Quest Journals
Journal of Architecture and Civil Engineering
Volume 9 ~ Issue 11 (2024) pp: 01-11
ISSN(Online) : 2321-8193
www.questjournals.org

Research Paper

Infrastructure Life Cycle Assessment and Comparative Total Estimation Costing Data Analysis for Bargarh District, Odisha, India

[1]Siddharth Acharya, [1]Prathamesh Naik, [2]Dr. Prasanna Venkatesan R
[1]School of Civil Engineering,
[2]Department of Structural and Geotechnical Engineering,
[1]Vellore Institute of Technology, Vellore, Tamil Nadu, India

Abstract: *This study thoroughly examines the infrastructure development in Bargarh District, Odisha, with a specific emphasis on the construction of ring roads and flyovers with conventional and sustainable materials and methods. The study analyses the amounts of materials, and types of materials, conducts a life cycle assessment (LCA), and estimates the total cost for the project. It emphasizes the importance of balancing urban expansion with environmental sustainability. Thorough computations of traditional and eco-friendly materials utilized in different stages of construction offer valuable information on cost-efficiency and techniques for reducing environmental impact. The Infra Works program has been employed to design and simulate the project, guaranteeing precise modelling and effective planning through which we can estimate the quantities and visualize the outcomes. Two scenarios were considered: one with conventional materials with conventional methods of construction and the other with sustainable materials with specific environmentally friendly construction methods. The main achievement of our study is to examine whether we can replace conventional materials and techniques to gain more efficiency in terms of sustainability and budgeting.*

***R**eceived 03 Nov., 2024; **R**evised 12 Nov., 2024; **A**ccepted 14 Nov., 2024 © The author(s) 2024.*
P**ublished with open access at **www.questjournas.org

I. Introduction:

Infrastructure projects, particularly those involving the construction of ring roads and flyovers, are crucial in reshaping urban environments by considerably boosting transportation efficiency and urban connectedness. These projects ease traffic congestion and improve accessibility, safety, sustainability, and economic vibrancy within increasing metropolitan areas. This research focuses on a comprehensive infrastructure development program in Bargarh District, Odisha, delving into crucial issues such as construction methodology, material selection criteria, and environmental considerations with the use of locally available materials.

1.1 Importance of Infrastructure Projects

Infrastructure developments like ring roads and flyovers serve as lifelines for modern cities, facilitating the seamless flow of products and people. In Bargarh District, Odisha, where growing urbanization is altering the socio-economic fabric, the demand for solid infrastructure is particularly critical. Ring highways bypass city centers, diverting through traffic and reducing congestion on arterial roadways. Flyovers, on the other hand, remove intersections, saving travel times and boosting road safety (Hou et al. 2009).

1.2 Objectives of the Research

This research aims to thoroughly examine the infrastructure development project in Bargarh District, focusing on several critical aspects. Firstly, it will delve into the construction processes, detailing the methodologies followed from the planning stage through to implementation (Mishra 2016), with a particular emphasis on efficiency and quality assurance. Secondly, it will evaluate material selection, comparing conventional materials with sustainable alternatives in terms of durability, cost-effectiveness, and environmental impact. This comparative analysis will provide insights into the benefits and drawbacks of various materials (Saleh and Alalouch 2015)(Bon and Hutchinson 2000) , promoting informed decision-making in construction practices. Thirdly, the research will assess environmental considerations, scrutinizing the project's carbon footprint, energy consumption, and resource utilization. This assessment aims to foster sustainable development practices by highlighting areas for improvement and suggesting eco-friendly alternatives (Huang et al. 2020). Fourthly, the life cycle implications of construction choices will be examined, focusing on their long-term impact on maintenance, operational efficiency, and overall infrastructure sustainability. This will involve a comprehensive analysis of the durability and performance of different materials over time, providing a holistic view of their viability (Chowdhury, Apul, and Fry 2010) (Sandin, Peters, and Svanström 2014). Lastly, the economic feasibility of the project will be evaluated, comparing the cost benefits of replacing conventional materials with eco-friendly, durable alternatives. This economic analysis will consider both initial investment and long-term savings, providing a balanced view of the financial implications of sustainable construction practices. By integrating these aspects, the research seeks to offer a comprehensive evaluation of the infrastructure development project in Bargarh District, emphasizing the importance of sustainable practices in modern construction. Through meticulous analysis and comparative evaluation, this study aims to contribute valuable insights to the field of infrastructure development, promoting practices that are not only efficient and cost-effective but also environmentally responsible and sustainable in the long term(Gerbrandt and Berthelot 2007).

1.3 Role of InfraWorks Software

InfraWorks software acts as a vital instrument in this project, offering advanced modelling, design visualization, and simulation capabilities. By using InfraWorks, we achieved:

Accurate Modelling: Creating detailed 3D models of the proposed infrastructure, including roads, bridges, and accompanying structures (Kuok et al. 2023).

Simulation Capabilities: Assessing traffic flow dynamics, environmental consequences, and construction phasing to improve design and avoid hazards (Kuok et al. 2023).

Data Analysis: Conducting extensive assessments of material quantities, construction costs, and environmental impacts, vital for informed decision-making (Kuok et al. 2023).

II. Methodology

2.1 Study Area Description

Bargarh District, located in the western region of Odisha, India, is the focus of this infrastructure development project. The district spans an area of roughly 5,837 square kilometers and lies between 20°43'N to 21°41'N latitude and 82°39'E to 83°58'E longitude. Known for its diversified geography, Bargarh features plains, rivers, and forests.

