Review Article

Evaluating the Role of Recycling Materials in Construction Industry (Case Study: City of Tehran)

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Abstract

Deploying new construction technologies and materials has solved many environmental problems caused by building waste materials, namely saves energy and natural resources, and reduces environmental pollutants through reusing and recycling building materials and increasing lifespan and durability of the materials. Nonetheless, in developing countries like Iran, due to lack of the Construction and Demolition (C&D) waste management plans and these new technologies, merely negligible amounts of C&D waste materials are recycled annually, resulting in environmental pollution and heavy costs in metropolitan cities such as Tehran. In this paper, along with reviewing previous researches done in the field of recycling building materials, their significant role and embodied energies in the environmental spaces was explained. The most important types of them (including plastics, textile, metal, glass, paper, aggregates, bricks, and wood), were identified to examine their potential in further plans and designs, as well as their unique recycling features and characteristics. The research method is descriptive-comparative, and after reviewing the existing literature, this issue has been considered in Tehran as one of the largest cities. Tehran is engaging with environmental pollution caused by C&D materials, especially mixing sand and cement, concrete, bricks which account for 30%, 19%, and 18% respectively. Finally, mid-term and long-term solutions were proposed in order to create a framework for the improvement of future recycling projects, especially in the city of Tehran.

Keywords: The Building Materials, Construction & Demolition Waste, Eco-Friendly, Recycling, Reusing

1. Introduction

Building materials, from their resource extraction through manufacturing, use, and disposal have become a major component of the total human effects on global ecosystems and the earth's climate, particularly in the two centuries since the advent of the industrial revolution. In the past half-century, with the rapidly advancing pace of urbanization worldwide, finding the raw materials and energy to produce building materials, and absorbing the waste from their production, use, and disposal have become pressing global problems. For instance, the production of Portland cement alone represents 8% of total global greenhouse gas releases deriving from human sources (WRI). Another highly visible example is the unprecedented degree of deforestation occurring worldwide to produce wood for building construction. The resulting loss of forest diversity, soil stability, water quality and other long-term ecological and economic values are well-known. Because all manufactured building materials industries are raw material and energy consumers and produce some degree of waste, they are important targets worldwide for efficiency improvements and environmental pollution reductions [1]. Global warming as the most challenging problems in the 21st century and the need for sustainable development due to the diminishing natural resources have urged recycling and reuse of wastes. Each year, a huge amount of waste is generated from different sectors including mining, power and energy, and construction [2].

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2. Recycling Building Material

The construction industry uses more resources and produces more waste than any other industrial sector; sustainable development depends on the reduction of both while providing for a growing global population [3]. According to the studies, construction wastes are included about 35% of municipal solid wastes in developed countries and 50% in developing countries which are a major amount of MSWs [4]. Construction trashes are being increased daily and building materials that are potential energy resources discarded in the form of construction waste. Thus, construction issues should be seriously considered due to current technology and in addition to producing more environmentally friendly materials, finding a way for decomposing buildings trashes and backing them in nature's cycle should be followed [5]. Ways of reducing resource extraction and process waste by the design of additions to stock include the following: (a) in production, increasing the yield of useful materials from extracted resources; and (b) in building construction, adopting various measures to reduce material inputs and 'design out waste' [6], such as off-site prefabrication, just-in-time delivery, and protection of goods on site [7]. While most circular economic thinking is focused at the individual product level, buildings are compositions of numerous products with different lifespans [8], which may be altered in a number of ways, from routine maintenance to structural adaptation. These factors mean that buildings are complex entities, and represent a different challenge to that of individual products [9]. Circular economy models are yet to reach widespread application beyond specific components that are easily removed and need frequent replacement, such as lighting [10] and carpet tiles [11].

Such ongoing contractual arrangements between the building owner and manufacturer have great benefits in forcing engagement with future end-of-life. Their suitability to long-lived components are less clear, given the likelihood of manufacturers ceasing trading before the circle closes [3].

3. Comparison of the Embodied Energy of the Building

Materials Embodied energy, an energy which is used for making and shaping a material and for evaluating potential weight/ strength of the material and its ability is necessary to recycle the next materials [12]. Embodied energy coefficients and the life-span of construction materials, expressed in MJ/kg and years respectively, are presented in Table. 1.

