CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT IN INDIAN CONSTRUCTION PROJECTS

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by

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Dedicated to

Parents, wife, daughter, and son

CERTIFICATE

This is to certify that the thesis entitled **"Construction and demolition waste management in Indian construction projects"**, being submitted by **Mr. Ravindranadh Chowdary Kamma** to the Indian Institute of Technology Delhi for the award of degree of **Doctor of Philosophy** is a bonafide record of the research work carried out by him under my supervision and guidance. The thesis work, in my opinion, has reached the requisite standard, fulfilling the requirements for the degree of Doctor of Philosophy.

The contents of this thesis, in full or in parts, have not been submitted to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

Construction and demolition (C&D) waste is generated in enormous quantities during construction, demolition, and renovation of buildings and infrastructure projects. The generated C&D waste, if not managed, harms the project's financials, environmental, and social aspects. The generated C&D waste causes a considerable loss to the economy by increasing the cost of projects due to poor efficiency and low productivity. Furthermore, the generation of C&D waste has adverse environmental impacts such as land deterioration, resource depletion, greenhouse gas emissions, air, dust, and noise pollution, and the discharge of toxic waste. The social aspects include the physical working environment in waste management, the practitioner's long-term health, and the operative's safety. Therefore, there is a need to manage the generated construction and demolition waste to move towards sustainable construction. Further, to manage the waste effectively and efficiently, the accurate estimation of construction and demolition generated is essential, along with identifying the factors causing the generation of waste and developing strategies for managing the waste.

The first objective attempts to estimate the quantity of construction and demolition waste generated in a region by collecting the building permit data for the Hyderabad region, India. A random sampling technique was adopted to select the building permit to estimate the proportion of types of buildings constructed and demolished, the average area of each type of building constructed and demolished, and the overall area of building construction and demolition activity. The building construction and demolition activity is used to estimate the total quantity of construction and demolition waste generated in a region. In addition, regression models were developed to predict the construction activity in a region based on the fee collected for issuing the permit.

Further, the management practices of the construction and demolition waste generated in a region are evaluated using environmental and economic performance. Life cycle assessment (LCA) and life cycle costing (LCC) approaches were used to assess the environmental and economic performance of the waste management practices adopted for the Hyderabad region of India. The data related to life cycle inventory were obtained from primary and secondary sources, and the environmental impacts were evaluated using Simapro software. The findings reveal that reducing the generation of C&D waste has maximum environmental and economic benefits, followed by replacing natural aggregates with recycled aggregates. Therefore, to minimize the generation of C&D waste, the study further estimates the quantity and composition of C&D waste generated in a project, identifying the factors causing the generation of C&D waste and exploring the strategies for managing the generation of C&D waste in a project.

Thus, the study identifies the highest waste-generating potential materials used in road projects to estimate the construction and demolition waste generated in a project. Further, the estimated quantity of materials, material waste percentages, demolition of buildings, and existing pavement data were collected from ongoing road construction projects in India. Quantitative analysis was used to estimate a project's construction and demolition waste. The construction and demolition waste generation rates obtained in road projects are 352.83 kg/m^2 and 129.64 kg/m^2, respectively. Moreover, the waste-generating materials were classified into high, medium, and low using k-means clustering analysis.

Subsequently, the significant factors causing construction and demolition waste were identified. The questionnaire was developed by initially determining the factors causing material waste from the literature and subsequently finalized using the Delphi technique. The questionnaire was administered to construction professionals in road projects, and the responses were analyzed using a relative importance index and regression analysis. The

regression analysis identified the significant factors causing waste generation in a project. The study results indicate that lack of on-site material control is the most common factor causing waste generation across materials, followed by unused/leftover materials and lack of supervision.

Lastly, the study explored the strategies for managing the construction and demolition waste generated in a project by collecting the data from case study projects using semi-structured interviews. The interviews were recorded, and thematic analysis was performed using NVivo 14 software. The themes identified from the study are the design phase, construction site planning and management, construction waste planning, and training and development. The results indicate that the strategies for managing construction and demolition waste vary across materials. This study will help policymakers and other stakeholders frame guidelines for managing the construction and demolition waste at the regional and project levels.

Keywords: Construction waste, demolition waste, sustainable construction, life cycle assessment, life cycle costing, waste management.

