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Assessment of Construction Waste to Identify Issues that Disrupt Sustainable Development: Case Studies in Sindh, Pakistan

Nadia Qamar, Ayesha Alam Khurram
[1]Civil Engineering Department, Sir Syed University of Engineering and Technology, Karachi, Pakistan
[2]Civil and Environmental Engineering, Auckland University Engineering Association (AUEA)

Abstract
Due to intensification of construction works throughout the globe, the construction industry is facing challenges of managing construction waste. Researchers are innovating advanced construction waste management (CWM) techniques that can tackle bulkiness of the waste that remains problematic even after the construction. In Pakistan, a very little research is done to promote effective handling of such wastes. This paper presents the study done at construction sites in Daulatpur, Sindh, Pakistan during their peak construction stages. The construction sites were surveyed to calculate the construction waste which was produced during ground excavation, reinforcement works (steel), cement usage, and fine and coarse aggregates preparation and utilization. The volume and type of construction waste was estimated by site surveying, analysis of BOQs (bill of quantities) and MBs (measurement bills). The study shows that there is lack of awareness about the degree of harm that construction waste causes to the sustainability of the environment. The wastes at construction sites are horribly taken care of during every stage of construction from executing construction to waste disposal, then to handing over the site to the client. This paper proposes CWM techniques that can easily be adopted in Pakistan to ensure a sustainable development and a restored environment. The CWM techniques explain that how to cope with the waste by waste minimization, waste reuse, waste reconditioning, and waste disposal.

Keywords: *Construction waste management (CWM), sustainable development, green environment, waste minimizing, waste reconditioning.*

****Author for Correspondence*** E-mail: akhu008@aucklanduni.ac.nz

INTRODUCTION

When there is expansion of urban localities due to rise in population growth, embracement of lavish lifestyle, and due to migrants, then there are continuous and haphazard construction works [1, 2]. Due to construction works, the spreading and dumping of construction waste is inescapable [3, 4]. Construction waste is a type of solid waste that is produced during construction projects of any type such as commercial and residential buildings or infrastructures like dams, roads, and airports etc. [5]. The renovation or demolition of existing buildings or infrastructures supplements construction waste as well. The construction industry hugely adds to the widespread usage, lessening, and deprivation of natural resources [6]. As a result of utilizing natural resources during construction, the industry produces a large amount of waste each year. This construction waste gets accumulated which has deleterious impact on sustainable development and the environment. Construction waste also puts a financial burden on the projects' budget and on the country in the wider scenario. Due to these reasons, many developing countries are in the process of making systematic regulations to counter the waste [7]. There is too little methodical research available in Pakistan that can identify the problems caused due to construction waste or how to handle such waste [8]. The analytical survey of the construction site is the prime technique for gathering data to root out the problems caused by such waste.

In Pakistan, the construction waste is not catered properly and ultimately becomes a part of solid waste that gets dumped into landfills [9, 10]. Managing over-bulging landfill sites is another catastrophic issue on its own [11]. To understand the construction site conditions, construction waste handling problems, and to propose a workable construction waste managing framework, studies were conducted at various sites in Sindh, Pakistan. The observations of construction waste are presented in this paper after visiting the selected sites. There is almost zero awareness regarding waste in the construction industry in Pakistan due to which there is mishandling of the waste, resulting in high volume of waste. Little interest in CWM from clients and architects side results in no training for skilled labor which causes increment in waste [12, 13]. The construction companies spend less on the raw material compromising its quality. As a result, the raw material gets damaged easily and some raw material is already damaged when it arrives at the site. Construction waste consists of large amount of fine and coarse concrete aggregates, masonry, bricks, full and empty cement bags, reinforcement (steel), excavated earth etc. If these wastes are reused, it will prevent, to some extent, the damage of urban environment [14]. This paper recommends CWM strategies that can be acted upon and eventually Pakistan can progress towards sustainable development and a greener environment. The CWM methods are advised keeping in view the general criteria of waste minimization, waste reuse, waste reconditioning, and waste disposal.