Economically, Bargarh is largely agrarian, with a significant portion of the people working in agriculture, especially rice production, earning it the nickname "Rice Bowl of Odisha." The district also has a burgeoning industrial sector, contributing to its economic landscape.The transportation network in Bargarh includes national and state highways, although it faces issues such as urban traffic congestion, limited road capacity, and the need for enhanced safety. The proposed project intends to address these concerns by constructing a ring road to deflect heavy traffic from urban areas and developing flyovers to promote smoother traffic flow at important crossings.This study focuses on a specific segment of the ring road and flyover project, assessing building procedures, material choices, and environmental factors. Key infrastructural components include highways, bridges, sidewalks, shoulders, lanes, and sloped medians. The project area experiences variable soil conditions and a tropical environment, which influence construction methods and material performance. The climate offers scorching summers, temperate winters, and a large monsoon season, affecting building timetables and material durability.By leveraging InfraWorks software, the project models and simulates the proposed infrastructure, enabling precise design, efficient planning, and complete analysis. This study intends to provide insights into sustainable construction practices, cost-effective material utilization, and the overall impact of large-scale infrastructure projects on the surrounding environment and community.

2.2 Data Collection

Project details

The Bargarh Ring Road project spans 5178.134 meters and incorporates three bridges, a combination of flyovers and overbridges, each with a height of 6.5 meters. The bridges are supported by pile foundations and have an average width of 16 meters. Embankments, varying in length based on bridge symmetry (26 meters for symmetric, 13 meters for asymmetric) as shown in *Fig.1 and Fig.2* accompany the bridges and stand at a height of 6.5 meters with a 1:2 slope.

Figure 1 Satellite view of project site

Figure 2 Rendering view of project

III. Components and Procedures

Feasibility Study and Planning: The initial phase involves conducting a comprehensive feasibility study to evaluate the environmental impact, traffic patterns, land acquisition needs, and economic viability of the project. The route of the ring road must be meticulously planned, taking into account geographical features such as rivers, hills, and urban areas to ensure optimal alignment and minimal disruption (Okoro, Musonda, and Agumba 2017).

Design and Engineering: This phase engages civil engineers and architects to design the road layout, bridges, and embankments. The design process must ensure compliance with local regulations and standards for road construction and environmental protection. Additionally, bridges must be designed to accommodate traffic flow, with considerations for height clearance over rivers and aesthetic integration with the surrounding environment (Mahamid et al. 2019).

Environmental Assessment and Permits: Obtaining environmental clearances and permits is crucial, particularly for construction near rivers and other sensitive areas. This phase includes planning and implementing mitigation measures to address potential environmental impacts, such as erosion control and habitat preservation, ensuring the project adheres to environmental regulations (Marzouk, El-zayat, and Aboushady 2017).

Land Acquisition and Clearing: Acquiring the necessary land rights and clearing the construction site of any existing structures or obstacles is a critical step. This process must be managed efficiently to avoid delays and ensure the site is ready for construction activities (Ghatak and Ghosh 2011).

Foundation and Earthworks: Preparing the foundation for the road and bridges involves ensuring stability and load-bearing capacity. This phase includes constructing embankments along the riverside to prevent erosion and manage water flow, which is essential for the durability and longevity of the infrastructure(Karpurapu 2017).

Bridge Construction: Building bridges involves building the foundations, abutments, and piers according to design specifications. Erecting the bridge superstructures, including girders and decks, requires the use of appropriate construction techniques and materials to ensure structural integrity and safety (Mahamid et al. 2019).

Road Construction: Constructing the road involves laying the road base, pavement layers, and drainage systems. Installing road safety features, such as guardrails, signage, and lighting, is essential to ensure the safety and functionality of the roadway for users (Mahamid et al. 2019).

Embankment and Landscaping: Completing the riverside embankments with suitable materials and vegetation is crucial for preventing erosion and enhancing environmental sustainability. Landscaping is incorporated to improve aesthetics and contribute to the environmental goals of the project(Mahamid et al. 2019).

Testing and Commissioning: Quality assurance tests on road surfaces, bridges, and drainage systems are conducted to ensure they meet safety standards and functional requirements. This phase is critical for verifying the integrity and readiness of the infrastructure before it is opened for public use (Tian and Zhang 2022).

Maintenance and Monitoring: Establishing a maintenance plan for the ongoing upkeep of the road, bridges, and embankments is essential for ensuring long-term functionality and safety. Regular monitoring and maintenance activities are necessary to address wear and tear and to sustain the infrastructure's performance over time (Shanmugapriya and Subramanian 2013).

3.1 Materials used

Conventional material used concerning the steps involved.

