

## MANAGEMENT OF AGGREGATE BASE COURSE WASTAGE IN ROAD CONSTRUCTION PROJECTS

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### Abstract

The construction industry in a country contributes significantly to the national economy. Developing countries in Asia produce a huge amount of construction waste. Road Construction (RC) projects, which are quite risky, often end up with cost and time overruns. Construction materials account for a major portion of the cost overruns. Thus, the management of material wastage in construction projects is important. Aggregate Base Course (ABC) wastage affects the cost of RC significantly. Thus, this study was on the waste management of ABC in RC projects executed in Sri Lanka. The study adopted a qualitative research approach and the required empirical data were collected by interviewing 13 experts. The interview findings were analysed manually using content analysis. The interviews were conducted based on the findings of a literature review. The interviews findings disclosed that improper material storage in sites, material wastage during transportation, improper material utilization, and professional inefficiency as the major factors that contribute to material wastage in road projects. Material reconciliation and proper documentation were identified as the two most common strategies that can be adopted to manage the material wastage in RC projects.

**Keywords:** *Aggregate Base Course; Material Wastage; Road Construction Projects.*

### 1. Introduction

According to Manamgoda et al. (2018), infrastructure systems play a dominant role in the economic growth of a country. They further state that road networks, which are vital for the development of a country, are one of the main infrastructure systems required by a country. Sri Lanka, although still a developing country, has an extensive road network comprising 217.825 km of expressways (Class E) and 12,220.587 km of national highways (Classes A and B) (Road Development Authority [RDA] 2019). These roads are the backbone of the transportation system of the country because the socioeconomic development of the country is facilitated by the roads through the speedy transportation of both people and cargo (Manamgoda et al. 2018). Road projects are notorious for being risky, and often end up with cost overruns (Ogbu & Adindu 2019). According to a study done by Gulghane and Khandve in 2015, construction material costs account for a large percentage of the construction project cost. Wijekoon and Aththanayaka (2013) found that one of the vital factors that contribute to cost overruns is material wastage. Thus, Choudhari and Tindwani (2017) emphasized the importance of material wastage management in Road Construction (RC) projects. Road construction relies mainly on non-renewable aggregate resources (Fladvad et al. 2017). According to Choudhari and Tindwani (2017), in road projects, Aggregate Base Course (ABC), a bulky and expensive material, is used to ensure the stability of pavement surfaces. They further state that the cost of transportation of construction material becomes high because of the large distance that exists between the material source and the construction site. ABC wastage in RC occurs mainly because of the bulkiness of ABC and the largeness of the quantities required (Wang et al. 2004). Hence, the control and management of material wastage in RC projects is essential throughout the supply chain of the project (Mahajan & Aher 2017). However, only few studies have so far been carried out on the material wastage management in RC projects (Choudhari & Tindwani 2017; Wijekoon & Aththanayaka 2013), especially on ABC waste management in RC projects (Wang et al 2004). None of these studies has focused on Sri Lanka.

Therefore, the aim of this study was to explore ABC wastage management in road construction projects in Sri Lanka. The objectives of the study were to identify the factors that cause ABC waste in RC projects executed in Sri Lanka, investigate the consequences of ABC wastage in those projects, and propose suitable ABC wastage control measures. The scope of the study was confined

to Sri Lanka. The study focused on the ABC material wastage in RC projects of Classes A and B and excluded road rehabilitation projects.

## 2. Literature Review

### 2.1. MATERIAL WASTAGE AND MATERIAL WASTAGE GENERATION FACTORS

Material wastage can be observed in almost all types of construction projects (Mahajan & Aher 2017). Construction waste, which can originate from various sources, is usually found throughout a building project (Jayamathan & Rameezdeen 2014). This construction waste has become a challenge to the construction industry in the achievement of its sustainable goals (Kulatunga et al. 2006). Construction project cost largely depends on the cost of the materials used (RathinaKumar et al. 2018). Patel and Poitroda (2017) mentioned that material cost accounts to 60% –80% of the total construction cost, which is a significant percentage. Therefore, to ensure cost control, the proper management of construction materials becomes crucial (Madhavarao et al. 2018).