Table. 1. Embodied energy coefficients and Life-Span of building materials [15].

Type of Material	Embodied Energy (MJ/kg)	Life Span of Materials (years)
Gravel	0.2 b	75 b
Concrete	1.2 a	75 b
Structural steel	32.0 a	75 b
Asphalt	50.2 b	75 b
Hollow concrete bricks	0.7 c	75 b
Hollow clay bricks	2.5 a,b	75 b
Ceramic floor and wall tile	2.5 a	75 b
Ceramic tile - roofs claddings	2.5 a	20 b
Stoneware	18.93 d	75 b
Glass	15.9 a	40-50 b
Raw aluminum	191.0a	50 b
Timber - veneer dried in autoclave	-	50 b
Cement rendering	7.8 a	5 b
Cork sheets	-	40 b

According to [13] it was decided to use 5% of total embodied energy in building materials to account for energy use during the erection phase (i.e. The electricity used for power tools and lighting, as well as diesel fuel used by heavy equipment at the construction site). Estimates of energy use during the erection phase range from 1.2 to 10% [14].

4. The Major Roles in the Reuse Process

Reuse of building components is a rather complex process. Many different businesses interact over a long building life. Their effect on the whole reuse cycle is described in Fig. 1.[16].

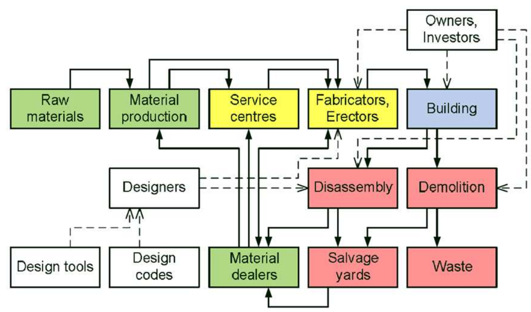

Fig. 1. The major roles in the reuse process and their interaction [16].

5. Environmental Benefit of Reusing building materials

5.1. Materials Efficiency and Eco-Efficiency

Materials efficiency in recycling building components usually refers to the economical use of natural resources in all operations, the effective management of side streams, waste reduction, and recycling of the material at different stages of the life cycle (Fig. 2.). The goal of efficient material use is also to reduce the adverse environmental impacts of the products during their life cycle. Material efficiency is displayed at different stages of the value chain, as the production of raw materials, processing of products, trade, and consumption, as well as opportunities for the durability of reuse, recycling and recovery of waste [17]. Material efficiency is to prevent the loss of material and reduce the amount of waste generated [16].

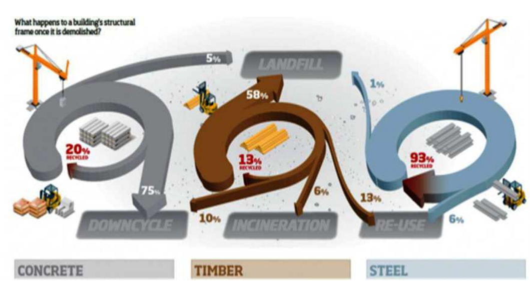

Fig. 2. Example of end-of-life scenarios for concrete, timber, and steel from the buildings [16].

5.1. Life Cycle Impact of Reuse

Life Cycle Assessment (LCA) is a systematic way to evaluate the environmental impact of systems, products, materials or services over the entire life cycle, from the extraction of raw resources to the waste. This approach implies the identification and quantification of emissions and material and energy consumptions which affect the environment at all stages throughout the product life cycle. This holistic perspective allows for a comparison of two or more options in order to determine which is better in terms of environmental impacts.

Environmental impacts commonly considered in the LCA of a building product

a. Depletion of abiotic resources (elements) in kg Sb equiv. and depletion of abiotic resources (fossil) in MJ

b. Global Warming Potential (GWP), in kg CO2 equivalent

c. Eutrophication Potential (EP), in kg PO4 equivalent

d. Acidification Potential (AP), in kg SO2 equivalent

e. Ozone Depletion Potential (ODP), in kg CFC-11 equivalent

f. Photochemical Ozone Formation Potential (POFP), in kg ethylene equivalent

Ligthart and Ansems [18] distinguish the recycling/reuse process based on where and how the recycled material is used again (Fig. 3.).

a. Closed loop recycling/re-use – here the material is used again in the same product system (e.g. re-use of windows)

b. Open loop recycling/re-use – the material goes to another product system, the inherent product properties are changed and the material is not used in 26 its original use (here the material is typically down-cycled and not the focus of re-use)

c. Semi-closed loop recycling/re-use – the material is used in another product system without changing the inherent materials properties (e.g. construction steel and aluminum) [16].