Table 1 Description of materials

Step	Description	Materials
Site Preparation	This involves clearing the land of vegetation, demolishing any structures, and grading the roadbed according to the design specifications.	Bulldozers, excavators, graders
Embankment Construction	Embankments are built up using soil and rocks to elevate the roadbed over low-lying areas or bodies of water.	Soil, rock

Foundation Construction	The foundation provides a stable base for the road structure. It's typically made of compacted layers of soil and aggregate.	Crushed rock, gravel, sand
Substructure Construction (Abutments and Piers)	Abutments and piers are support structures for bridges. They transfer the weight of the bridge deck to the foundation.	Concrete, steel reinforcement bars, formwork materials
Superstructure Construction (Bridge Deck and Beams)	The bridge deck is the driving surface on the bridge. Beams span between the piers or abutments to support the deck.	Concrete, steel reinforcement bars, formwork materials, pre-stressed or precast concrete beams
Deck Finishing	This involves waterproofing the bridge deck and applying a wearing surface for vehicles.	Waterproofing materials, asphalt, concrete
Parapets and Railings	Parapets and railings provide safety features for vehicles and pedestrians on the bridge.	Concrete, steel reinforcement bars, formwork materials, parapet railing materials
Joint Sealing and Waterproofing	Joints in the bridge deck and other structures are sealed to prevent water infiltration.	Joint sealants, waterproofing membranes

Table 2 Proposed / sustainable alternative materials

Conventional Material	Sustainable Alternative	Benefits	Considerations
Concrete	Recycled concrete aggregate (RCA) or precast concrete panels	Reduces demand for virgin materials, lowers embodied energy	May require specific sourcing or processing, strength limitations for some applications
Steel	Recycled steel	Reduces demand for virgin materials, lowers embodied energy	Availability and cost may vary depending on location
Asphalt	Recycled asphalt pavement (RAP)	Reduces demand for virgin materials, lowers embodied energy	May require specific mixing ratios, potential for leaching contaminants
Aggregates	Crushed recycled materials (e.g., demolition debris)	Reduces demand for quarrying virgin materials	May require size sorting and quality control
Soil	Stabilized local soils with minimal transport	Reduces transportation emissions	May require additional treatments for strength or workability depending on soil type

Recycled Concrete Aggregate (RCA):

Recycled Concrete Aggregate (RCA) is produced from concrete waste collected from demolition sites and construction projects. The waste is sorted to remove contaminants, crushed into various sizes using crushers, washed to eliminate fine particles, and screened for construction use. RCA has a comparable lifespan to natural aggregates, with durability depending on mix design, curing, and conditions.(Wang et al. 2023) It is cost-effective due to reduced extraction and transportation expenses and potential recycling incentives, although it requires significant initial investment in processing equipment. RCA properties vary, typically having lower density, higher porosity, and lower strength than natural aggregates. Applications include base materials for roads, pavements, subbases, non-structural concrete, soil stabilization, fill materials, drainage layers, lightweight concrete, precast products, and cement production. Proper testing and quality control are essential for RCA use.(Ohemeng and Ekolu 2020)

Recycled steel, or scrap steel, is sourced from end-of-life vehicles, construction debris, household appliances, and industrial scrap. The production process involves collection, sorting, shredding, melting in electric arc or basic oxygen furnaces, purification, alloying, and casting or rolling into various steel products. Recycled steel is highly versatile, finding use in construction, the automotive industry, appliances, machinery, and other applications. It retains the same properties as virgin steel, offering identical strength, durability, and versatility. The lifespan of recycled steel matches that of virgin steel, dependent on its application and conditions. (Frazão et al. 2022)Abundantly available, recycled steel is a cornerstone of the steel industry due to its high recycling rate.(Zarei, Rooholamini, and Ozbakkaloglu 2022) It provides environmental, energy-saving, economic, and resource-conservation benefits, promoting a circular economy through material reuse.

Recycled Asphalt Pavement (RAP**)** is derived from milling existing asphalt pavements during road maintenance or reconstruction. The production process involves milling, stockpiling, quality control testing, and incorporating RAP into new asphalt mixtures at varying percentages. Utilizing RAP significantly reduces the carbon footprint of road construction by lowering energy consumption, conserving natural resources, and reducing greenhouse gas emissions. RAP offers environmental protection, cost savings, improved pavement performance, and energy conservation. While RAP has lower stiffness, higher air voids, and different aggregate gradation compared to virgin asphalt, proper processing, and blending can manage these properties. The lifespan of RAP pavements can match or exceed that of those using virgin materials, and RAP is widely available. Its use reduces material costs and benefits from potential government incentives. RAP is applicable in various asphalt pavement layers, promoting sustainable road construction practices.(Jaawani et al. 2021)

Table 3 Lifetime and sustainability

Material	Lifespan	Sustainability Benefits	Considerations
Recycled Concrete Aggregate (RCA)	20-50 years	Reduces demand for virgin materials, lower embodied energy	May require specific sourcing or processing, strength limitations for some applications
Recycled Steel	50+ years	Reduces demand for virgin materials, lower embodied energy	Availability and cost may vary depending on location
Recycled Asphalt Pavement (RAP)	10-15 years	Reduces demand for virgin materials, lower embodied energy	May require specific mixing ratios, the potential for leaching contaminants
Crushed Recycled Materials	20-50 years	Reduces demand for quarrying virgin materials	May require size sorting and quality control
Stabilized Local Soils	15-25 years	Reduces transportation emissions	May require additional treatments for strength or workability depending on soil type

Table 4 Conventional materials and specifications

Conventional Material	Lifespan (Estimated)	Considerations
Concrete	20-50 years	High embodied energy, requires significant resources
Steel	50+ years	Energy-intensive production
Asphalt	10-15 years	Requires frequent maintenance, petroleum-based
Aggregates	N/A (Base material)	Extraction disrupts natural habitats