सार

निर्माण और विध्वंस (सीएंडडी) अपशिष्ट निर्माण, विध्वंस और इमारतों और बुनियादी ढांचे की परियोजनाओं के नवीनीकरण के दौरान भारी मात्रा में उत्पन्न होता है। यदि उत्पन्न सीएंडडी अपशिष्ट का प्रबंधन नहीं किया जाता है, तो यह परियोजना के वित्तीय, पर्यावरणीय और सामाजिक पहलुओं को नुकसान पहुंचाता है। उत्पन्न सीएंडडी अपशिष्ट खराब दक्षता और कम उत्पादकता के कारण परियोजनाओं की लागत बढ़ाकर अर्थव्यवस्था को काफी नुकसान पहुंचाता है। इसके अलावा, सीएंडडी अपशिष्ट के उत्पादन से भूमि की कमी, संसाधनों की कमी, ग्रीनहाउस गैस उत्सर्जन, वायु, धूल और ध्वनि प्रदूषण और विषाक्त अपशिष्ट के निर्वहन जैसे प्रतिकूल पर्यावरणीय प्रभाव होते हैं। सामाजिक पहलुओं में अपशिष्ट प्रबंधन में भौतिक कार्य वातावरण, व्यवसायी का दीर्घकालिक स्वास्थ्य और ऑपरेटिव की सुरक्षा शामिल है। इसलिए, टिकाऊ निर्माण की ओर बढ़ने के लिए उत्पन्न निर्माण और विध्वंस अपशिष्ट का प्रबंधन करने की आवश्यकता है। इसके अलावा, अपशिष्ट को प्रभावी ढंग से और कुशलता से प्रबंधित करने के लिए, उत्पन्न निर्माण और विध्वंस का सटीक अनुमान आवश्यक है, साथ ही अपशिष्ट के उत्पादन के कारणों की पहचान करना और अपशिष्ट के प्रबंधन के लिए रणनीति विकसित करना भी आवश्यक है।

पहला उद्देश्य भारत के हैदराबाद क्षेत्र के लिए बिल्डिंग परमिट डेटा एकत्र करके किसी क्षेत्र में उत्पन्न निर्माण और विध्वंस अपशिष्ट की मात्रा का अनुमान लगाने का प्रयास करता है। निर्मित और ध्वस्त किए गए भवनों के प्रकारों के अनुपात, निर्मित और ध्वस्त किए गए प्रत्येक प्रकार के भवन का औसत क्षेत्र और भवन निर्माण और विध्वंस गतिविधि के समग्र क्षेत्र का अनुमान लगाने के लिए बिल्डिंग परमिट का चयन करने के लिए एक यादृच्छिक नमूना तकनीक अपनाई गई थी। भवन निर्माण और विध्वंस गतिविधि का उपयोग किसी क्षेत्र में उत्पन्न निर्माण और विध्वंस अपशिष्ट की कुल मात्रा का अनुमान लगाने के लिए

किया जाता है। इसके अलावा, परमिट जारी करने के लिए एकत्र किए गए शुल्क के आधार पर किसी क्षेत्र में निर्माण गतिविधि की भविष्यवाणी करने के लिए प्रतिगमन मॉडल विकसित किए गए थे।

इसके अलावा, किसी क्षेत्र में उत्पन्न निर्माण और विध्वंस अपशिष्ट के प्रबंधन प्रथाओं का पर्यावरणीय और आर्थिक प्रदर्शन का उपयोग करके मूल्यांकन किया जाता है। भारत के हैदराबाद क्षेत्र के लिए अपनाए गए अपशिष्ट प्रबंधन प्रथाओं के पर्यावरणीय और आर्थिक प्रदर्शन का आकलन करने के लिए जीवन चक्र मूल्यांकन (एलसीए) और जीवन चक्र लागत (एलसीसी) दृष्टिकोण का उपयोग किया गया था। जीवन चक्र सूची से संबंधित डेटा प्राथमिक और माध्यमिक स्रोतों से प्राप्त किए गए थे, और पर्यावरणीय प्रभावों का मूल्यांकन सिमाप्रो सॉफ्टवेयर का उपयोग करके किया गया था। निष्कर्ष बताते हैं कि सी एंड डी अपशिष्ट के उत्पादन को कम करने से अधिकतम पर्यावरणीय और आर्थिक लाभ होते हैं, इसके बाद प्राकृतिक समुच्चय को पुनर्चक्रित समुच्चय से बदल दिया जाता है। इसलिए, सी एंड डी अपशिष्ट के उत्पादन को कम करने के लिए, अध्ययन एक परियोजना में उत्पन्न सी एंड डी अपशिष्ट की मात्रा और संरचना का अनुमान लगाता है, सी एंड डी अपशिष्ट के उत्पादन का कारण बनने वाले कारकों की पहचान करता है।