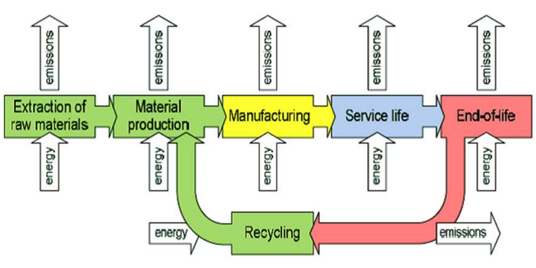

Fig. 3. The life cycle stages of a construction product including recycling according to [18].

6. Construction and Demolition (C&D) Waste

The C&D waste mainly consists of concrete, brick, ceramic and mortar together constitution around 80%, whereas wood and metal around 10%. Wood and metal are generally recycled easily however concrete, brick, ceramic and mortar are generally available in the mixed form and need processing before being put to use. Although the use of Recycled Aggregates (RA) is being studied since last 50 years but not being used in new structures due to lack of consistency in their properties and non-availability of the regulatory framework for their use.

Various experimental results have shown that the use of these recycled aggregate leads to poor concrete performance mainly in durability aspect. Reasons reported are higher porosity in these aggregates and high water absorption lead to poor water to cement (w/c) ratio. Also during demolition process lot of micro-cracks develops in these aggregate leading to higher penetration and high permeability [19].

A lot of processed recycled Aggregates are still used in nonstructural components like paver Cement Concrete, Sub-blocks, Plain-base broad pavement, Concrete pipes, sub-base below asphalt mix and fire insulation blocks [20].

7. Recycling Potential

Energy is considered at the beginning and in building destruction again regarded.

Two works are necessary to be done: first, ensure that potential of reuse and recycling influence on the choice of materials by designers at the beginning; second, ensure that the remaining energy to be extracted before transferring materials to the landfill. The remaining energy may be generated electricity by burning in a burn waste furnace or extracted through composition (material energy decompose to chemical products or by-products).

Recycling takes place when a material is reused in the form of the new product similar to the same material type [21].

7.1. Reuse of C&D Waste

There is an urgent need to understand the reuse and recycle potential of C&D waste which on one hand will generate potential business opportunity, employment generation and above all environmental sustainability. Useful products like reinforcement, Mild Steel, doors and windows, Structural steel, Bricks and other metal items can be taken out easily and again put to reuse without much processing [22]

Not only building material but also asphalt toppings can be used as the base for new asphalt pavement.

In developing countries like India and China where there are poverty and massive requirement of low-cost housing, these products can be consumed easily and also reduce the cost of construction of affordable houses. Once the reusable item is taken out rest of the C&D waste can be processed for recycling [23].

7.2. Recycling of C&D Waste

Once the reusable material is taken out the rest of the material is mainly consists of C&D Waste aggregate. As per BS 8500 (2002) this C&D waste aggregate are classified into two category one recycled concrete aggregates (RCA) and other crushed masonry based aggregate known as the recycled aggregate (RA) [24].

However, the small amount of contaminants like wood particles, gypsum, paper, cardboard, glass, and plastics has to be removed to get usable aggregates. Various techniques such as eddy current magnetic separation, Air shifting, dry density separation, and spirals are few of the techniques applicable today to automatically separate the contaminants [21].

8. Types of Recycling Building Materials

8.1. Plastics

Plastics have become an inseparable and integral part of human daily activities, the steady growth in its consumption may be attributed to its low density, strength, user friendly designs, fabrication capabilities, long life, lightweight, and low cost characteristics Large quantities of varieties of plastics such as high-density polyethylene from milk bottles, polyethylene terephthalate (PET) from beverage bottles, or even unsegregated plastic mixture are available in municipal solid waste stream. The world’s annual consumption of plastic materials increased from around 5 million tons in the 1950s to nearly 100 million tons in 2001 [25] Building materials can be an alternative means of using recycled waste plastics resulting from packaging.