IV. LIFECYCLE ASSESSMENT OF MATERIALS

The construction industry is integral to modern civilization, shaping the urban landscapes where millions of people live, work, and travel. Bridges stand out for their significance and complexity among the myriad structures that support contemporary society. They not only connect communities but also facilitate economic growth and development. However, the environmental impact of bridge construction, particularly concerning carbon emissions, has become a pressing issue as global awareness of climate change and sustainability increases. The traditional materials used in bridge construction—primarily concrete and steel—are known for their robustness and durability. Nevertheless, their production processes are heavily carbon-intensive, contributing substantially to global greenhouse gas emissions. As the world grapples with the consequences of climate change, the construction industry faces mounting pressure to adopt more sustainable practices. This paper presents a comparative analysis of conventional and sustainable materials used in bridge construction, with a focus on their carbon emissions and the broader environmental challenges associated with their use.(Barbhuiya and Das 2023)(Hasan et al. 2022)

4.1 Carbon Emissions from Conventional Materials

Concrete and steel have been the backbones of bridge construction for decades. Their widespread use is largely owing to their strength, durability, and versatility. However, the environmental cost of these materials is significant primarily because of the carbon emissions associated with their production.

Concrete, which is a composite material composed of cement, aggregates, and water, is the most widely used construction material worldwide. Its production, particularly cement manufacturing, is a major source of carbon dioxide (CO2) emissions. Cement production alone accounts for approximately 8% of global CO2 emissions (International Energy Agency, 2021). This high level of emissions is attributable to the thermal decomposition of limestone (calcium carbonate) into lime (calcium oxide) and CO2, coupled with the energy-intensive nature of the cement kilns. The burning of fossil fuels to achieve the high temperatures required for cement production exacerbates this issue. Steel, which is another essential material in bridge construction, also has a considerable carbon footprint. Steel production involves the reduction of iron ore in blast furnaces, a process that releases a substantial amount of CO2. According to the World Steel Association (2020), the steel industry is responsible for approximately 7-9% of global CO2 emissions. This is because of the high energy requirements and reliance on fossil fuels during the steelmaking process. Steel production generates other pollutants, including sulphur dioxide (SO2) and nitrogen oxides (NOx), which contribute to air quality issues.

The environmental impacts of concrete and steel extend beyond their production. The energy consumed during the construction and maintenance phases of structures built with these materials further increases their carbon footprints. Concrete's curing process, for instance, requires significant amounts of water and energy, while steel structures often need additional treatments to prevent corrosion and ensure longevity. The disposal and recycling of these materials poses challenges. Concrete, when demolished, often ends up in landfills, and the recycling process for steel, although more energy-efficient, still involves considerable emissions.

4.2 Problems Faced Globally

Carbon emissions associated with conventional construction materials present several global challenges that are primarily related to climate change and environmental degradation. Substantial CO2 emissions from cement and steel production contribute to the greenhouse effect, which drives global warming and leads to a range of adverse environmental impacts. These include rising sea levels, more frequent and severe extreme weather events, and disruptions to ecosystems and biodiversity (Intergovernmental Panel on Climate Change 2021).

Climate change poses significant risks to infrastructure including bridges. Increased temperatures and extreme weather events can accelerate the deterioration of conventional materials, leading to frequent repairs and replacements. This in turn exacerbates the environmental impacts of construction and maintenance activities. The financial costs associated with these repairs are substantial, straining public resources and impacting communities.

Resource depletion is a critical issue associated with the use of conventional materials. The extraction of raw materials for concrete and steel production places a considerable strain on natural resources. Mining for limestone, iron ore, and coal results in habitat destruction, water pollution, and other environmental impacts. The demand for these resources can lead to over-exploitation and long-term ecological damage (Environmental Protection Agency, 2020). Moreover, the energy-intensive processes involved in material production contribute to the depletion of non-renewable energy sources.

Air quality is also a significant concern. The emissions from cement and steel production contribute to air pollution, which has direct implications for public health. Particulate matter and other pollutants released during production processes can lead to respiratory problems, cardiovascular diseases, and other health issues (World Health Organization, 2021). The global burden of air pollution is a pressing public health challenge, particularly in urban areas where construction activities are concentrated. The environmental impacts of conventional materials also extend to their end-of-life stage. The disposal of concrete and steel structures at the end of their service life can create significant waste management challenges. Concrete, for example, is often difficult to recycle in large quantities and can contribute to landfill growth. Although steel can be recycled, the process requires substantial energy and may not fully mitigate the environmental impact of initial production.

4.3 Sustainable Alternatives in Bridge Construction

In response to the environmental challenges posed by conventional materials, the construction industry is increasingly exploring sustainable alternatives. These materials aim to reduce carbon emissions, minimize resource depletion, and lower the overall environmental impact of bridge construction. Several innovative approaches and materials are gaining traction as viable alternatives to traditional concrete and steel.

One notable approach is the use of recycled materials. *Recycled concrete aggregate (RCA)* involves crushing demolished concrete structures and using the material in new concrete mixes. This method reduces the demand for *virgin aggregates* and lowers the carbon footprint associated with concrete production (U.S. Environmental Protection Agency, 2019). Similarly, recycled steel, obtained from scrap metal, helps to reduce the need for raw ore and the energy-intensive processes associated with steel production. Utilizing recycled materials not only conserves natural resources but also reduces the overall environmental impact of construction projects.

