# Development of a Quantitative Material Wastage Management Plan for Effective Waste Reduction in the Building Construction Industry

Kwok Tak Kit

**Abstracts**—Combating climate change is becoming a hot topic in various sectors. Building construction and infrastructure sectors contributed a significant proportion of waste and greenhouse gas (GHG) emissions in the environment of different countries and cities. However, there is little research on the micro-level of waste management, "building construction material wastage management," and fewer reviews about regulatory control in the building construction sector. This paper focuses on the potentialities and importance of material wastage management and reviews the deficiencies of the current standard to take into account the reduction of material wastage in a systematic and quantitative approach.

*Keywords*—Quantitative measurement, material wastage management plan, waste management, uncalculated waste, circular economy.

#### I. INTRODUCTION

NDER the Paris agreement 2015 and United Nations Climate Change Conference COP 26th 2021, the race of those countries committed to the GHG reduction to combat climate change became more vigorous. Broadly, the reduction of GHG emissions involved different sectors in the economy to contribute in order to achieve the global and government target. The construction sector is one of the major sectors in different countries in terms of its contribution to gross domestic production (GDP) and the generation of GHG emissions in most developed and developing countries and cities, and more effort should be deployed to alleviate the problem of GHG emissions. Different government and professional agents have stepped up to set up a roadmap to reduce GHG emissions. However, the action plan in reduction of GHGs due to excessive material wastage and disposal is still in the theoretical and planning stage, and needs to have an imminent action to develop a more comprehensive and all directions approach to meet the target of GHG emissions reduction. In this paper, we will focus on the concept of material wastage management based on experience and literature review and conduct a holistic review of the deficiencies of current standards to reduce the material wastage in a systematic and quantitative approach. Recommendations will be summarized in this paper for further research and study.

## II. CONSTRUCTION WASTE

The term construction and demolition (C&D) waste is

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commonly used in the construction and commercial sector and it generally describes the waste generated in the construction process. The construction wastage including surplus materials arising from site clearance, excavation, construction, refurbishment, renovation, demolition and road works. The realization of the importance of waste quantification to overall waste management is crucial to sustainable development of the building construction industry [17].

## Current Government Policy and Practitioners' Practice of Building Material Wastage Management Adopted in the Building Construction Industry

The national standard, government policy and management of C&D waste generated in the building and construction industry have been developed and based on the 3R principle (Reduce, Reuse and Recycle). The C&D waste generated in the construction process is monitored and regulated to ensure proper disposal to government landfill.

Current industry practice in most of the developed countries and major cities has been included the waste management plan in public and private projects to regulate waste generation and management but it solely serves to reduce the C&D generation in a macro level management [3], [5]. At the micro level, there is no quantitative standard to control and monitor the reduction of "construction material wastage" as it forms the majority of the total C&D waste generated from fabrication and installation during the construction phase.

## Classification of Material Wastage Type in Building Construction Industry

Currently, there is no specific term to describe and classify the terminology of material wastage. In this paper, the material wastage in the building and construction industry will be classified and named based on the nature of generation of material wastage as follows:

- Calculated Material Wastage included the normal wastage generated during normal construction methodology and work sequence. It cannot be avoided but can be controlled by careful planning and use of advanced building construction technologies
- Uncalculated Material Wastage mostly due to human behavior and errors including labor practice, error in material procurement, poor site management, change of design due to improvement or poor planning. It can be

avoided and reduced significantly through better project and construction site management, and training.

Both types of wastage heavily contribute to unnecessary disposal and to heavily overloaded landfill.

## Cause of Building Material Wastage

According to the findings of [1], [2], [4], [6], [7], [10], [19], [20], [25], the cause of building material wastage is generally categorized as follows:

(a) Application wastes:

- Incompetence of skilled men
- Poor monitoring/incompetence of site officer
- Carelessness of workmen
- Treachery and nonchalance of workmen
- (b) Residual wastes
- (c) Storage wastes
- (d) Abortive work
- (e) Design wastes
- (f) Transportation wastes
- (g) Estimating wastes
- (h) Production wastes
- (i) Learning wastes
- (j) Pilfery
- (k) Vandalism
- (l) Unmotivated workmen
- (m) Poorly coordinated work programme
- (n) Poor site organization/improper positioning of materials on site
- (o) Substitution
- (p) Negligence

#### Waste Management Plan and Wastage Management Plan

The waste management plan is widely adopted in the public and private building construction projects like new building construction, renovation and demolition. It is also part of the green building assessment in different internationally recognized certification systems.

Unfortunately, uncalculated material wastage generated in construction sites is always ignored in the building and construction industry with the reason for high profit of the construction industry and inflation in some cities which offsets the cost of material wastage. In the absence of statutory and quantitative measurement of actual material wastage generated on site and off site, as well as regulations and contractual control, there is also no incentive for investors and building contractors to strictly control and reduce the uncalculated material wastage [14], [16].