इस प्रकार, अध्ययन सड़क परियोजनाओं में उपयोग की जाने वाली सबसे अधिक अपशिष्ट पैदा करने वाली संभावित सामग्रियों की पहचान करता है, ताकि किसी परियोजना में उत्पन्न निर्माण और विध्वंस अपशिष्ट का अनुमान लगाया जा सके। इसके अलावा, भारत में चल रही सड़क निर्माण परियोजनाओं से सामग्रियों की अनुमानित मात्रा, सामग्री अपशिष्ट प्रतिशत, इमारतों के विध्वंस और मौजूदा फुटपाथ के डेटा एकत्र किए गए। किसी परियोजना के निर्माण और विध्वंस अपशिष्ट का अनुमान लगाने के लिए मात्रात्मक विश्लेषण का उपयोग किया गया। सड़क परियोजनाओं में प्राप्त निर्माण और विध्वंस अपशिष्ट उत्पादन दर क्रमशः 352.83 किग्रा/मी2 और 129.64 किग्रा/मी2 है। इसके अलावा, अपशिष्ट पैदा करने

वाली सामग्रियों को के-मीन्स क्लस्टरिंग विश्लेषण का उपयोग करके उच्च, मध्यम और निम्न में वर्गीकृत किया गया था।

इसके बाद, निर्माण और विध्वंस अपशिष्ट पैदा करने वाले महत्वपूर्ण कारकों की पहचान की गई। प्रश्नावली को शुरू में साहित्य से सामग्री अपशिष्ट पैदा करने वाले कारकों का निर्धारण करके विकसित किया गया था और बाद में डेल्फी तकनीक का उपयोग करके अंतिम रूप दिया गया। प्रश्नावली सड़क परियोजनाओं में निर्माण पेशेवरों को दी गई थी, और प्रतिक्रियाओं का विश्लेषण एक सापेक्ष महत्व सूचकांक और प्रतिगमन विश्लेषण का उपयोग करके किया गया था। प्रतिगमन विश्लेषण ने एक परियोजना में अपशिष्ट उत्पादन के महत्वपूर्ण कारकों की पहचान की। अध्ययन के परिणाम बताते हैं कि साइट पर सामग्री नियंत्रण की कमी सामग्री में अपशिष्ट उत्पादन का सबसे आम कारक है, इसके बाद अप्रयुक्त/बचे हुए पदार्थ और पर्यवेक्षण की कमी है।

अंत में, अध्ययन ने अर्ध-संरचित साक्षात्कारों का उपयोग करके केस स्टडी परियोजनाओं से डेटा एकत्र करके एक परियोजना में उत्पन्न निर्माण और विध्वंस अपशिष्ट के प्रबंधन के लिए रणनीतियों की खोज की। साक्षात्कार रिकॉर्ड किए गए, और NVivo 14 सॉफ़्टवेयर का उपयोग करके विषयगत विश्लेषण किया गया। अध्ययन से पहचाने गए विषय डिजाइन चरण, निर्माण स्थल योजना और प्रबंधन, निर्माण अपशिष्ट योजना और प्रशिक्षण और विकास हैं। परिणाम बताते हैं कि निर्माण और विध्वंस अपशिष्ट के प्रबंधन की रणनीतियाँ सामग्रियों के अनुसार अलग-अलग होती हैं। यह अध्ययन नीति निर्माताओं और अन्य हितधारकों को क्षेत्रीय और परियोजना स्तरों पर निर्माण और विध्वंस अपशिष्ट के प्रबंधन के लिए दिशा-निर्देश तैयार करने में मदद करेगा।

कीवर्ड: निर्माण अपशिष्ट, विध्वंस अपशिष्ट, टिकाऊ निर्माण, जीवन चक्र मूल्यांकन, जीवन चक्र लागत, अपशिष्ट प्रबंधन।

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LIST OF ABBREVIATION

ANOVA	Analysis of Variance
BIM	Building Information Modeling
BMTPC	Building Materials and Technology Promotion Council
BoQ	Bill of Quantity
C&D	Construction and Demolition
CDW	Construction and Demolition Waste
CDWM	Construction and Demolition Waste Management
CMIE	Centre for Monitoring Indian Economy
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organization
CPWD	Central Public Works Department
CSA	Classification System Accumulation
DPMS	Development Permission Management System
GDP	Gross Domestic Product
GHMC	Greater Hyderabad Municipal Corporation
GRC	Generation Rate Calculation
HRB	High-rise Building
ISO	International Standard Organization
LA	Lifetime Analysis
LBM	Load-bearing Masonry
LCA	Life Cycle Assessment
LCC	Life Cycle Costing

LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LOD	Level of Development
LRB	Low-rise Building
MoEFCC	Ministry of Environment, Forests, and Climate Change
MRB	Mid-rise Building
NA	Natural Aggregate
NHAI	National Highway Authority of India
RA	Recycled Aggregate
RCC	Reinforced Cement Concrete
SFL	Standardized Factor Loading
SPSS	Statistical Package for the Social Sciences
SV	Site Visit
UAE	United Arab Emirates
UK	United Kingdom
US	United States
USD	United State Dollar
VIF	Variance Inflation Factor
VM	Variables Modeling
WGR	Waste Generation Rate