High-performance concrete (HPC) represents another advancement in sustainable construction. HPC incorporates supplementary cementitious materials (SCMs) such as *fly ash, slag, and silica fume*. These materials replace a portion of the traditional cement, thereby reducing the overall carbon footprint of the concrete mix. Additionally, HPC offers improved durability and longevity compared to conventional concrete, which can extend the lifespan of bridge structures and reduce the need for maintenance (American Concrete Institute, 2021). The use of SCMs also helps to mitigate the environmental impact of cement production by reducing the quantity of cement required.

Engineered timber is emerging as a promising alternative to concrete and steel in bridge construction. Engineered timber products, such as cross-laminated timber (CLT) and glulam, offer several environmental benefits. Timber is a renewable resource and can sequester carbon throughout its lifecycle, which helps to offset the carbon emissions associated with its production. The production of engineered timber generally involves lower energy consumption compared to concrete and steel, making it a more sustainable option for bridge construction

(Forestry Commission, 2020). Moreover, advances in timber engineering and construction techniques are enabling the use of timber in increasingly large and complex structures.

Geopolymer concrete is another innovative material that shows promise in reducing the carbon footprint of bridge construction. Geopolymer concrete uses industrial by-products such as fly ash or slag as a binder instead of traditional Portland cement. This approach significantly reduces the carbon emissions associated with cement production while offering comparable or superior performance characteristics to conventional concrete (Davidovits, 2021). Geopolymer concrete also has the potential to enhance the sustainability of construction projects by utilizing waste materials and reducing the reliance on virgin raw materials.

4.4 Comparative Analysis of Carbon Emissions

A thorough comparison of conventional and sustainable materials involves evaluating various factors, including their carbon emissions, resource use, and overall environmental impact. Sustainable materials generally offer advantages in terms of reduced carbon footprints due to their lower energy requirements and the use of recycled or renewable resources.

Recycled concrete and steel, for instance, have significantly lower emissions than their conventional counterparts. The use of recycled materials reduces the need for raw material extraction and processing, which in turn lowers the associated *carbon emissions (Environmental Protection Agency, 2020)*. High-performance concrete, with its incorporation of SCMs, also demonstrates a reduced carbon footprint compared to traditional concrete. The extended durability and reduced maintenance requirements of HPC contribute to its overall sustainability.

Engineered timber presents a compelling case for sustainability due to its renewable nature and lower production energy requirements. The carbon sequestration potential of timber products further enhances their environmental benefits. However, the adoption of engineered timber is influenced by factors such as availability, cost, and construction practices. The use of timber in large-scale and complex structures requires careful consideration of structural and environmental factors.

Geopolymer concrete, while promising, is still in the early stages of widespread implementation. Continued research and development are necessary to optimize its use in bridge construction and address any potential challenges related to material performance and long-term durability.

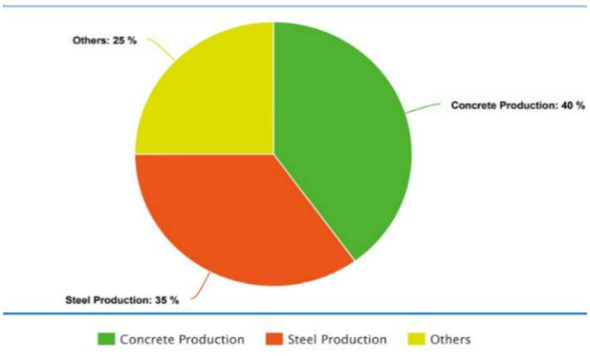

Figure 3 Carbon Emissions by Conventional materials

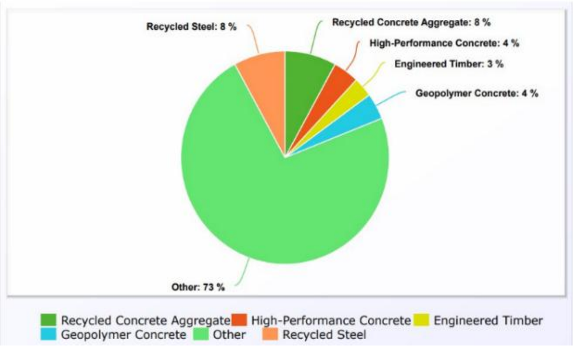

Figure 4 Carbon Emissions by Sustainable materials

V. COMPARATIVE ESTIMATION AND TOTAL COSTING

Comparative cost analysis is an important factor whenever we think of changing the material of the process. Conventional materials are easily available and widely used throughout the country but recycled materials can be procured at a cheaper price in some conditions, the availability plays an important role as it increases the transportation cost and ultimately ends up making the material unfeasible. But in our case, Odisha is one of the largest producers of steel and contributes 25% to the national consumption thus using recycled steel can be beneficial in Odisha. As it is a developing state demolition of old buildings is common and RCA can be procured easily. Whereas the use of PBS as an alternative to Conventional geotextile makes the idea uneconomical. Thus, here is the rate comparison of materials that are used commonly and the substitute materials. (Jain, Singhal, and Jain 2021)(Yadav and Sinha 2022)

5.1 Conventional materials

Table 5 Comparative analysis of materials based on cost.