METHODOLOGY

The two similar construction sites in Daulatpur, Sindh, Pakistan were chosen for this study. Daulatpur is a town and its GPS coordinates are 26.4944ºN, 67.9732ºE. Figure 1 shows location of Daulatpur in Pakistan and Figure 2 shows map of Daulatpur. At both the chosen sites, constructions types were same as constructions were being done for making commercial oil depot. Due to this similarity, it was easy to compare the CWM techniques and to recommend methods to improve CWM. These sites were preferred over other sites because construction phases were in full swing at both of the construction sites, the ongoing constructions matched the time frame allocated for site survey during this study, both of the sites were easily accessible via highway, site managements were welcoming, and there were open spaces adjacent to both construction sites that allowed proper segregation and handling of construction waste.

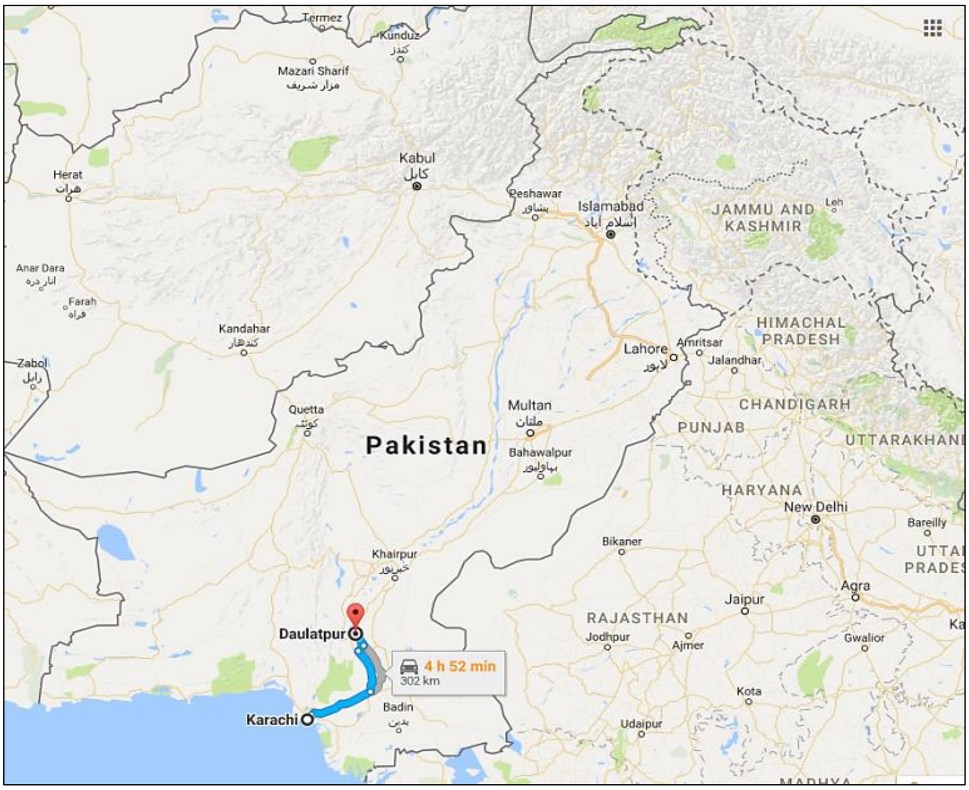

Fig. 1: *Location of Daulatpur in Pakistan (Taken from google.com/maps).*

Fig. 2: *Map of Daulatpur (Taken from google.com/maps).*

At both the sites, construction wastes were generated in high amount during the middle stages of construction works. The specific construction wastes were observed and calculated namely, excavated earth, reinforcement works (steel), full and empty cement bags, and fine and coarse aggregates. These wastes were chosen for analysis because these were the main waste streams at both sites and it was appropriate to figure out waste minimization, waste reuse, waste reconditioning, and waste disposal techniques for these wastes.

At both sites, MBs were gone through and evaluated using the methods of quantity surveying. Then the difference between BOQs and MBs was found out in order to scrutinize actual waste generation on sites. Following are the methodologies for the observations of construction waste at both the sites i.e. site I and site II. The construction waste includes excavated earth, reinforcement (steel), full and empty cement bags, and fine and coarse aggregates.

