recycled aggregate of gray residue, the texture is rougher and the angular grains making it difficult for the particles to slip and resulting in the loss of dejection. The higher the content of substitution of the natural aggregate for the recycled aggregate, the greater the loss of workability and the greater the amount of water needed to correct the workability [58]. In the research carried out by Martín-Morales et al., (2011); Rodrigues et al., (2013), the concretes produced with recycled aggregates from civil construction waste for the same water-cement factor showed less reduction. One way to improve the abatement of fresh concrete with recycled aggregate is to pre-wet the aggregate [59, 60]. They found that concretes produced with recycled pre-wetted aggregates obtained greater abatement than concretes produced with dry aggregate. The authors stated that the water absorbed by the aggregate in the pre-wetting may be available in the mixture after a certain time, contributing to the workability of fresh concrete. The characteristics of recycled aggregates also interfere with the properties of concrete in the hardened state [53]. A study has been conducted in Taiwan, (2003) examined the behavior of concretes produced with recycled aggregates from mixed civil construction waste at the levels of 0%, 17%, 33%, 50% and 67%. The water-cement factor also varied from 0.38; 0.46; 0.50; 0.67 and 0.80. The concretes produced with recycled aggregates and a water-cement factor of 0.38, reached only 60% of the compressive strength of the reference concrete. For batches with a water-cement factor greater than 0.60, the compressive strength of concrete with civil construction waste reached 75% of the strength of the reference concrete [61]. The modulus of elasticity for concretes with civil construction waste showed a reduction of about 30% when compared to the reference concrete. Sagoe-Creantsil et al., (2001) produced concretes using 100% recycled coarse aggregate from concrete waste. The concretes produced with the recycled aggregate presented values of compressive strength similar to the reference concrete, but a significant reduction in the tensile strength was verified [62].

9. Conclusion

In conclusion, a lot of research indicates that it is possible to produce concrete with recycled aggregates from civil construction wastes which present properties similar to conventional concrete. It is worth mentioning that it is important to adopt procedures such as pre-wetting the aggregates to improve the workability of fresh concrete, and procedures that seek to reduce the variability of these materials aiming at applications compatible with the performance requirements in civil construction. Coarse recycled aggregates from civil construction waste, specially of gray waste (mortar, concrete), are more suitable for application in concrete due to their less porosity and water absorption when compared to civil construction waste from red waste (ceramic, soil). The following can also be recommended: (i) using the best method developed in different types of projects; (ii) analyzing infrastructure projects and the generation of construction wastes, from the perspective of complex systems theory; (iii) developing a method to assess the environmental impacts related to the generation of construction wastes; and (iv)
elaborating a method for the management of urban infrastructure projects that combines minimization of construction wastes with other factors of environmental, economic and social sustainability.

10. References

[1] Gulghane A and Khandve P 2015 Management for construction materials and control of construction waste in construction industry: a review International Journal of Engineering Research and Applications 5 59-64

[2] Institute C S 2013 The CSI Sustainable Design and Construction Practice Guide: Wiley

[3] Yahya K and Boussabaine A H 2006 Eco-costing of construction waste Management of Environmental Quality: An International Journal

[4] Lino F and Ismail K 2012 Analysis of the potential of municipal solid waste in Brazil Environmental Development 4 105-13

[5] Córdoba R E, Neto M, da Costa J, Santiago C D, Pugliesi E and Schalch V 2019 Alternative construction and demolition (C&D) waste characterization method proposal Engenharia Sanitaria e Ambiental 24 199-212

[6] Neto M and da Costa J 2003 Diagnóstico para estudo de gestão dos resíduos de construção e demolição do município de São Carlos-SP. Universidade de São Paulo

[7] André R N, Pinto F, Franco C, Dias M, Gulyurtlu I, Matos M and Cabrita I 2005 Fluidised bed co-gasification of coal and olive oil industry wastes Fuel 84 1635-44

[8] Wu Z, Ann T, Shen L and Liu G 2014 Quantifying construction and demolition waste: An analytical review Waste management 34 1683-92

[9] Letcher T M and Vallero D A 2019 Waste: A Handbook for Management: Elsevier Science

[10] Ferreira S B, Domingues P C, Soares S M and Camarini G 2015 Recycled plaster and red ceramic waste based mortars International Journal of Engineering and Technology 7 209

[11] Tam V W 2009 Comparing the implementation of concrete recycling in the Australian and Japanese construction industries Journal of cleaner production 17 688-702