MATERIALS	UNIT	QUANTITY (Approx)	PRICE PER UNIT	TOTAL
Concrete	CUM	23789	5800	13,79,76,200
Steel (HYSD BARS)	TONNE	1608	35,700.00	5,74,05,600
Asphalt (Bitumen-5%)	CUM	15187 (760 cum bitumen)	32,146.18 (cost of bitumen only)	2,44,10,201
Geotextiles	M2	97500	15	14,62,500

The price of materials depends upon their availability and location of production. Bargarh is an industrial area with rapid construction most of the conventional materials are available readily. The cost of the above-mentioned materials has been taken from local suppliers and producers and thus the price may vary from place to place. We have not considered the lead cost and thus these prices are subject to change from season to season and place to place. Although from the above data, we conclude that conventional materials are easily available and working with these materials is easier than sustainable materials because of habitual behavior.(Hou et al. 2009)

5.2 Sustainable alternatives

Table 6 Comparative analysis of sustainable materials based on cost.

MATERIALS	UNIT	QUANTITY (Approx)	PRICE PER UNIT	TOTAL
Recycled Concrete Aggregate (RCA) (75% RCA)	CUM	23789	4257	10,12,69,773
Recycled Steel	TONNE	1608	32,000	5,14,56,000
Recycled Asphalt Pavement (RAP)	CUM	15187	253	38,42,311
Bio-Polybutylene succinate (PBS)	KG		780	

(Desai, Yadav, and Desai 2023)

There are a lot of sustainable alternatives for the conventional materials used in construction but the durability and physical properties of the materials like strength, hardness, ductility, etc play an important role as we are using this for the construction of river banking ring road with bridges and overfly also the availability of the material and transportation costs decides the feasibility of the material.(Ali, Qureshi, and Khan 2020) Steel does not lose its structural properties like strength and hardness in recycling and thus recycled steel can be one of the best alternatives but we need proper recycling facilities. Similarly, when we talk about recycled concrete we consider mixing up recycled concrete in virgin concrete to get the optimum strength (Marinković and Carević 2018)we can analyse that mixing up 13% recycled concrete into the virgin concrete we can reduce the cost of concrete by 11% and have very low strength impacts but the availability of properly recycled concrete is a difficult task as we have to distinguish and separate the reusable concrete and the waste products as per the strength and size criteria.(Bon and Hutchinson 2000)(Okoro, Musonda, and Agumba 2017)

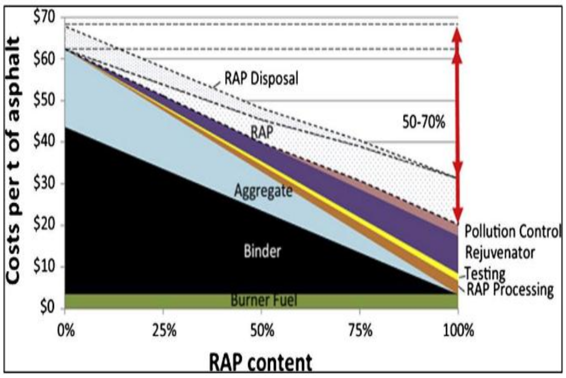

Figure 5 RAP Content vs Cost of Asphalt

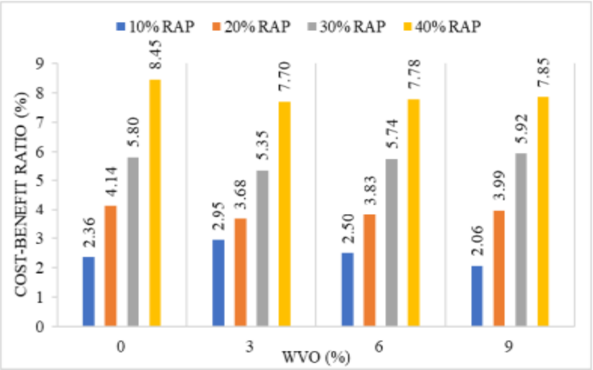

Figure 6 WVO % vs Cost Benefit Ratio

VI. LIMITATIONS:

This research, while providing a foundation for understanding infrastructure development in Bargarh District, has certain limitations. Relying heavily on simulated data from InfraWorks software, the study may not fully capture real-world complexities. Additionally, cost estimations can be inaccurate due to market fluctuations and the omission of factors like labour and equipment costs. The life cycle assessment is incomplete, focusing only on the production and construction phases. Furthermore, the study's focus on Bargarh District limits its generalizability to other regions. Hypothetical material quantities and the absence of field testing for sustainable materials also impact the study's reliability. These factors underscore the need for further research to refine understanding of sustainable infrastructure development.

VII. ETHICAL CONSIDERATIONS:

In conducting a comparative life cycle assessment (LCA) of ring road construction using conventional versus sustainable materials, several ethical considerations were rigorously addressed. Transparency and honesty were upheld by openly reporting all data sources, methodologies, and assumptions, and disclosing any potential conflicts of interest. Ensuring the accuracy and reliability of the data was paramount, achieved through credible sources and rigorous testing. Environmental responsibility motivated the research, aiming to reduce the environmental impact of road construction and promote sustainable practices. Social responsibility was considered, highlighting potential benefits for local communities and public health. Respect for the local context acknowledged regional availability and feasibility of sustainable materials, respecting local construction industry challenges. Informed consent was obtained from all stakeholders, ensuring they were fully aware of the study's purpose. Confidentiality was maintained to protect sensitive information. The findings were presented objectively, avoiding misrepresentation and accurately portraying the benefits and limitations of both material types. Efficient and ethical use of resources minimized the environmental impact of the research itself. While maintaining objectivity, the research advocated for sustainable materials where feasible, contributing to sustainable development and environmental conservation. These ethical principles ensure the integrity and social responsibility of the research.