Site I

The entire construction site I was surveyed for ground excavation calculations. Excavations for footings, foundations, beams, and walls were observed and calculated separately. The total excavation was found out by summing up all the above excavation calculations. Total reinforcement usage was calculated by adding steel used as: (i) steel tore bar used for foundations, footings, columns, and RCC (reinforced cement concrete), (ii) steel ring, (iii) wall vertical bars, (iv) wall horizontal bars for inner and outer sides, (v) vertical bar ring, (vi) plinth beams, (vii) under plinth beam (viii) extra support bar, (ix) horizontal top beam bar, (x) angle iron, (xi) bar bending wire, and (xii) boundary wall steel bar.

After the construction was over, the wasted reinforcement was calculated. Total amount of cement bags were counted that were used to prepare 1:2:4, 1:4:8 and 1:3:6 concrete for the entire construction. Left over packed cement bags were counted at the end of construction. These packed cement bags were regarded as waste at the site but were in usable condition. Total numbers of unpacked and empty cement bags were counted after cement had been utilized for construction.

Fine and coarse aggregates were measured in CFT (cubic feet) that were used to prepare 1:2:4, 1:4:8 and 1:3:6 concrete for the construction. Remaining aggregates were measured after the construction. Figure 3 shows reinforcement (steel) stock before the laying of foundation at site-I and steel waste that was generated after the use of steel during laying of foundation.

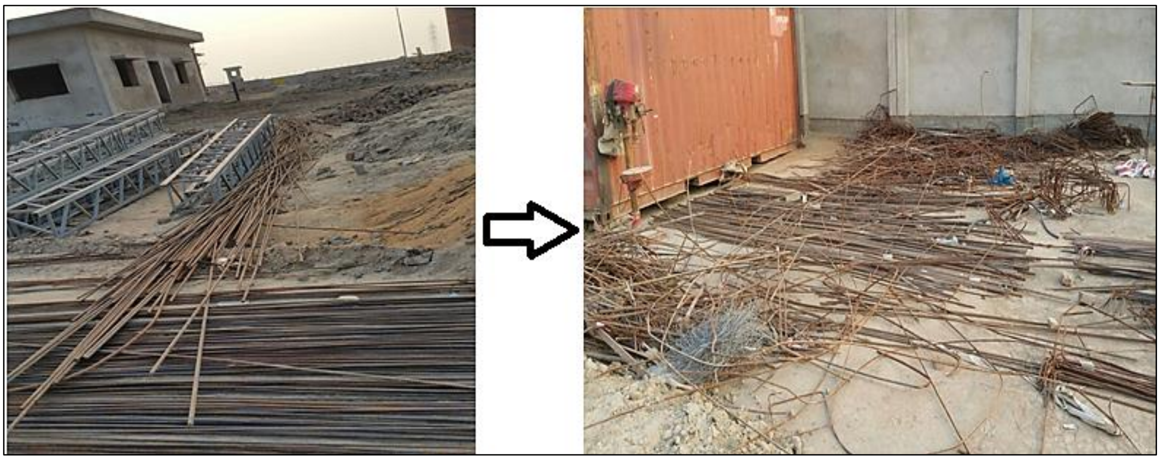

Fig. 3: *Reinforcement (Steel) before the Laying of Foundation at Site-I and Steel Waste That was Generated Afterwards.*

Fig. 4: *Construction Works at Site-II.*

Site II

The complete survey was undertaken at site II to observe and calculate excavation for inside pit all around four sides, mid of pit, foundations, stair case, side slope, generator foundations, control room, and trenches. The total excavation was found out by adding up all the above excavation calculations. Total reinforcement usage was calculated by adding up steel used as (i) steel bar, (ii) steel structure for staircase, (iii) C-channels, (iv) pipe, (v) angel, (vi) flat bar, (vii) platform plate, (viii) step plates, (ix) top plate, (x) steel pipe, and (xi) deformed steel bar. After the construction was over, the wasted reinforcement was calculated. Calculations for the amount of cement, counting of empty and damaged cement bags, and measurements of the volume of coarse and fine aggregates were conducted as per method explained for site I. Figure 4 shows construction works at site II.

RESULTS AND DISCUSSION

During the site surveying at site I and site II, the specific construction wastes which are explained in methodology were observed and calculated. Following is the result of the calculation that was done to calculate excavated earth, reinforcement works (steel), full and empty cement bags, and coarse and fine aggregates:

Site I
The ground was excavated before construction and the total excavated earth was 31878 CFT (cubic foot). The excavated earth was deposited off the site at a rate of 5 PKR (Pakistani rupee) per CFT. There was a total of 240000 kg reinforcement (steel) present at the site, out of which 238688.86 kg was used and 1311.14 kg came under the category of being wasted. Few smaller pieces of steel were utilized onsite later on. Number of empty cement bags was 4830.

