Tackling Demolition Waste – An en route to Sustainable Development

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***Abstract*— In Pakistan, construction and demolition waste (CDW) is generated in voluminous amount each year. CDW is widely ill-handled and ultimately fed to landfills causing harm to the already alarming environmental conditions. In order to search for the solution of this drastic matter, a study was done, which is explained in this paper. This paper presents the study done at a demolition site near Karachi, in Sindh while the demolition works were being carried out. At the site there were old barracks which were being demolished. Before the demolition works were commenced, the site was surveyed and structural components of the barracks were counted and their dimensions were measured. When the demolition was over, the demolished waste was calculated which comprised of concrete and masonry rubble, steel round bars, steel doors, steel windows, steel ceiling, steel girders, steel main gate, and plastic water tank. This study interpreted that construction and demolition (C&D) works were progressing considering the works' deadline and the clients' requirements but the ecosystem's ecology and the environmental health were not taken into account. Recommendations are made to handle CDW properly throughout its lifecycle. These recommendations aim to provide technological and logical solutions to grip CDW. The recommendations include waste reduction and reusing waste, life cycle assessment and costing, environmental and economic impact, material flow analysis, and advanced computerized-tools.**

***Index Terms*— Construction and demolition waste (CDW), greener ecosystem, sustainable development, deteriorating environment.**

I. INTRODUCTION

WE dwell in the era where technology is encompassing our lives and industries. The world today is investing to flourish high-tech solution for each and every issue. Like other industries, construction and demolition (C&D) industry is struggling to move at the pace of technology and trying to acquaint (C&D) works with the same. Construction of new structures, and demolition of old structures, is an unavoidable part of this technological development and innovation. As a consequence of this scientific sprint in the construction industry, large amount of C&D waste gets piled-up. Production of CDW has increased globally in past decades [1]. CDW is causing irreversible harm to lives, health, flora, and fauna i.e., the environment.

CDW includes all those waste materials that are produced during the construction works of new buildings and structures, renovation of existing structures, and demolition of old structures. These structures include, but are not limited to residential houses and apartments, commercial high-rises, and infrastructure of a metropolis like institutional and industrial buildings**,** roads, bridges, and airports. Encountering CDW in outsized quantities is a challenge because there are ever-increasing volumes of CDW, a lesser space in the landfills, and environmental, social, and economic impacts of the CDW on the society as a whole. This is the reason why managing CDW is crucial, to economically budget C&D activities and for the overall public health and greener ecosystem. In Pakistan, C&D is going on aiming at achieving clients' desires, finished and furbished structure, and meeting projects' deadline. The management of CDW is just to the extent of hauling it out of the site and sight as soon as possible. CDW is generally not seen as an ecological threat that is why, there are not much brainstorming done to find out answers to this problematic and persistent issue. Gradually, CDW is being dumped into the landfill or any non-populated nearby area. As CDW management is not seen as a problem, therefore, is not realized as worthy of being investigated methodologically. To highlight above issues and to find solutions to this problem, a study was done, which is registered in this paper.

Precautions during the demolition and handling of CDW not only save lives, but also lead to a better salvage value of the waste. Some precautions should be taken during demolition of those materials that can be recycled or reused like cabinets and doors, plumbing fixtures, pipes and insulation, steel ceilings, girders, windows, and steel doors. When these are demolished properly, then these can be reprocessed and used further. Demolition waste should not be buried on the property as it can be hazardous for the vicinity and may restrict future construction in that area. Concrete, masonry rubble, soil, and unpainted concrete are non-hazardous and can be sent for recycling. Hazardous materials like concrete painted with lead-based paint, asbestos in insulation, toxic chemicals in air conditioners cleaning products, and mercury in electronics should be separated from other materials and send to the hazardous material facility to remove the contaminants and send to landfill [2]. Other precautions before demolition starts include developing safety guidelines, educating workers and managers, a thorough clean up if the site, hiring experienced staff, and providing protective equipment and wearable, and fixing barriers at the site [3], [4].

Whenever there is a construction or demolition activity, there are different kinds of emissions that pollute the vicinity like dust and noise pollution. Nearby residents get disturbed due to extra noise and are forced to use alternate travel routes and walkways. There is potential for accidents and toxic chemical

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discharges. Debris gets dumped into nearby land and streams. Pests can thrive in these wastes which can release bad odor and effects health, of nearby habitat and humans. Aesthetics of the area are also disturbed.