VIII. CONCLUSION:

The ring road construction's comparative life cycle assessment (LCA) using conventional materials versus sustainable alternatives revealed several key insights. The analysis indicated that sustainable alternatives like recycled concrete, recycled steel, and recycled asphalt can effectively replace conventional materials such as concrete, steel, and aggregate. These substitutions offer significant environmental benefits by reducing the depletion of natural resources and minimizing waste. One of the most notable findings from the LCA was the substantial reduction in carbon footprint achieved by using sustainable alternatives. The use of recycled concrete, steel, and asphalt significantly lowered the greenhouse gas emissions associated with the production and transportation of these materials. This reduction in carbon footprint contributes to mitigating climate change and aligns with global sustainability goals. However, the study also highlighted the challenges associated with replacing other conventional materials. For instance, the use of bitumen and geotextile in the conventional approach proved difficult to substitute with sustainable options. The sustainable alternatives, such as biopolymer-based geotextiles (PBS) and other eco-friendly binders, were either prohibitively expensive or not readily available in the local market. This scarcity and high cost pose significant barriers to their widespread adoption in ring road construction. The comparative rate analysis of conventional construction materials versus sustainable alternatives revealed that while some sustainable materials offer cost advantages, others are more expensive. For example, recycled concrete, recycled steel, and recycled asphalt were found to be cost-effective alternatives. In contrast, sustainable options for bitumen and geotextiles were more costly, which impacted the overall budget of the construction project.

In summary, while the integration of sustainable materials in road construction is feasible and beneficial for certain components like concrete, steel, and asphalt, further advancements and availability improvements are needed for other materials to make a comprehensive shift toward sustainability. This finding underscores the importance of continued research and development in sustainable construction materials to overcome the current limitations and foster broader implementation in infrastructure projects.

IX. DECLARATION STATEMENT:

Funding	No, I did not receive.
Conflicts of Interest	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material	Not relevant.
Authors Contributions	All authors have equal participation in this article.

REFERENCE

[1]. Ali, Babar, Liaqat Ali Qureshi, and Sibghat Ullah Khan. 2020. "Flexural Behavior of Glass Fiber-Reinforced Recycled Aggregate Concrete and Its Impact on the Cost and Carbon Footprint of Concrete Pavement." Construction and Building Materials. https://doi.org/10.1016/j.conbuildmat.2020.120820.

[2]. Barbhuiya, Salim, and Bibhuti Bhusan Das. 2023. "Life Cycle Assessment of Construction Materials: Methodologies, Applications and Future Directions for Sustainable Decision-Making." Case Studies in Construction Materials. https://doi.org/10.1016/j.cscm.2023.e02326.

[3]. Bon, Ranko, and Keith Hutchinson. 2000. "Sustainable Construction: Some Economic Challenges." Building Research and Information. https://doi.org/10.1080/096132100418465.

[4]. Chowdhury, Raja, Defne Apul, and Tim Fry. 2010. "A Life Cycle Based Environmental Impacts Assessment of Construction Materials Used in Road Construction." Resources, Conservation and Recycling. https://doi.org/10.1016/j.resconrec.2009.08.007.

[5]. Desai, Margi, Neetu Yadav, and Nensikumari Desai. 2023. "Application of Recycled Soil and Sand in Brick Production over Conventional Clay Brick: A Sustainable Alternative." In Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2022.12.039.

[6]. Frazão, Cristina, Joaquim Barros, J. Alexandre Bogas, Verónica García-Cortés, and Tiago Valente. 2022. "Technical and Environmental Potentialities of Recycled Steel Fiber Reinforced Concrete for Structural Applications." Journal of Building Engineering. https://doi.org/10.1016/j.jobe.2021.103579.

[7]. Gerbrandt, Ron, and Curtis Berthelot. 2007. "Life-Cycle Economic Evaluation of Alternative Road Construction Methods on Low-Volume Roads." Transportation Research Record. https://doi.org/10.3141/1989-07.

[8]. Ghatak, Maitreesh, and Parikshit Ghosh. 2011. "The Land Acquisition Bill: A Critique and a Proposal." Economic and Political Weekly.

[9]. Hasan, Umair, Andrew Whyte, Hamad Al Jassmi, and Aisha Hasan. 2022. "Lifecycle Cost Analysis of Recycled Asphalt Pavements: Determining Cost of Recycled Materials for an Urban Highway Section." CivilEng. https://doi.org/10.3390/civileng3020019.

[10]. Hou, Xiaohui, Jing Zhang, Chong Du, and Lianjun Zhang. 2009. "Research the Influence of the Ring Road Factor on Route Choice." In 2009 17th International Conference on Geoinformatics, Geoinformatics 2009. https://doi.org/10.1109/GEOINFORMATICS.2009.5292898.

[11]. Huang, Beijia, Xiaofeng Gao, Xiaozhen Xu, Jialing Song, Yong Geng, Joseph Sarkis, Tomer Fishman, Harnwei Kua, and Jun Nakatani. 2020. "A Life Cycle Thinking Framework to Mitigate the Environmental Impact of Building Materials." One Earth. https://doi.org/10.1016/j.oneear.2020.10.010.