Previous studies by [26] showed that it is indeed possible to use plastic waste in concretes or mortars. In particular, a research into the use of recycled polyethylene terephthalate (PET), a packing material byproduct, as the binder in the production of high-performance composite known as polymer concrete was reported. The plastic was transformed by means of a transesterification reaction, in the presence of glycols and the dibasic acid, into the unsaturated polyester resin. The resin was then mixed with sand and gravel.

The polymer concrete obtained was reported to exhibit high resistant in both compression and flexion, compared to conventional Portland cement concrete , it also has the advantage of developing over 80% of its ultimate mechanical strength within 1 day but with low resistance to temperature [27].

The use of plastic as an ingredient for the production of building material from the combination of plastic and wood was reported in a study by [28], an example of such is known as thermo-formable wood plastic fiber composite which is classified into processed melt blending and non-woven mat formulation, they result from the combination of powdered or pelletized thermoplastic such as polypropylene or polyethylene with wood flour or cellulose fiber. The primary application of these thermoformed composites, both melt and blended and air laid type is for interior door panels and trunk liners in automobiles [28].

8.2. Textile

There has been increasing environmental concern regarding the textile industry waste and those generated as postconsumer textile waste, due to the enormous amount not being used. In European Union (EU) alone, around 5.8 million tons of post-consumer textiles are discarded per year, only 1.5 million tons (i.e. 25%) go into recycling by charities and industrial enterprises. The remaining 4.3 million tones go to landfill or to municipal waste incinerators, thereby making textile wastes from the textile industry another significant source of waste [29]. In 2009, 293,000 tons of textile waste was produced, in Portugal, and the main textile waste generated in the country comes from wool, cotton and synthetic and artificial fibers.

Textile waste integrates the group of reusable materials that can be included in the building construction and which have different possibilities of application. These textile wastes may have the origin in the textile industry or may simply result from clothes that are no longer used. The study of the performance of these types of wastes in the construction is partly based on the behavior of the tissues when they are used as clothing. The primary function of clothing is to protect the human body from cold and heat, in order to keep thermal comfort conditions. This can be acquired ensuring an appropriate heat transfer between the human body and the outside environment. In this regard, studies to analyze the phenomena of heat transfer through the textile fabrics showed that their thermal insulation properties are highly related to the properties and configuration of their components, namely to the capillary structure, surface characteristics of yarns and air volume distribution in the fabrics [30].

8.3. Metal

Metal recycling is the process of reusing old metal material, mainly aluminum and steel, to make new products. Recycling old metal products uses 95% less energy than manufacturing it from new materials [31].

Million tons of energy is required in the chemical reaction process required to produce aluminum and steel products, meanwhile, for the recycling of metal products, only 4% of this total energy is utilized which serves as means of conserving natural resources and reducing greenhouse gas emissions.

Ferrous metal is regarded as the most profitable and recyclable material with the highly developed market and demand all over the world and therefore, the applications of these materials had been well accepted on site. Steel can be melted to produce new one, apart from it direct reuse, unlike few other waste materials, scrap steel allows repeated recycling, which is one of the factors that enables its 100% recyclability, Steel organization reports that roughly 100% steel reinforcement is made from recycled scrap and 25% steel sections are made from recycled scrap [32].

Waste steel slag which is a by-product produced during the conversion of iron ore or scrap iron to steel is another waste material that has potential for use in construction, it mineralogy composition changes with its chemical components, solid compound of CaO–FeO–MnO–MgO, and free CaO are the common minerals in steel slag [33].

8.4. Glass

Waste glass constitutes a problem for solid waste disposal in many municipalities and the practice of landfilling it does not provide an environmentally friendly disposal, due to its non-biodegradability. Consequently, there is a strong need to utilize/recycle waste glasses. In 1997, the glass industry recycled 425,000 tons of glass in the United Kingdom.However, the recycling rate is relatively low in Hong Kong (1%) in comparison with other countries (the rates in the USA, Japan, and Germany are 20, 78 and 85%, respectively). Glass can be reused in the construction industry for a number of applications such as: window, tiles, glass fiber, filler materials, paving blocks and aggregate in concrete.