Akanni (2007), after studying 146 Nigerian building projects, identified ten major factors that are responsible for material wastage and their percentage contribution to the total amount of the material wastage generated. According to the author, site storage (43%), transportation and delivery to site (14%), pilfering and theft (14%), wrong specifications (6%), intra-site transits (5%), fixing (5%), wrong use (5%), conversion waste (3%), negligence (3%) and management (2%) contribute to material wastage in construction projects. Kulatunga et al. (2006) stated that the behaviour of the construction workforce affects most of the factors responsible for material wastage. They concluded that the attitudes and perceptions of the construction workforce can influence the generation of waste and the implementation of waste management strategies.

### 2.2. IMPORTANCE OF MATERIAL WASTAGE MANAGEMENT

Material wastage results when inaccurate quantities of materials are purchased; poor quality materials are procured; and materials are used inefficiently and ineffectively (Shen & Tam 2002). The main consequence of construction material wastage is cost overruns (Kanimozhi & Latha 2014) because construction cost estimates are generally based on a straight take off of the required quantities (Sakantu et al. 2003). Hence, the proper management of material wastage will ensure efficient and effective material use (Hwang & Yeo 2011) with the right quantity and quality (Kanimozhi & Latha 2014). This will in turn control the cost overruns of the project (Saidu & Shakantu 2017).

Mahajan and Aher (2017) stated that with proper construction material waste management, the average saving of the material cost can be as much as 8.80%. In order to effectively manage material wastage in construction projects, material waste control measures that can control cost overruns at both pre-contract and post-contract stages of a project should be introduced (Saidu & Shakantu 2017). Material reconciliation is one of the material wastage management techniques, which ensures that no difference exists between the quantity of the procured material and the quantity of material required according to the Bill of Quantities (Rameezdeen et al. 2004). Furthermore, Ling and Nguyes (2013) emphasized that waste management in the construction industry can effectively be implemented by employing subcontractors capable of waste management; conducting training programmes; auditing and supervising subcontractors and workers closely; sequencing activities to reduce damage to completed work; setting the level of wastage allowable; and offering rewards and enforcing punishments.

### 2.3. RC PROJECTS AND ABC MATERIAL WASTAGE

Cost and time overruns are common in infrastructure and building construction projects (Mahamid 2011). Road construction involves the movement and relocation of large quantities of materials (Choudhari & Tindwani 2017). RC projects are considered high-risk projects because of their probable cost overruns (Ogbu & Adindu 2019), which occur mainly because of material

wastage (Wijekoon & Aththanayaka 2013). Hence, proper material management is necessary in RC projects (Choudhari & Tindwani 2017).

Use of unbound aggregates as base course layers in the construction of flexible pavements is common around the world (Patil & Pataskar 2013). The materials used in each layer of the pavement have to comply with the stipulated specifications. The main type of construction material used in RC projects is non-renewable aggregate resources. A considerable percentage of the material cost of road projects can be attributed to the aggregate cost (Ogbu & Adindu 2019). ABC is a durable and well graded aggregate, which has been moistened uniformly and stabilized mechanically through compaction (Unified Facilities Guide Specifications [UFGS] 2017). According to Arnold et al. (2007), most road controlling authorities, generally specify dense graded ABC materials for road construction because they have few voids, high strength, and high stability owing to the interlocking particles present in them. These ABC materials, which are compact, are difficult to handle and do not possess their specified strength (Arnold et al. 2007). Thus, the wastage of the ABC materials used in RC projects is high. The study of the management of ABC material wastage in RC projects is therefore important because by properly managing the ABC waste, a project can be made a success.

**3. Methodology**

Hammarberg et al. (2016) state the qualitative research approach is best for collecting opinions and facts from people based on their experience and behaviour. Therefore, this study used the qualitative approach to collect the data required to identify the specific factors that cause ABC wastage in RC projects, by interviewing experts in the field of road construction. Purposive sampling was used to select, as interviewees, experts who had experience in road projects. William (2015) emphasized that semi-structured interviews are more relevant to situations where the researcher requires the interviewees to have in-depth knowledge in their field of expertise. To collect the in-depth data required, thirteen experts with knowledge on ABC wastage that occurs in RC projects and a minimum of ten years’ experience in RC projects were interviewed until data saturation was reached. Interviews were conducted face to face with each interview lasting for about 50 to 65 minutes. Content analysis was used to manually analyse the collected data because it allows the researcher to become familiar with the collected data and maintain a full control over the data. Table 1 below lists the details of the experts who were interviewed.