[12] Lucena J, Downey G, Jesiek B and Elber S 2008 Competencies beyond countries: The re-organization of engineering education in the United States, Europe, and Latin America Journal of engineering education 97 433-47

[13] Kovler K and Jensen O M 2005 Novel techniques for concrete curing Concrete International 27 39-42

[14] Osei V 2013 The construction industry and its linkages to the Ghanaian economy-policies to improve the sector’s performance International Journal of Development and Economic Sustainability 1 56-72

[15] Mussa M H, Abdulhadi A M, Abbood I S, Matalih A A and Yaseen Z M 2020 Late Age Dynamic Strength of High-Volume Fly Ash Concrete with Nano-Silica and Polypropylene Fibres Crystals 10 243

[16] Nistorescu T and Ploscaru C 2010 IMPACT OF ECONOMIC AND FINANCIAL CRISIS IN THE CONSTRUCTION INDUSTRY Management & Marketing Journal 8

[17] Yuan J, Liu Y, Xu J, Gao S and Li X 2019 Carbon Emission Prediction of Civil Buildings in China based on Improved Grey Prediction Method. In: IOP Conference Series: Materials Science and Engineering: IOP Publishing) p 012138

[18] Li B, Li J, Ikmayies S, Zhang M, Kalay Y E, Carpenter J S, Hwang J Y, Monteiro S N, Bai C and Escobedo-Diaz J P 2019 Characterization of Minerals, Metals, and Materials 2019: Springer International Publishing)

[19] Gehring A 2011 The Back to Basics Handbook: A Guide to Buying and Working Land, Raising Livestock, Enjoying Your Harvest, Household Skills and Crafts, and More: Skyhorse

[20] Siddique R and Cachim P 2018 Waste and Supplementary Cementitious Materials in Concrete: Characterisation, Properties and Applications: Elsevier Science

[21] Zhu H, Zhang J, Tang F, WANG Y and ZHOU Z 2015 Study on properties of concrete with admixture of construction waste powder performance J Water Res & Water Eng 1 183-8
[22] Liu Y, Lu C, Zhang H and Li J 2016 Experimental study on chemical activation of recycled powder as a cementitious material in mine paste backfilling Environmental Engineering Research 21 341-9

[23] Yan C-Y and Ye J-J 2012 Experimental study on preparing ecological building mortar by using solid waste [J] Concrete 39

[24] YAN T, ZHOU M and SU X 2015 Effect of addition of classified construction waste powder on sintering of Portland cement clinker Cement 3

[25] Tam V W and Tam C M 2006 A review on the viable technology for construction waste recycling Resources, conservation and recycling 47 209-21

[26] Mohebbi M 2017 Enhancing the Beneficial Use of Fly Ash in Concrete and in Mine Reclamation: Measurement of Organic Carbon and Predicting the Long Term Leaching of Harmful Elements

[27] Muhwezi L, Kiberu F, Kyakula M and Batambuze A O 2012 An assessment of the impact of construction activities on the environment in Uganda: A case study of Iganga municipality Journal of construction Engineering and Project Management 2 20-4

[28] Shen L and Tam V W 2002 Implementation of environmental management in the Hong Kong construction industry International Journal of Project Management 20 535-43

[29] Lau H H, Whyte A and Law P 2008 Composition and characteristics of construction waste generated by residential housing project

[30] da Farias A B, Fucale S P and Gusmão A D 2012 Use of CCW (Civil Construction Waste) in soil improvement Journal of Civil Engineering and Architecture 6 913

[31] Markina I, Tereshenko S, Heyenko M, Kuksa I and Shulzhenko I 2019 Development of the Export/Import Activities Supply Chain of the Construction Industry of Ukraine Int. J Sup. Chain. Mgt Vol 8 453

[32] Wu P and Low S P 2013 Lean and Cleaner Production: Springer) pp 13-45

[33] Kasanko M, Barredo J I, Lavalle C, McCormick N, Demicheli L, Sagris V and Brezger A 2006 Are European cities becoming dispersed?: A comparative analysis of 15 European urban areas Landscape and urban planning 77 111-30

[34] Bal M, Bryde D, Fearon D and Ochieng E 2013 Stakeholder engagement: Achieving sustainability in the construction sector Sustainability 5 695-710

[35] Berardi U 2012 Sustainability assessment in the construction sector: rating systems and rated buildings Sustainable development 20 411-24