Glass windows units from construction demolition can be reused directly depending on how carefully they are handled, stored, transported and contaminated. Recycled glass can be used for properties enhancement in the manufacture of glass fiber, which is used in thermal and acoustic insulations, which can be mixed with strengthening cement, gypsum or resin products [32].

8.5. Paper

Paper can be described as a sheet of cellulose fiber mostly obtained from wood, rags or grass fiber and sometimes other plants such as cotton, rice, and papyrus for production of special papers. Ever since its invention, it has formed an important part of the human day to day activities, with uses in many applications due to its versatile properties, the most common of such uses being writing and printing upon, others are but not limited to the packaging material, cleaning products, industrial and construction processes. The need to recycle paper is paramount upon the fact that, the more it is being utilized for several applications, the more the amount of waste paper generated and major percentage of these, finds their way to the municipal solid waste stream, according to the US environmental protection agency (US EPA), paper and paper board products make up the largest portion of the municipal solid waste stream in the United States, occupying 40% of the landfill composition in 2005 [34] and 27.4% of the total MSW before recycling in 2012 [35] Similarly, paper and cardboard waste form largest fraction of the municipal waste stream in Europe, accounting for 35% [36].

8.6. Aggregate

Structural concrete offers another range of potential sources, concrete is very durable (if properly implemented), hence, concrete structures as structural skeleton are considered for recycling. Waste concrete results from structures destruction can be re-crushed and used as aggregate in concrete construction. Using recycling concrete, environmental problems caused by concretes retail piled on the ground surface are reduced and also unsustainable extraction of natural stone aggregates prevented. Concrete does not usually need polishing, so, it has fewer health risks and is also durable environmentally if the necessary climate benefits are added for other types of buildings. The experiments show that recycling concrete with more compressive and higher tensile strengths than ordinary concrete is achieved in most projects using micro silica and lubricants. Also, using local producing concrete products, the costs of energy used in transport will be reduced dramatically. Characteristics of recycled concrete[37]:

a. Recycled crushed concrete has lower density and more porosity and consequently more water absorption than broken stone.

b. Replacing retail concrete instead of part or all of aggregate causes, reduction in concrete specific weight.

c. Ultimate stress is for 25% of recycled concrete less than normal concrete which indicates a low modulus of elasticity of recycled concrete than normal concrete.

d. Based on the gained results, recycled concrete shows more shrinkage than normal concrete [37].

Several kinds of research had been carried out to investigate the properties of concrete containing recycled aggregates of various types and quantities. Chemical stability, physical durability, workability, strength, permeability and shrinkage resistance are some of the properties that have been investigated. Most of these studies came up with the general conclusion that, concrete containing recycled coarse aggregate which is properly cleaned, and in quantities, not more than 50% replacement of virgin aggregate would have adequate durability, workability, and strength when compared with concrete containing 100% virgin aggregate [38]. Although, concrete containing recycled aggregate is expected to display slightly more shrinkage than that containing virgin aggregate [39]. The compressive and splitting tensile strengths of concrete made with recycled coarse aggregate depend on the mix proportions. The permeability of concrete containing recycled aggregate at w/c ratios same as that of concrete containing only virgin aggregate is also expected to increase [40]. With regards to chemical stability, it is important that waste aggregates being used do not contain reactive silica in order to avoid alkali-silica reaction (ASR) in the final product.

8.8. Wood

Wood waste may be sawdust from the sawing of wood or any other wood wastes. It is used in large quantities in many different sectors and is a part of human everyday lives; large volumes of sawdust and other recovered wood have accumulated in many places over the years. Sawdust can be described as loose particles or wood chippings obtained as byproducts from sawing of timber into standard useable sizes [41]. Other wood wastes may include, solid or chipped wood in its natural stage without chemical contamination, glued coated lacquered wood without halogenic materials as timber preservative, wood with halogenic materials (i.e. PVC) but no timber preservatives and wood with timber preservatives .About 30million tons of recovered wood is generated in Europe annually . Timber waste from C&D works is produced in large quantity all over the world. It is estimated that more than 2.5 million tons of timber wastes are generated in the United Kingdom each year [32]. The potentials of wood waste being recycled and utilized or reuse easily and directly in other construction projects after cleaning, de-nailing and sizing have been considered in some studies, Undamaged wood can be reused as the plank, beam, door, floorboard, rafter, panel, balcony parapet and pile .A new technology in turning timber waste into furniture, shoring wooden pile for relocated pine trees, bench and timber stair were developed in Japan in 2004. A special lightweight concrete can be produced from aggregate made from recycled small wood chunk [42].