In the construction industry, there is a threshold of minimum 50%-75% of construction waste to be disposed of at public landfill facilities in different environmental rating and assessment tools, however, this approach is only limited to control of the overall waste disposal without taking into account how to properly use building materials and quantitatively reduce uncalculated material wastage. Valuable building material may be disposed of without being properly and effectively used or their value and life cycle being fully explored. Data released by government agents related to the

amount of C&D disposed to landfill only provide a general figure of the different building waste generated but it cannot truly reflect the total amount of uncalculated material wastage generated and how it is being controlled.

In the current construction industry ecosystem, there is no measurement gauge to determine the actual amount of calculated and uncalculated material wastage in building contracts. The contract sum only reflects the lump sum building costs which the contractor already included a certain amount and percentage of wastage in their contract and profits margin. In simple terms, there is in fact no contractual or statutory control to mandate the determination of the threshold of the amount of C&D generation and wastage of building material generated on site during the construction phase of the building project [8], [12].

To a certain extent, the limitation of C&D generated during the whole period of construction can limit and reduce the material wastage [21]. However, surplus material in construction may directly be disposed of to the landfill during the construction phase or stored in a warehouse for several years and then finally disposed of as scrap material. Therefore, quantitative measurement and limitation of calculated and uncalculated material wastage generation shall be explored to include in building projects.

### III. REVIEW OF RATING CRITERIA ON WASTE REDUCTION IN HK BEAM AND LEED RATING SYSTEMS

Taking HK BEAM Plus 2.0 (HKGBC) and LEED BD+C New Construction V4.1 (USGBC) as the example for comparison and study on the current waste reduction approach in the green rating system, findings show that most of the rating systems and assessment tools mainly focus on the effective use of material, reduction of C&D waste disposed of in landfills and adoption of the 3R principle of reusing, recovering and recycling and conserving of resources as a base for waste control which aims to the put more focus on minimizing the operational materials and waste [27].

## Possible Allowable Wastage of Construction Materials [11]

Construction works are measured according to the Standard Method of Measurement (SMM), but the allowable waste percentage is clearly determined. There are no international standards or codes to evaluate construction wastage in a quantitative way. The unofficial channel of LCETED Institute for Civil Engineers provided a recommendation on the allowable building material wastage percentage as a reference guide to contractors, estimators and quantity surveyors; however, there is still a need for an internationally recognized and official standard that governs the wastage amount for architecture, engineering and construction (AEC) practitioners to adopt and follow.

The data shown in Table II only serve as a reference basis for determining the generic wastage amount. With the advancement of building construction technologies, economy model and variation of culture in various countries and cities, a systematic and quantitative standards and measurement gauge shall be further developed by government and building

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professions to adopt a comprehensive and flexible approach to a construction building material wastage standard.

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REVIEW OF BEAM PLUS 2.0 (HKGBC) AND LEED BD+C NEW	CONSTRUCTION V4.1 (USGBC) IN WASTE MANAGEMENT ASPECT
HKBEAM Plus 2.0 [9]	LEED BD+C New Construction V4.1 [26]
C&D Waste Recycling	C&D Waste Management
(a) Demolition Waste Recycling	(a) Develop and implement a C&D waste management plan
(b) Construction Waste Recycling	(b) Provide a final report detailing all major waste streams generated, including disposal and diversion rates.
	(c) Alternative daily cover (ADC) does not qualify as material diverted from
	disposal. Include materials destined for ADC in the calculations as waste. Land-clearing debris is not considered construction, demolition, or
	renovation waste that can contribute to waste diversion
	(d) Commingled, source separated and counting material streams
	(e) Counting waste prevention techniques/source reduction as a material stream
	(I) Waste recovery strategies
Minimum Waste Handling Facilities - provisions of waste recycle facilities for	Building Life-Cycle Impact Reduction
the collection, sorting, storage, recycling (recovered material) and disposal	
(waste).	
Building Ke-use	Building Product Disclosure and Optimization - Environmental Product Declarations
Modular and Standardized Design - Prefabrication	Building Product Disclosure and Optimization - Sourcing of Raw Materials
Design for Durability and Resilience	Building Product Disclosure and Optimization - Material Ingredients
(a) Building Material Selection Appraisal	
(b) Protecting Vulnerable Parts of the Building from Damage	
(c) Protecting Exposed Parts of the Building from Material Degradation	
Enhanced Waste Handling Facilities	C&D Waste Management
a) Additional Recyclables Collection	Option 1. Diversion
(b) Additional Facility Provisions to Enable enhanced Municipal Solid Waste	Option 2. Reduction of Total (C&D) Waste Material
(MSW) Charing Scheme	
(c) Waste Treatment Equipment	
(d) Alternatives to Recycling Facilities	