[36] Behera M, Bhattacharyya S, Minocha A, Deoliya R and Maiti S 2014 Recycled aggregate from C&D waste & its use in concrete–A breakthrough towards sustainability in construction sector: A review Construction and building materials 68 501-16

[37] Lombrano A 2009 Cost efficiency in the management of solid urban waste Resources, Conservation and Recycling 53 601-11

[38] Nagapan S, Rahman I A and Asmi A 2012 Factors contributing to physical and non-physical waste generation in construction industry International Journal of Advances in Applied Sciences 1 1-10

[39] Lee S, Xu Q, Booth M, Townsend T G, Chadik P and Bitton G 2006 Reduced sulfur compounds in gas from construction and demolition debris landfills Waste management 26 526-33

[40] Weber W J, Jang Y-C, Townsend T G and Laux S 2002 Leachate from land disposed residential construction waste Journal of environmental engineering 128 237-45

[41] Bravo M, De Brito J, Pontes J and Evangelista L 2015 Mechanical performance of concrete made with aggregates from construction and demolition waste recycling plants Journal of cleaner production 99 59-74

[42] Tam V W and Tam C M 2006 Evaluations of existing waste recycling methods: a Hong Kong study Building and Environment 41 1649-60

[43] Ortiz O, Pasqualino J and Castells F 2010 Environmental performance of construction waste: comparing three scenarios from a case study in Catalonia, Spain Waste management 30 646-54

[44] de Souza Manfrinato J W and Martins B L USE OF CONSTRUCTION AND DEMOLITION RESIDUES IN NEW MATERIAL FOR CONSTRUCTION
[45] de Pádua P G L, Bezerra A C, Aguilar M T P and Cetlin P R MORTARS TO STRUCTURAL CONCRETES MADE WITH FINE AGGREGATES FROM SINTERIZED DEMOLITION AND CONSTRUCTION WASTE FINES

[46] Tam V, Sartipi F and Le K N 2018 Gaps between supply and demand of recycled aggregate: Sydney metropolitan case study Presented at the CRIOMC 2018

[47] Brunner P H and Rechberger H 2016 Handbook of Material Flow Analysis: For Environmental, Resource, and Waste Engineers, Second Edition: CRC Press)

[48] Brunner P H and Rechberger H 2016 Practical Handbook of Material Flow Analysis: CRC Press)

[49] Concepts for Reuse and Recycling of Construction and Demolition Waste: DIANE Publishing)

[50] Bilitewski B, Härdtle G and Marek K 1997 Waste management: Springer) pp 21-62

[51] Velimi A A 2007 Landfill Research Trends: Nova Science Publishers)

[52] Winkler G 2010 Recycling Construction & Demolition Waste: A LEED-Based Toolkit (GreenSource): McGraw-Hill Education)

[53] Rathoure A K 2019 Zero Waste: Management Practices for Environmental Sustainability: Management Practices for Environmental Sustainability: CRC Press)

[54] Rahal K 2007 Mechanical properties of concrete with recycled coarse aggregate Building and environment 42 407-15

[55] Santos E, Palmeira E and Bathurst R 2014 Performance of two geosynthetic reinforced walls with recycled construction waste backfill and constructed on collapsible ground Geosynthetics International 21 256-69

[56] Yu R and Shui Z 2014 Efficient reuse of the recycled construction waste cementitious materials Journal of cleaner production 78 202-7

[57] Monish M, Srivastava V, Agarwal V, Mehta P and Kumar R 2013 Demolished waste as coarse aggregate in concrete J. Acad. Indus. Res 1 540-2

[58] Gómez-Soberón J M 2002 Porosity of recycled concrete with substitution of recycled concrete aggregate: An experimental study Cement and concrete research 32 1301-11

[59] Martín-Morales M, Zamorano M, Ruiz-Moyano A and Valverde-Espinosa I 2011 Characterization of recycled aggregates construction and demolition waste for concrete production following the Spanish Structural Concrete Code EHE-08 Construction and building materials 25 742-8

[60] Rodrigues F, Carvalho M T, Evangelista L and De Brito J 2013 Physical–chemical and mineralogical characterization of fine aggregates from construction and demolition waste recycling plants Journal of cleaner production 52 438-45

[61] Chen H J, Yen T and Chen K H 2003 The use of building rubbles in concrete and mortar Journal of the Chinese Institute of Engineers 26 227-36

[62] Sagoe-Crentsil K K, Brown T and Taylor A H 2001 Performance of concrete made with commercially produced coarse recycled concrete aggregate Cement and concrete research 31 707-12