8.9. Brick

Construction brick has a satisfactory appearance for a long-time and brick buildings are relatively healthy (no need to pay extra cost), they easily recycled at the end of their life and can be easily repaired in their longevity. If the building is destructed, the brick itself can be reused only if lime mortar (instead of cement) is attached. Brick can only be recycled as the low-value aggregate if mortar connection is strong, also recycled compositions can be used in brick production i.e. increasing a percentage of consuming waste paper in bricks, the porosity is increased with the steady trend and the strengths and specific weight are decreased. Investigating the results and comparing them with the relevant standards indicate that produced bricks can be used in different parts of buildings, while the existed paper in brick composition due to heating value is effective on fuel cost saving at brickyard furnace [43].

9. C & D Wastes in Tehran

Based on the results obtained from MAPSA, the generated C&D waste in Tehran between 2011 to 2016 was about 82,646,051 m3 (average 16,529,210 m3 per year) Most of the waste was generated in the construction of bridges and tunnels. The amount of each construction and maintenance of infrastructure in Tehran is shown in Table. 2 [4].

Table.2. Construction and Maintenance of the infrastructure waste in Tehran [4].

Laminating, cutting and manual asphalt	5,909,774
Creek and curb(m)	2,242,456
Pavement (m2)	1,112,491
Bridge (m)	652,038
Tunnel (m)	225,200
Stabilization, such as separation wall (m2)	617,334
Parks (m2)	3,293,286
Digging and wells (m3)	1,317,097

Looking at the pie chart (Fig. 4.), most of building materials' waste in Tehran is related to mixing sand and cement, concrete and brick, around 67% of all solid waste, especially in the bridge and tunnel sections. Therefore, the precise evaluation of these sections should be given priority for the construction and recycling projects.

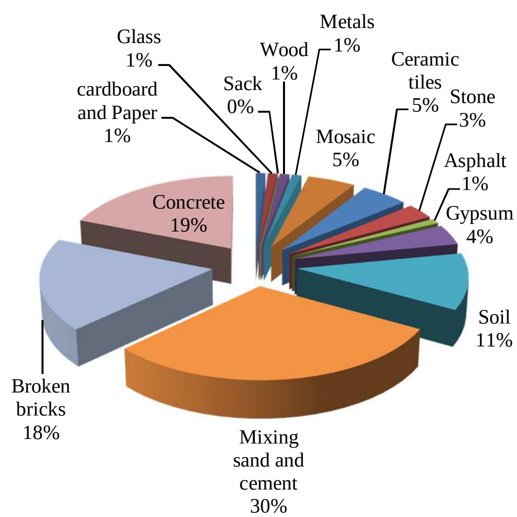

Fig. 4. The comparison of C&D wastes in Tehran [4].

Achieving an optimal management pattern is approachable through new technological strategies in the design, construction, renovation, and deconstruction of concrete structures. In addition, the scarcity of virgin aggregate can be the main motivation for the recycling of this type of material.
In Tehran, about 30,000 tons of C&D wastes are daily produced by the civil project and Table. 3. shows the components of these C&D wastes. More than 57% of these C&D wastes are recycled. About 16.7% of these C&D wastes are soil and rubble which are recycled and converted in situ into sand and gravel. Fig. 4. shows the percentage curve of materials which are recycled separately. The main purposes of recycling C&D wastes are making good materials with cheap price (subject to compliance with the standard), to avoid filling landfills, and reducing environmental impact and job creation.The most useful C&D waste that is recycling is mixed soil and rubble which can be considered as the main material in many civil projects after recycling. Mixed soil and rubble recycling process is shown in Fig. 6. It should be noted that during the recycling process, environmental tips such as not engaging contaminated materials should be considered [44]. The composition of C&D waste consists of wood, metals, concrete, soil, stone, paper, broken bricks, mixing sand and cement, gypsum, asphalt, rock, ceramic tile, mosaic, cardboard and paper, glass and sack. Salvageable materials like wood and metals usually resold or reused that caused to reduce the cost of collection and transfer of wastes [44].