Some of international standards and international practices for management of the CDW are mentioned here. In its article 11.2, the Waste Framework Directive (2008/98/EC) guides about demolition waste that at least 70% by weight should be reused, recycled, or reprocessed. Source separation is also encouraged, especially for hazardous materials. European commission scheduled a study to detect difficulties for recycling of demolition waste and to improve the quality of recycling. The Joint Research Centre has a provided guide on how to carry out a Life Cycle Assessment (LCA) of construction materials in order to reduce waste and support better environment. These guidelines are based on the International Organization for Standardization (ISO) standards 14040 and 14044 for LCA [5]. In India, the Ministry of Environment and Forests has mandated environmental clearance for all big construction projects. In Hong Kong, there are Public Works Programs under which the contractors are required to formulate waste management plans. In China, Municipal Construction Waste regulations impose stricter management on construction waste. In Malaysia, reuse and recycling have been practiced [6].

This study was done at a demolition site near Karachi, in Sindh while the demolition of old barracks was being carried out. Statistics of demolition waste at that site are presented in this paper along with recommendations to cater C&D waste. Prior to the demolition stage, the site was surveyed and structural components of the barracks were calculated and their dimensions were measured. Post demolition, the waste was calculated which contained concrete and masonry rubble, plastic water tank, steel bars, doors, windows, ceiling, girders, and main gate. This study showed that works' deadline and the clients' desires are priorities during demolition. Recommendations are given after the results to improve the management of CDW, to retain the ecosystem's ecology and to cater the environmental health.

II. RESEARCH METHODOLOGY

A demolition site near Karachi in Sindh was chosen to study demolition works. The demolition was being carried out of old barracks on the site. This site was chosen as the demolition study of the small barracks could set a benchmark, for future larger studies. The management of the site was welcoming and while they carried out their routine works, it was allowed to study, move around, and photograph the site. The site was also chosen because the demolished components lay around near the site for a while so it was manageable to calculate and measure the structural components properly. Fig. 1 shows the site survey prior to demolition.

The entire site was surveyed prior to demolition to count structural components of the barracks and to measure their dimensions. The structural components were concrete walls, steel ceilings, steel round bars, steel girders, steel doors, steel windows, and steel main gate. When the demolition works were accomplished, various types of massive demolition wastes were generated in large quantities. Almost all the demolished components were examined to prepare exact data.

Fig. 1: Site Survey prior to Demolition

The actual demolition waste production was calculated by measuring the quantities of separate structural components. The demolished concrete and masonry rubble was measured in cubic feet (ft^3). Steel round bars, steel doors, steel windows, steel ceiling, steel girders, and steel main gate were measured separately in kilograms (kg). Capacity of plastic water tank was measured in gallons, water supply Galvanized Iron (GI) pipe was measured lump sum, and electrical wiring connection with switched socket were also measured lump sum. Fig. 2 shows the plan of one barrack. Fig. 3 shows a view of barracks being demolished. Fig. 4 shows the demolition waste that was produced after the demolition. Fig. 5 shows steel waste. Fig. 6 shows the initial crushing of rubble waste. Fig. 7 shows material ready for recycling.