Table 1: Details of the interviewees

Expert Code	Designation	Total Experience in Years	Experience in RC in Years
a	Senior Quantity Surveyor	14	12
b	Materials Engineer	14	10
c	Quantity Surveyor	12	11
d	Senior Engineer	15	11
e	Costing Executive	10	10
f	Technical Officer	13	12
g	Senior Engineer	18	13
h	Site Engineer	15	12
i	Chief Quantity Surveyor	34	30
j	Technical Superintendent	25	20
k	Senior Material Engineer	13	10
l	Senior Engineer	17	15
m	Project Manager	18	13

*RC- Road construction*

**4. Analysis and Findings**

**4.1. MATERIAL WASTAGE AND MATERIAL WASTAGE GENERATION FACTORS**

Several factors cause ABC wastage in RC projects. Table 3 shows 21 factors identified from the literature and 6 factors identified from the interviews. The experts agreed that all 21 factors identified from the literature are relevant to ABC wastage in RC projects in Sri Lanka. In Table 3,

the factors identified from the interviews are highlighted. Poor workmanship, lack of a waste management plan, and rework, which are in bold italics, were identified as factors directly responsible for ABC wastage in RC projects, as revealed by Adewuyi and Oтали (2013) and Saidu and Shakantu (2017) as well. Some of the interviewees classified the other factors as indirect factors responsible for ABC wastage in RC projects. The errors in contract documents and complicated design were identified as indirect factors by the interviewees as also stated by Adewuyi and Oтали (2013) and Wang et al (2004). Complicated design was considered an indirect factor by the interviewees because such a design becomes a challenge when the professionals handling the design lack the required skills.

Table 2: Key Factors responsible for ABC wastage generation in RC Projects

#	Factor	L	a	b	c	d	e	f	g	h	i	j	k	l	m
1	Design changes and client changes	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	<b>Poor workmanship</b>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	Poor and wrong storage of materials	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4	Lack of on-site material control	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5	Double handling of materials	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6	Poor quality of the materials	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
7	<b>Lack of a waste management plan</b>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8	Inadequate supervision	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
9	Complicated design	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10	<i>Rework</i>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
11	Incorrect materials	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
12	Use of untrained labour	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
13	Adverse weather conditions	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
14	Poor quality equipment and non-availability of equipment	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
15	Theft and vandalism	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
16	Errors in contract documents	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
17	Wrong construction method	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
18	Manufacturing defects	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
19	Ordering errors	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
20	Quantity surveying mistakes and over payment of allowances	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
21	Damage during transportation	✓	✓	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
22	<b>Laying ABC without construction shoulders</b>			✓			✓		✓			✓			
23	<b>Use of inappropriate machinery to spread ABC</b>			✓			✓		✓	✓			✓		
24	<b>Use of ABC in place of soil because ABC is easier to handle than soil</b>			✓					✓	✓		✓			
25	<b>Increased time taken for internal transport</b>					✓	✓		✓			✓			
26	<b>Material segregation during loading, unloading, and laying of mortar grader</b>					✓	✓				✓	✓			
27	<b>Uncovered materials or material storage in open areas</b>								✓				✓	✓	

L- Literature findings

Interviewee B did not agree that damage during transportation causes ABC wastage in RC projects as revealed by Adewuyi and Oтали (2013) and Saidu and Shakantu (2017). Interviewee B was of the view that since wastage occurs during all three processes of loading, unloading, and transportation of material, naming wastage as transportation wastage is incorrect. Interviewee K also agreed with the view of Interviewee B. The interviewees also mentioned six new factors which in their opinion contribute to ABC wastage in RC projects. These six factors were not mentioned in the literature. Laying ABC without construction shoulders, using inappropriate machinery to spread ABC, using ABC in place of soil because ABC is easy to handle, increased time taken for the internal transportation of materials, segregation of materials, and storing ABC in open spaces were the six factors. Among the factors, using ABC in place of soil because ABC because of its ease of handling was identified as an indirect factor causing ABC wastage. All other factors were considered direct factors responsible for the ABC wastage in RC projects.

#### 4.2. CONSEQUENCES OF ABC WASTAGE IN RC PROJECTS

The consequences of ABC wastage highlight the importance of proper waste management. As illustrated in Table 3, altogether 15 consequences of ABC wastage could be identified; 11 of them which were identified from the literature were accepted by the experts as being applicable to RC projects executed in Sri Lanka as well.