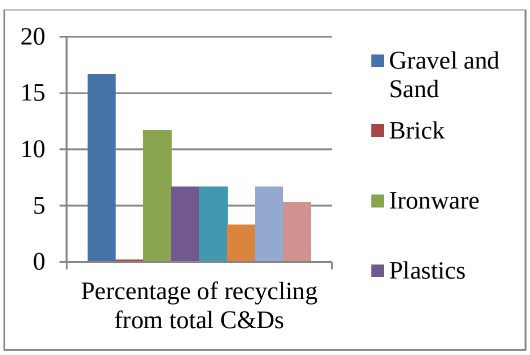

Fig. 5. Percentage of recycled materials [44].

Table. 3. Recycled products and rates[44].

	Recycling Products	The weight of recycled products (ton)	Percent of recycling from total C&Ds
1	Gravel and Sand	5000	16.7
2	Brick	50	0.2
3	Ironware	3500	11.7
4	Plastics	2000	6.7
5	Cardboard	2000	6.7
6	Plaster	1000	3.3
7	Sack	2000	6.7
8	Wood	1600	5.3

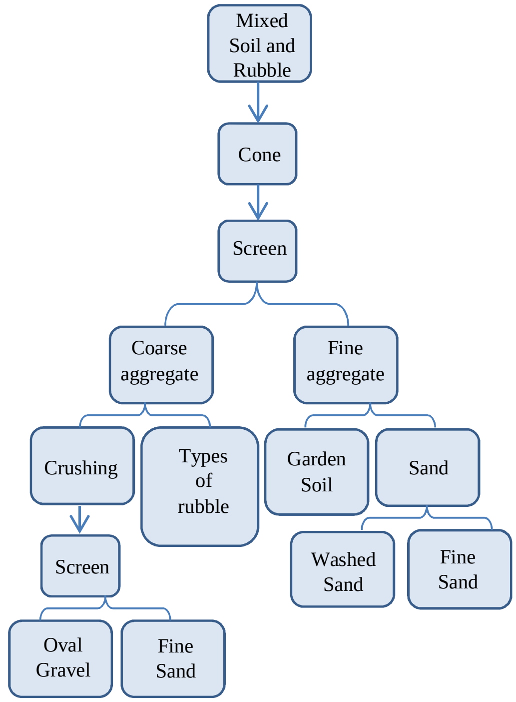

Fig. 6. Flowchart of mixed soil and rubble recycling process [44].

There are some scrap dealers in Tehran that collect the salvageable materials and sold them to secondhand buyers.
Unfortunately, this system of collecting and sale of these materials by collectors cannot have benefits at an efficient level, although it may consider as an effective application of reuse and recycling.
So, municipality's significant attention is required to handle this situation [44].
Table. 4. and Fig. 7. show that despite the fact that C&D waste generation rate has been fallen in a 7-year period, yet the total C&Ds recycled and reused remained stable, on average less than 20% of C&Ds generated.

Table. 4. C&D wastes which has been recycled and reused in Tehran [4].

Year	Total C&Ds generated in Tehran from 2009 to 2015	Total C&Ds recycled and reused in Tehran from 2009 to 2015
2009	24,717,122	3,440,280
2010	18,134,061	2,150,797
2011	18,312,841	3,798,405
2012	17,448,272	3,707,077
2013	16,144,926	3,991,870
2014	15,062,348	3,991,871
2015	15,701,904	3,991,872

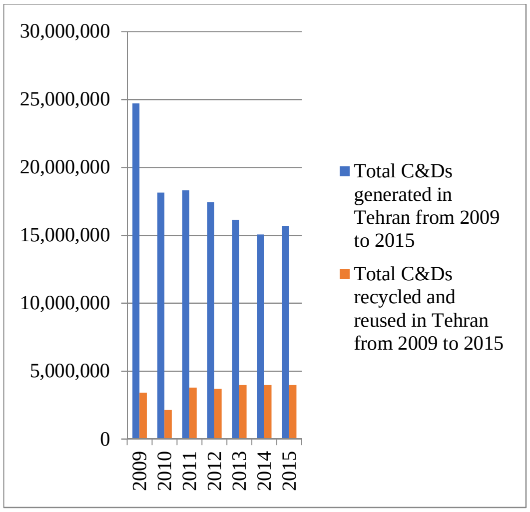

Fig. 7. Comparing the amount of left in landfill and C&D wastes which has been recycled and reused in Tehran[44].