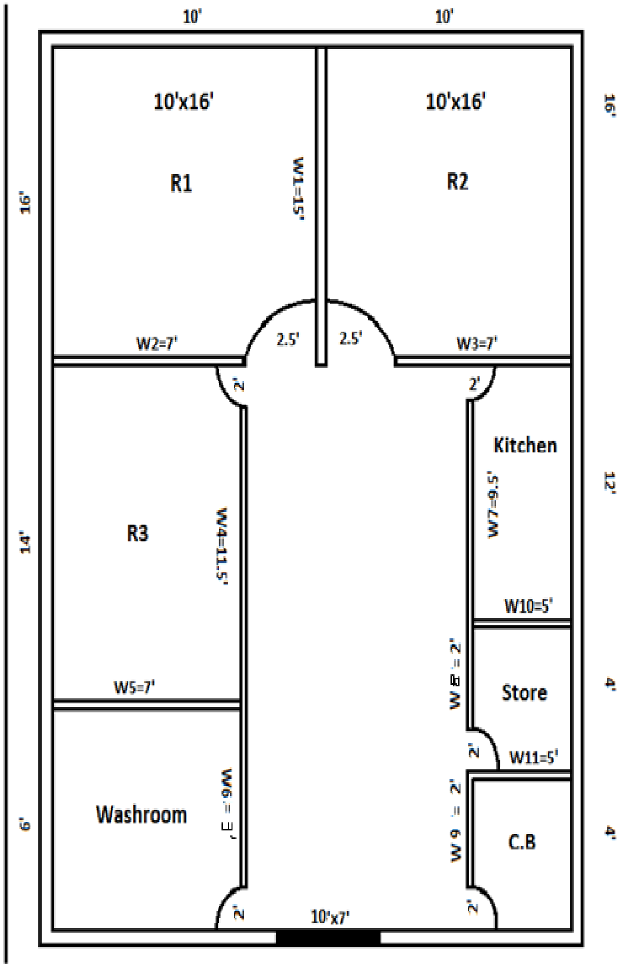

Fig. 2: Plan of One Barrack

Fig. 3: A View of Barracks being Demolished

Fig. 4: The Demolition Waste that was Produced after the Demolition

Fig. 5: Steel Waste

Fig. 6: Initial Crushing, of Rubble Waste

Fig. 7: Material Ready for Recycling

III. RESULTS AND DISCUSSION

A. Prior to demolition works

The demolition site was surveyed and structural components were counted and their dimensions were measured. The structural components were namely; concrete walls, steel ceilings, steel round bars, steel girders, steel doors, steel windows, and steel main gate. In the paper, the results of calculations of one barrack are mentioned for ease of understanding the entire scenario instead of getting lost in such calculations. Because the main purpose of this study is to create awareness towards sustainable development by reporting the site situations. Following is the result of number counts of structural components of one barrack: There were 11 inner concrete walls of various dimensions. There were two outer walls. The dimensions of both the outer walls were 36’ x 0.5’ x 20’. There was one UGWT (underground water tank) slab and bed with the dimensions of 16’ x 0.5’ x 10. Total concrete was 1250 cubic feet (ft^3). There were nine steel ceilings of gauge 20. Dimension of four of the ceilings was 12’ x 10’. Other two ceilings were with the dimension of 6’ x 7’. Remaining three ceilings were with the dimensions of 15’ x 8’, 9’ x 8’, and 9’ x 6’ respectively. Total steel ceilings were about 810 square feet (ft^2). There were 13 steel girders in total and all were with the dimensions of 6” x 4”. Out of 13 steel girders, five were 10 feet long, five were 8 feet long, and three were 6 feet long. Steel girders were a total of 108 running feet (RFT). Steel doors were seven in numbers. 2.5’ x 7’ was the dimensions of two doors and 2’ x 7’ was the dimensions of remaining five doors. Steel doors were a total of 105 ft^2. Steel windows were also eight in numbers. Three windows were with the dimensions of 4’ x 4’. The other three windows (ventilators) were with the dimensions of 1’ x 1.6’. One window had the dimensions of 6’ x 4’. The remaining window had the dimensions of 2’ x 2’. There were a total of 80.5 ft^2, of steel windows. There was one steel main gate with the dimensions of 10’ x 7’ which was a total of 70 ft^2. Table I shows the count of separate structural components with their dimensions and quantities prior to demolition.

B. *Prior to demolition works*

At the end of the demolition phase, there was a pile of demolition waste lying around. Demolished concrete and masonry rubble, steel round bars, steel doors, steel windows, steel ceiling, steel girders, and steel main gate were all piled up together. This demolition waste was calculated by looking into the quantities of different structural components. The demolished concrete and masonry rubble was 1569 cubic feet (ft^3). Steel ceilings of gauge 20 were 16.53 kg. Steel round bars of 40 grades weighed a total of 30 kg. Seven steel doors each weighing 1.4 kg/ ft^2 weighed 230 kg altogether. Eight steel windows, each weighing 1.2 kg/ ft^2, weighed 96.6 kg altogether. The only steel main gate weighed 1.8 kg/ ft^2 and its total weight was 126 kg. Thirteen steel girders each weighing 1.5 kg/ ft, weighed 162 kg altogether. The capacity of plastic water tank was 500 gallons. Water supply, GI pipes were lump sum 3000 feet long. Electric wiring connection and switch socket lump sum were 6000’ in length altogether. Table II shows the waste quantities after demolition.

Table I: Separate Structural Components with their Dimensions and Quantities Prior to Demolition.