TABLE II

ALLOWABLE MATERIAL WASTAGE OF DIFFERENT BUILDING MATERIALS [11]			
Building Material	Allowable Percentage of Wastage (per Overall Consumption)	Possibilities of Uncalculated Wastage [15]	
Cement	3% to 4%	Uncalculated wastages occur due to poor housekeeping, human behavior and storage during on site mixing	
Sand	6% to 15%	Uncalculated wastage occurs due to poor housekeeping and human behavior during on site mixing	
Coarse Aggregates	6% to 8%	Uncalculated wastage occurs due to poor housekeeping and human behavior during on site mixing	
Tile	1% to 2%	During pouring concrete in the shuttering area and excessive ordering results in concrete wastage	
Granite	8% to 12%	Granite can break and wasted during transport and breakage caused during work	
Reinforcement Steel	4.5% to 6%	Cutting and bending process of steel for reinforcement causes steel wastages [18]	
Structural Steel	12% to 15%	Structural uncalculated wastages occur on fabrication work like cutting and bending steel plates or sections	
Bricks	3% to 4%	During the transportation and on site cutting of bricks causes brick breakages and uncalculated wastages	
Filling Soil	4% to 5%	Uncalculated, occurs due to poor housekeeping and human behavior	
Paint	3% to	Uncalculated, occurs due to poor housekeeping and human behavior	
Wood	5%	Uncalculated, occurs due to poor housekeeping and human behavior during on site cutting	
Concrete	1% to 5%	During pouring concrete in the shuttering area and excessive ordering results in uncalculated concrete wastages	
Mortar	1% to 2%	During applying mortar on the wall results in uncalculated wastages in mortar from poor housekeeping and human behavior	
Shuttering Board	6% to 7%	The shuttering boards are carved or cut for concrete works	

Flexible Approach on Quantitative Material Wastage Management Adoption in Different Countries

The control and incentives toward building material wastage management in the construction industry are varied across different countries based on their construction methodology, economy models and healthiness of the property market. The construction of high rise buildings in well developed countries and cities Asia Pacific like Hong Kong, etc., are mainly by reinforced concrete and steel structure. In terms of the high property price and the developer high profit margin, it made the importance of wastage management are insignificant. While in developing countries and cities, the type of housing and construction method is comparatively simple and the control and management of material wastage is significant in the construction cost [22]-[24]. Therefore, a flexible approach to different economy-based countries shall be adopted rather than the imposition of a rigid and extreme material wastage control. Recommendations for a flexible approach to waste control include:

1) Developed Countries - Mandatory control through government policy and regulations shall be adopted including material wastage tax, compulsory wastage control in waste management planning to enforce the adoption of effective or zero wastage.

Underdeveloped and Developing Countries - Government 2) incentive schemes to promote effective wastage control through funding and tax reduction encouragement to the development of wastage management through introduction and technical assistance of more advanced building construction technologies like prefabrication, standardization of building design shall be adopted. It is also important that the cost for implementation of internationally recognized certification programs will be a financial burden to the investors and contractors, local government assistance may be one of the ways to improve the material wastage management.

## IV. FINDING AND RECOMMENDATIONS

Based on the research and literature review in this paper, some salient points and recommendations are summarized and provided for further discussion and research on the development and adoption of a quantitative material waste management plan:

- Third-party green assessment rating systems used in tandem in terms of their assessment system containing reduction of total waste material generation which can indirectly control the building material wastage. It may serve as an imminent supplementary and interim tool to fill up the current deficiencies in the local government policy and standard on statutory material wastage quantitative control before the establishment and implementation of wastage management in developed and developing countries and cities.
- Development of a quantitative measurement and control standard and building code for on site and off site material wastage generation by means of government policy and regulations or government incentives scheme to achieve effective material wastage reduction and finally toward zero material wastage in the construction industry.
- Promotion of advanced building construction technologies to improve and enhance the productivity and effective wastage management like early adoption of higher level of Building Information Modeling, wide adoption of prefabrication and modular construction, and standardization of building design in public and private building and infrastructure projects.
- Education and training of the highest skilled trade labor to improve human behavior, error and practices and increasing awareness of the importance of reduction of material wastage and environmental conservation.
- Improvement of procurement practices and system to achieve a commitment to the reduction of uncalculated material wastage in the tendering and construction stage.
- Enhancement of project management practice, communication, housekeeping and awareness of reduction of uncalculated material wastage through careful planning, design and implementation to minimize necessary design change, alterations and defect rectification.
- Establishment of a building material wastage management

plan in the construction early stage to identify the potential amount of material wastage on a quantitative basis and undertake early planning on material selection to cater for the generation of uncalculated material wastage which can be fully reused and recycled rather than directly disposed.

- Adoption of latest and advanced technologies like RFID, QR code for monitoring of material delivery, storage and use on site to facilitate quantitative material wastage management and real-time measurement of building material throughout the whole construction process and ensure immediate action can be taken if unusual consumption against a pre-estimated assumption or condition is observed.
- Adoption of lean construction theory to eliminate waste accumulation and accurately assess the possible quantity of material wastage generated [13].

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