Furthermore, C&D waste generation in Tehran in next eight years is shown in Table. 5. In this case, the coefficient for converting volume to weight ratio was 1.5. Based on the results, 2,784,158 t wastes will generate in 2025 and generation rate will be increased considerably, by 76% in comparison with 2018.

Table. 5. Generated waste in Tehran in next 8 years [4].

Year	Volume(m^3)	Weight(ton)
2018	910,001	1,578,852
2019	1,009,244	1,751,039
2020	1,108,287	1,923,225
2021	1,207,730	2,095,412
2022	1,306,973	2,267,599
2023	1,406,216	2,439,785
2024	1,505,459	2,611,972
2025	1,604,702	2,784,158

Thus, discovering the unchangeable pattern of recycling/reusing in Tehran from Fig. 7., and estimation around increasing C&D generation amounts in Tehran, suggest that if there is no comprehensive management in this regard Tehran will face a serious environmental degradation and problems in the near future.
Since the main C&D waste production belongs to the bridges and tunnels construction sectors, these sectors could be given higher priority in urban planning and C&D waste management programs. Through monitoring the construction and destroying process such waste could be minimized, and ultimately they could be recycled or reused in other building projects. Since most of these materials are in the "mixing sand and cement" and "concrete" sectors, modern technological solutions such as eco-concrete and nanotechnology in cement production are highly recommended.

10. Alternative Solutions for Managing Tehran's C&D Wastes

Generally, for overcoming to Construction and demolition (C&D) waste management issues in Tehran as the biggest city of Iran, paying attention to reuse, minimization and recycle program of the C&D solid waste and decreasing the amount of buried waste, using new technologies in this field and the successful experiences of other countries are recommended [4].

10.1. Mid-Term Actions

In Iran, buildings are conventionally constructed with a reinforced concrete or steel structure, plastered and painted masonry walls and steel fenestration. Floor finishes are terrazzo or ceramic tiles, while plumbing pipes and conduits for electric wiring are embedded in masonry walls. Buildings constructed with such materials are not easy to deconstruct; while the type and amount of recoverable building components is limited. The joints and mortar that are used in structural and non-structural connections are major reasons for the failure in appropriate deconstruction and severe drop in quality of recycled materials. The use of cement mortar in many of non-structural joints is a reason for impossibility of recycling stones, tiles, bricks, and etc. A revision in current practice of construction methods should be made to solve this problem by using simple methods that are possible according to national capabilities.
For instance, using dry joints in building facades and floorings and passing pipes through the false ceiling and shafts instead of passing them through mortars in walls and floors.
Applying these simple construction methods not only increases deconstruction ease and quality, but also extends life span of buildings by developing possibilities of building maintenance and lowering materials damages caused by their contact [45].

10.2. Long-Term Actions

Considering recycling potential of all building components in the design phase and investigating creative methods for design for deconstruction is the most efficient solution to promote deconstruction and recycling quality and quantity. Local capabilities and vernacular architecture should be considered in these studies, since they have advantages such as environmental friendly design, accessibility to materials, environmental compatibility of materials, localization of construction techniques, local employment, and less construction costs [45].

4. Conclusions

Considering the predictions of generated wastes in Tehran, it can be clearly established that they are significantly increased each year and will continue to be enhanced along with population growth and economic development.

Lacking comprehensive management of reducing and recycling C&D wastes would result in serious consequences in urban and environmental spaces, and compensation for the losses would also be time-consuming and costly.

Financial investment in this area may seem costly at first glance, requiring thorough and comprehensive planning and technological development in large urban areas like Tehran, however in the not-so-distant future, not only will it solve existing problems, but also will diminish the need for resource consumption. Furthermore, it will help to achieve an eco-friendly pattern which will prevent losing energy.

Hence, through adopting design and technological solutions in the recycling process, as well as minimizing C & D wastes, improvement in this area will be ensured. Making great use of successful experiences of other countries could also accelerate the progress towards this goal.

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