S#	Items		No.	Measurement			Qty	Total
				L ft	B ft	H ft		
1	Concrete walls	Wall 1	1	15	0.5	10	75	1250 ft^3
		Wall 2	1	7	0.5	10	35	
		Wall 3	1	7	0.5	10	35	
		Wall 4	1	11.5	0.5	10	57.5	
		Wall 5	1	7	0.5	10	35	
		Wall 6	1	3	0.5	10	15	
		Wall 7	1	9.5	0.5	10	47.5	
		Wall 8	1	2	0.5	10	10	
		Wall 9	1	2	0.5	10	10	
		Wall 10	1	5	0.5	10	25	
		Wall 11	1	5	0.5	10	25	
		Outer Wall	2	36	0.5	20	720	
		UGWT Slab & Bed	2	16	0.5	10	160	
2	Steel ceilings of 20 gauges	Room 1, 2 & 3	2	12	10		240	810 ft^2
			1	15	8		120	
			1	9	8		72	
			1	9	6		54	
			2	12	10		240	
			2	6	7		84	
3	Steel girders (6”x4”) 1.5 kg/ ft		2	10			20	108 ft^2
			3	8			24	
			2	8			16	
			2	6			12	
			3	10			30	
			1	6			6	
4	Steel doors 1.4 kg/ ft^2		2	2.5	7			105 ft^2
			5	2	7			
5	Steel windows @ 1.2 kg/ ft^2		3	4	4		48	80.5 ft^2
			1	6	4		24	
			1	2	2		4	
		Ventilator	3	1	1.6		4.5	
6	Steel main gate @ 1.8 kg/ ft^2			10	7			70 ft^2

C. *After demolition was accomplished*

At the end of the demolition phase, there was a pile of demolition waste lying around. Demolished concrete and masonry rubble, steel round bars, steel doors, steel windows, steel ceiling, steel girders, and steel main gate were all piled up together. This demolition waste was calculated by looking into the quantities of different structural components.

Table II: The Waste Quantities After the Demolition

Structural Items	Quantities	Remarks
Concrete and masonry rubble	1569 ft^3	Concrete sent at various sites for recycling Masonry rubble sent for brick making
Steel round bars, 40 grades	30 kg	Bigger pieces were sold out Smaller pieces were picked by a garbage truck
Steel doors, 1.4 kg/ ft^2.	230 kg	All steel items were sold out to be used on other sites after refurbishment
Steel windows, 1.2 kg/ft^2.	96.6 kg	
Steel ceilings, gauge 20	16.53 kg	
Steel girders, 1.5 kg/ft.	162 kg	
Steel main gate, 1.8 kg/ ft^2.	126 kg	
Water tank (plastic)	500 gallons	It was algal from inside so garbage truck picked it
Water supply, GI pipes	3000 feet	Sold out
Electric wiring connections & switched socket	6000 feet	Garbage truck picked these

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IV. RECOMMENDATIONS

A. Source Separation and Reprocessing

It is highly recommended that C&D waste be segregated at the source rather than hauling it to some other point altogether. In this way separate structural items can be put to better use in good condition. The concrete can be reprocessed and shaped into fresh building materials [7], [8]. For example, if masonry rubble is separated, from other items, at the source, then it would be not too difficult to send it for brick making. The rubble, concrete can be crushed and reprocessed for brick molds.

B. Maximize the 3R (Reduce, Reuse, and Recycle)

More than half the quantity CDW has a residual value [9]. After considering the point of reducing the waste at source, CDW can be reused as it is, and the rest of it can be recycled. At least 70% of non-hazardous part of CDW can be recycled [10]. After reduction and source separation of CDW, the idea of re-using needs to be introduced into our culture, of a show-off. Individuals and construction companies want to decorate their construction no matter how much the eco-system is compromised to achieve that fine finish. Appropriate CDW management procedures should be devised prior to the commencement of C&D in order to deal with the over-flowing waste. The first steps in the management of the CDW are the on-site waste minimization, then consider reusing the returnable items [11]. The second step is that the leftover C&D material should be refurbished and put into use as much as possible. At last but not the least, CDW should be considered to dump into a waste disposal site.

C. Environmental Life-Cycle Costing (LCC)

LCC is a technique to evaluate investment decisions on projects [12]. LCC is beneficial when done programmatically to calculate the cost of resources required for green construction, to evaluate the overall cost of nature friendly construction, and to gauge the financial and environmental impact of the construction in the neighborhood [13], [14].

D. Environmental and Economic Impacts Of CDW

Studies should be done to find out these impacts and measures that need to be taken to make construction and management of CDW as eco-friendly as possible and make this development sustainable. Care should be taken on site that moisture content, if any, must be reduced from CDW before sending it to landfill so that it is free from pathogens and it doesn't attract vectors at the landfill site [15].