Empty cement bags were sold at a rate of 3 PKR per kg (kilograms). 70 cement bags were found packed and in usable condition but were not being used at the site. These packed cement bags were sent to another construction site. In addition to these, coarse and fine aggregates were 18551.9 and 9275.9 CFT respectively at the start of construction. Remaining aggregates were unmeasured and lying around at site after their utilization. Some were used on-site, remaining were wasted.

Site II
The ground was excavated before construction and the total excavated earth was 2200316.98 CFT. Excavated earth was deposited off the site at a total deposition cost of 1 lakh PKR. There was a total of 443000 kg reinforcement (steel) present at the site, out of which 442420 kg was used and 580 kg came under the category of being wasted. Few smaller pieces of steel were utilized onsite later on. Number of empty cement bags was 4000. Empty cement bags were sold to generate revenue for extra expenses of the site. 55 cement bags were found that got damaged and were not being used at the site. Damaged cement bags were sold to garbage collectors.

In addition to these, remaining coarse and fine aggregates were 21534 and 10800 CFT respectively at the start of construction. Remaining aggregates were unmeasured and lying around at site after their utilization. Some were used on-site, remaining were wasted.

The Table 1 illustrates the amount of construction wastes at both sites. The construction wastes were: excavated earth, packed, damaged and empty cement bags, reinforcement (steel), coarse aggregates and fine aggregates.

RECOMMENDATIONS
After systematic observation of the handling of wastes at the construction sites, the recommendations are brought up to improve the management and overall health of construction waste prior to, during and post construction. These recommendations focus on how to handle the waste in a sustainable manner in terms of CWM plan, advance technology, the government, waste minimization, waste reuse, waste reconditioning, and waste disposal.

Table 1: *Amount of Construction Wastes at Site-I and Site-II.*

Construction Waste	Site #	Wasted on Site	Remarks
Excavated earth	Site I	31878 CFT	100% wasted, deposited off the site at 5 PKR per CFT
	Site II	2200316.98 CFT	100% wasted, deposited off the site with total deposition cost of 1 lakh PKR
Empty cement bags	Site I	4830	100% wasted, sold at 3 PKR per kg
	Site II	4000	100% wasted, sold to generate revenue
Packed and usable cement bags	Site I	70	Sent to another construction site
	Site II	-	
Damaged cement bags	Site I	-	Sold to garbage collectors
	Site II	55	
Reinforcement (steel)	Site I	1311.14 kg	Few smaller pieces were utilized onsite
	Site II	580 kg	
Coarse aggregates	Site I	Unmeasured piles	Some percentage used onsite, rest of it wasted
	Site II	Unmeasured piles	
Fine aggregates	Site I	Unmeasured piles	
	Site II	Unmeasured piles	

CWM Plan

The construction waste handling, segregation, transportation, and treatment should be predefined, methodical, environmental friendly, commercially feasible, and functional. In order to achieve this level of CWM, the CWM plan should be prepared and dispatched to project managers, contractors, suppliers, builders, supervisors, and to labors beforehand, prior to initiation of the construction phase. CWM plan should not be in form of complicated documents rather they should be user friendly, reasonable, practicable for specific projects, and easily accessible for effective and on-time execution. A CWM plan can be resourcefully applied during construction stages only when it is taken into consideration at the conceptual stages of a construction project.

Also, during the major phases of construction, a CWM plan should be incorporated i.e. from resources exploration to planning and detailed design phase then to tendering phase and finally to construction phase. When the construction commences, the entire life cycle of the project should be considered to keep the project environmentally sustainable and ecofriendly. The goal of CWM plan should primarily be to redirect construction waste from depositing into landfill to minimizing, reusing and reconditioning it.