Table 3: Consequences of ABC wastage in RC projects

#	Consequences	L	a	b	c	d	e	f	g	h	i	j	k	l	m
1	<b><i>Cost overruns</i></b>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	Quality issues	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	Time overruns/Delays	✓	✓	✓	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4	Project delays	✓	✓	✓	x	✓	✓	✓	✓	✓	x	✓	✓	✓	✓
5	Environmental issues	✓	✓	✓	x	✓	✓	x	✓	✓	x	✓	✓	✓	✓
6	Negative effects on the society	✓	✓	✓	x	✓	✓	x	x	x	x	✓	✓	✓	✓
7	Increased material prices	✓	✓	✓	x	x	✓	✓	✓	x	x	✓	✓	✓	✓
8	Health issues of the people	✓	✓	x	x	✓	✓	x	x	x	x	✓	✓	✓	✓
9	Increased illegal dumping	✓	x	x	x	✓	✓	✓	✓	✓	x	x	✓	✓	x
10	Project termination	✓	✓	✓	x	x	✓	x	x	✓	x	x	✓	✓	✓
11	Land shortage	✓	x	✓	x	x	✓	✓	x	✓	x	x	✓	x	✓
12	<b><i>Financial issues of the contractors</i></b>			✓			✓	✓		✓		✓	✓		
13	<b><i>Increased number of government regulations</i></b>			✓			✓		✓		✓				✓
14	<b><i>Disputes among the parties</i></b>			✓	✓	✓						✓			✓
15	<b><i>Issues related to quantity calculations</i></b>								✓	✓			✓	✓	
L- Literature findings															

The four highlighted consequences were identified by the interviewees as those unique to Sri Lanka. Of the consequences identified from the literature, only cost overruns (Ogbu & Adindu 2019; Wijekoon & Aththanayaka 2013) given in bold italics was accepted by all of the interviewees as being applicable to ABC wastage in RC projects executed in Sri Lanka. Most of the interviewees agreed with the literature review findings. By contrast, financial issues of the contractors, increased number of government regulations, disputes among the parties, and issues related to quantity calculations were also identified by the interviewees as the consequences of ABC wastage encountered in RC projects executed in Sri Lanka. A majority of the interviewees did not accept project termination identified from the literature as resulting from ABC wastage in RC projects in Sri Lanka stating that parties to a contract try to avoid disputes to prevent project termination. Most of the other material wastage consequences are applicable to ABC wastage in Sri Lankan road projects.

#### 4.3. KEY MEASURES THAT CAN BE USED TO MANAGE ABC WASTAGE IN RC PROJECTS

As illustrated in Table 4, 25 measures are available to manage ABC wastage in RC projects. Twenty measures that were identified from the literature were accepted by all of the interviewees as being applicable to ABC wastage management in RC projects in Sri Lanka as well. Measures that are highlighted were identified by the interviewees based on their experience in RC projects which are unique to ABC waste management in Sri Lanka.

Table 4: Measures that can be used to manage ABC wastage in RC Projects

#	Measures	L	a	b	c	d	e	f	g	h	i	j	k	l	m
1	<b><i>Improved material transportation</i></b>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	<b><i>Proper material storage</i></b>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	<b><i>Improved onsite construction management by the contractor</i></b>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4	<b><i>Proper site control and supervision</i></b>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5	<b><i>Protection of material from weather damage</i></b>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6	<b><i>Use of skilled and experienced labor</i></b>	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
7	Use of appropriate materials	✓	✓	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓
8	Maintenance of proper records and	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	✓