E. Material Flow Analysis (MFA)

Material flow analysis (MFA) is used to classify and trace the flow of any type of material for example C&D material [16]. To develop a, MFA model for investigation of the CDW: firstly, the generation quantity of CDW has to be assessed at various C&D sites; secondly, sales data has to be incorporated into MFA model; thirdly, surveys need to be conducted to collect data that defines consumers' priorities of storing, re-using, and disposing CDW; and lastly, CDW management should also be evaluated with respect to time and space [17]. When all the above steps are accomplished, keeping the prime objectives at the front, i.e., managing CDW at source and limiting its flow towards landfill so that it causes lesser harm to the environment, then a workable MFA model can be shaped. If and when MFA models are developed after proper investigation of CDW, then the waste can be suitably channeled according to its type and quantity. As a result the country can progress towards sustainable and eco-friendly C&D practices.

F. Life Cycle Assessment (LCA)

LCA is the process of finding out the situation of CDW from its initial temporary storage at the source sites to its final usage or disposal [18]. To establish CDW management plan, LCA of multiple sites should be done. LCA at various construction and demolition C&D sites can un-lock the management directions and reveal the limitations that hinder CDW management. Proper study of CDW sources and almost exact estimate of CDW quantities can largely benefit in problem solving of CDW management issues [19]. Throughout the lifecycle of a construction starting from its conceptual stage, various types of waste are produced in different amounts. CDW is produced to its maximum extent during a C&D stage of the construction project. LCA is important to find out the resource utilization, to find out the environmental impacts, to ensure sustainable projects, and to make decisions throughout the project's various phases.

G. Best Available Technology

Building Information Modeling (BIM) is a user friendly tool which offers a visual data display. BIM can be utilized to efficiently manage construction data [20]. Using BIM, the project can be virtually planned prior to the commencement of construction works. BIM can be used to store, change, and retrieve construction information which helps in managing project's resources, time-framing of the construction stages, coordination among clients and Construction Company, and preparing a practicable CDW management plan. Environmental sensory equipment that is based on lab-on-a-chip can be a cost-effective solution for environmental monitoring of the hazards that CDW offers [21]. Geographic Information System (GIS) is a geospatial technology, in which any sort of data can be saved, calculated, managed, and displayed [22]. To develop a mature and achievable CDW management system, spatial and temporal analysis of CDW is required. GIS is good for this type of analysis. The data in GIS are spatially referenced for exact analysis and understanding.

For CDW management, GIS can be ingeniously used as a computer-based tool feed and access the information about C&D waste separation, reduction, storage at the generation point, CDW transportation and final disposal. Furthermore, thematic mapping of separate and overlapping C&D sites can be done using an open source GIS software namely QGIS [23]. This type of mapping can help in better management of CDW.

V. CONCLUSION

Rise of urbanization and industrialization has been accumulating harmful C&D waste around the globe [24]. To tackle with the hazards and bulkiness of CDW, eco-design strategies should be established. Sustainable, eco-friendly, and high-tech handling of CDW is essential due to limited spaces at landfills, health problems, crumbling environment, and lack of green-awareness amongst the layman, architects, constructors, waste collectors, clients, and authorities [25], [26].

To tailor CDW management in a suitable way in Pakistan and to make the concerned authorities aware of CDW disarray, a study was done at a demolition site near Karachi in Sindh when the demolition of old barracks was going on there. The site was surveyed prior to demolition stage and demolition waste was calculated after the demolition works were over. This site study comprehended that during C&D works; large amount CDW is produced which get piled up at the site in a haphazard manner, there is no consciousness of managing CDW in an eco-friendly fashion, and even the reusable waste is considered as landfill feed. Because of these reasons; CDW causes a hostile influence on the ecosystem as it plays its role to decline the environmental conditions.

This paper suggests that if and when C&D works are done with prior and proper recognition of sustainable structures and green ecosystem, then CDW can be handled in a neat manner. This paper also advocates the procedures that how the environment can be prevented from being faded due to toxicity of cumbersome CDW. When the collection, recovery, recycling, and disposal of CDW is done via brainstormed decisions, resource management, advanced technology, and sustainable construction awareness then a better-quality surroundings can be hoped for. This study puts optimism in today's culture of environmental ignorance and forwards the sketch that green practices can preserve the environment while the high-rises are rising.

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