Advance Technology

Today, the explosion of the technological advancements in every field is inevitable. If any field is not at the pace of the technology, it results in damaging that field along with negative impact on the environment which finally affects human species. Every study and research project is deemed to make life sustainable, fast, and stress-free. Surveying of construction site using global positioning system (GPS) and modeling the outcomes using geographic information systems (GIS) can advance CWM. If a proper GIS based data is collected, managed and delivered, then there can be efficient, easy and on-time control over construction waste [15]. During the phases of construction, the use of GIS can promote the tracking of supply chain, provide timely information of materials, surveillance of materials transportation spatially, modeling of construction phases, and mapping of the entire scenario and all the aspects of the construction [16]. The GIS can also be used to find out the spatial vastness of the construction waste at a particular construction site over a period of time. Then using GIS, the accumulation of construction waste can be mapped temporally to help the CWM plan [17].

The Government

If and when the government educates about CWM techniques from high to low level, assists market for recovered materials, develops construction industry standards, facilities reprocessing industry at or near construction venues, incorporates all types of construction works from residential to industrial and mining developments, mandates the utilization of recyclable products during specific construction, and provides training to the designers, authorities and labor; then CWM can be enhanced nationwide.

Waste Minimization

Minimization of construction waste at the source should be encouraged to the possible extent. The project's design tactics affect directly on construction waste reduction [18]. The inclusion of prefabricated construction items during the design phase and by incorporating the resources' dimensions available in the market can largely reduce construction waste on-site. Moreover, optimum construction material utilization, managing a smooth and timely materials flow to and from the site according to its demand, accepting and using high quality and standardized materials, ensuring less wear and tear by using reclaimed material present at or near site, and precise handling of unwanted construction waste can add to construction waste trimming to a desirable extent.

Waste Reuse

During the management of voluminous construction waste, the goal should be to choose such options such that waste can be reused efficiently while reducing the transportation cost of the remaining construction waste [19]. After applying all the above strategies for minimizing construction waste, reuse of rest of the construction material should be ensured [20]. Those sorts of materials that cannot be reduced should be reused as they are or after conditioning them. For example agricultural earth can be used for landscaping and old architectural features can be reused during renovation works.

Waste Reconditioning
On-site segregation of construction waste from large to small materials and from reusable to recyclable materials will improve the CWM process. Only after having gone through the procedures of waste minimization and waste reuse, construction waste should then be recycled or reconditioned into a form that can be used as secondary raw material. If and when planned prior to the beginning of actual construction, the recyclable items like concrete aggregates, reinforcement bits, and gravels can be utilized during construction.

Waste Disposal
Once successfully applying all the tactics for waste minimization, waste reuse, and waste reconditioning, waste disposal should be thought of. Controlled and slow paced flow of construction waste to its ultimate destination i.e. landfills would cause much lesser harm to the environment as it would if it is uncontrolled and thought-less.

CONCLUSION

Construction waste has become a global concern in today's fast paced and luxurious lifestyle. As the construction industry thrives and opens doors for improved socio-economic conditions of a country, the issue of CWM tags along. To cater this issue in Pakistan, onsite studies were conducted at selected construction sites in Daulatpur, Sindh, Pakistan, during their construction activities. Due to limited time and resources, the specific construction waste was observed which was amassed during ground excavation, reinforcement works, cement utilization, and aggregates' usage for preparation of concrete. The study interpreted that due to high volume of on-site construction waste projects' expenditure is increased, construction waste occupies large area on site limiting the productive utilization of that area, CWM gets trickier, aspects of waste minimization and waste reconditioning are bypassed in order to haul away construction waste quickly, and there is detrimental impact on the near-by flora, fauna, localities, and environment. All these issues are not favorable for sustainable development and green environment.

This paper infers that there is a lot of room for improving the decisions to cater construction waste in an elegant manner. This paper also recommends that research and technological innovations are vital in the field of construction as well for a brighter and healthier planet [21]. Solicitous, infused, and technological CWM practices during construction of small to large scale projects can help to achieve the goal of waste minimization, waste reuse, waste reconditioning, and waste disposal [22]. Finally a sustainable, ecofriendly, fresh, rich, and green environment can be maintained. This study is a step ahead if not a leap to stimulate CWM behaviorism and practices throughout Pakistan and in other developing countries. Future CWM research can impact positively to improve projects' economic conditions and can develop models via recent technology that can easily be adopted at construction sites while preserving the environmental greens [23]. Once that stage is accomplished, it can bounce back a better and brighter environmental setting [24].

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