#	Measures	L	a	b	c	d	e	f	g	h	i	j	k	l	m
	documentation on the materials used														
9	Ordering of correct quantities of the materials and timely delivery of the materials	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10	Proper scheduling and planning	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
11	Proper onsite administration of 5 Ms (men, material, money, machines and management)	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓
12	On-site and off-site re-use/ recycle of waste, and on-site waste sorting	✓	✓	✓	×	✓	✓	✓	✓	✓	×	✓	✓	✓	✓
13	Efficient unloading of materials supplied in loose form	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓
14	Procurement of material complying with the specifications	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	✓	✓
15	Provision of easy access to delivery vehicles	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	✓	✓
16	Provision of security, security lighting, and temporary fencing for the site	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓
17	Integration of waste management into construction contractor assessment	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓
18	Adoption of good material abstracting	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×
19	Adoption of a unified method for estimating the procurement process	✓	×	×	✓	✓	×	✓	✓	✓	×	✓	✓	✓	✓
20	Obtaining insurance cover for the procured materials	✓	✓	✓	✓	×	×	×	✓	×	×	✓	✓	×	×
22	<b>Adoption of an innovative method for laying ABC</b>		✓	✓			✓			✓		✓			✓
23	<b>Finding an alternative for ABC that is similar in performance to ABC</b>			✓					✓	✓	✓				✓
24	<b>Storage of materials free of dust, organic matter, clay and silt or any other matter</b>		✓		✓	✓								✓	
25	<b>Ensuring the required humidity level when storing ABC</b>			✓				✓	✓					✓	
L- Literature findings															

Among the identified measures, improved transportation of materials, use of skilled and experienced labour, proper material storage, and proper site control and supervision were accepted by all the interviewees as being applicable to ABC wastage management in the RC projects executed in Sri Lanka. These measures are bolded and italicized in Table 4. All other measures were also accepted by most of the interviewees. However, obtaining insurance coverage for the procured material recommended by Saidu and Shakantu (2017) was not accepted by most of the interviewees as according to them although such coverage provides for the reimbursement of the cost of wasted materials it does not help manage the ABC wastage.

The interviewees identified four new measures as well, namely use of an innovative method for laying ABC; finding a good alternative for ABC that is similar in performance to ABC; storage of materials free of dust, organic matter, clay and silt or any other matter; and ensuring the required humidity level when storing ABC. Two of these measures relate to the proper storage of materials (Saidu & Shakantu 2017), while other measures focus on finding an alternative material for ABC and using an innovative method for ABC laying (Agyekum et al. 2012).

## 5. Conclusion and Recommendations

This study explored material wastage in road construction projects by identifying the significance of material wastage management in road construction projects, consequences of material wastage, and the measures that can be taken for wastage management. The study particularly focused on the ABC waste management in RC projects in Sri Lanka. It identified the key factors that are responsible for ABC wastage in RC projects. Poor workmanship, lack of a waste management plan, and rework were identified by all the experts who were interviewed, as the key factors that cause ABC wastage in RC projects executed in Sri Lanka. Major consequences of ABC wastage in RC projects were also revealed during the study. Cost overrun was the key consequence noted by all of the interviewees, while other consequences were also considered by them as being indirectly or directly related to cost overruns. Waste management measures were also discussed in detail. Use

of skilled and experienced labour, improved transportation of materials, proper material storage, and proper site control and supervision were highlighted by the interviewees as the measures that can be taken to manage ABC wastage in RC projects executed in Sri Lanka. Thus, this study will provide new knowledge by identifying the causes of ABC wastage and the strategies that can manage that waste. In addition, waste generation factors, and consequences and key measures of waste management of other material in RC projects are applicable to ABC. The study contributed to research by identifying the factors causing ABC waste generation, consequences of ABC waste generation and key ABC waste management measures in respect of Sri Lankan RC projects. The study will also contribute to practice by helping to reduce the cost of road construction projects by minimizing wastage, saving natural resources, and enhancing the sustainability of construction. More importantly, the study findings will be useful to other developing countries as an initial study.

ABC wastage management in RC projects in Sri Lanka can be made more effective and systematic by including ABC wastage in RC projects in the curricular of relevant study programmes to make the students aware of the value of proper ABC waste management techniques; conducting continuous professional development programmes to help industry professionals gain knowledge of ABC wastage in RC projects and the new trends and technologies of ABC wastage management in RC projects; facilitating research and development on ABC waste management in RC projects to ensure the continuous growth of road development in Sri Lanka; initiating action by government agencies like Road Development Authority to highlight the importance of ABC waste management in RC projects in their annual reports and publications, which will help to build awareness among both the professionals and the public, about the importance of ABC waste management. The major limitation of the study is the confining of the interviews only to Sri Lanka making it difficult to generalize the results to developed countries, which are economically, environmentally, technically, socially, and financially more advanced than Sri Lanka. Further research could be conducted on the use of modern technologies, such as building information modelling (BIM), that will ensure accurate quantity calculations in ABC waste management in RC projects (use of BIM in ABC waste management in RC projects).

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