[12]. Jaawani, Salma, Annalisa Franco, Giuseppina De Luca, Orsola Coppola, and Antonio Bonati. 2021. "Limitations on the Use of Recycled Asphalt Pavement in Structural Concrete." Applied Sciences (Switzerland). https://doi.org/10.3390/app112210901.

[13]. Jain, Sourabh, Shaleen Singhal, and Nikunj Kumar Jain. 2021. "Construction and Demolition Waste (C&DW) in India: Generation Rate and Implications of C&DW Recycling." International Journal of Construction Management. https://doi.org/10.1080/15623599.2018.1523300.

[14]. Karpurapu, Rajagopal. 2017. "The Geosynthetics for Sustainable Construction of Infrastructure Projects." Indian Geotechnical Journal. https://doi.org/10.1007/s40098-016-0215-5.

[15]. Kuok, King Kuok, Kia Wee Kingston Tan, Po Chan Chiu, Mei Yun Chin, Md Rezaur Rahman, and Muhammad Khusairy Bin Bakri. 2023. "Application of Building Information Modelling (BIM) Technology in Drainage System Using Autodesk InfraWorks 360 Software." In Lecture Notes in Civil Engineering. https://doi.org/10.1007/978-981-19-5947-9_18.

[16]. Mahamid, Mustafa, Didem Ozevin, Ines Torra-Bilal, Minoo Kabir, Steve Mastny, Soliman Khudeira, Brett W. Sauter, and Deborah Zroka. 2019. "Structural Design and Inspectability of Highway Bridges." Practice Periodical on Structural Design and Construction. https://doi.org/10.1061/(asce)sc.1943-5576.0000425.

[17]. Marinković, Snežana, and Vedran Carević. 2018. "Comparative Studies of the Life Cycle Analysis between Conventional and Recycled Aggregate Concrete." In New Trends in Eco-Efficient and Recycled Concrete. https://doi.org/10.1016/B978-0-08-102480-5.00010-5.

[18]. Marzouk, Mohamed, Mohamed El-zayat, and Ahmed Aboushady. 2017. "Assessing Environmental Impact Indicators in Road Construction Projects in Developing Countries." Sustainability (Switzerland). https://doi.org/10.3390/su9050843.

[19]. Mishra, Pradeep Kumar. 2016. "Managing International Development Projects: Case Studies of Implementation of Large-Scale Projects in India." International Journal of Rural Management. https://doi.org/10.1177/0973005216633955.

[20]. Ohemeng, Eric A., and Stephen O. Ekolu. 2020. "Comparative Analysis on Costs and Benefits of Producing Natural and Recycled Concrete Aggregates: A South African Case Study." Case Studies in Construction Materials. https://doi.org/10.1016/j.cscm.2020.e00450.

[21]. Okoro, Chioma Sylvia, Innocent Musonda, and Justus Ngala Agumba. 2017. "Feasibility Study Considerations for Transport Infrastructure Performance: A Desk Study." In The Ninth International Conference on Construction in the 21st Century (CITC-9).

[22]. Saleh, Mohamed S., and Chaham Alalouch. 2015. "Towards Sustainable Construction in Oman: Challenges & Opportunities." In Procedia Engineering. https://doi.org/10.1016/j.proeng.2015.08.416.

[23]. Sandin, Gustav, Greg M. Peters, and Magdalena Svanström. 2014. "Life Cycle Assessment of Construction Materials: The Influence of Assumptions in End-of-Life Modelling." International Journal of Life Cycle Assessment. https://doi.org/10.1007/s11367-013-0686-x.

[24]. Shanmugapriya, S, and K Subramanian. 2013. "Investigation of Significant Factors Influencing Time and Cost Overruns in Indian Construction Projects." International Journal of Emerging Technology and Advanced Engineering.

[25]. Tian, Yongding, and Jian Zhang. 2022. "Recent Advancements in Mobile Impact Vibration-Based Bridge Rapid Testing and Flexibility Identification." Tumu Gongcheng Xuebao/China Civil Engineering Journal. https://doi.org/10.15951/j.tmgcxb.21080835.

[26]. Wang, Dayang, Chenxuan Lu, Zhimeng Zhu, Zhenya Zhang, Shaoyi Liu, Yongcheng Ji, and Zhiqiang Xing. 2023. "Mechanical Performance of Recycled Aggregate Concrete in Green Civil Engineering: Review." Case Studies in Construction Materials. https://doi.org/10.1016/j.cscm.2023.e02384.

[27]. Yadav, Madhura, and Surabhi Sinha. 2022. "Waste to Wealth: Overview of Waste and Recycled Materials in Construction Industry." In Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2022.06.245.

[28]. Zarei, A., H. Rooholamini, and T. Ozbakkaloglu. 2022. "Evaluating the Properties of Concrete Pavements Containing Crumb Rubber and Recycled Steel Fibers Using Response Surface Methodology." International Journal of Pavement Research and Technology. https://doi.org/10.1007/s42947-021-00049-7.

AUTHORS PROFILE:

Siddharth Acharya

I am Siddharth Acharya, a third-year B.Tech Civil Engineering student at VIT Vellore, with a passion for structural design and sustainable construction. Throughout my studies, I have developed a keen interest in project management, structural analysis, and environmental sustainability. I am committed to applying my skills and knowledge to real-world projects, aiming to contribute to innovative and efficient engineering solutions.

My academic journey has equipped me with a solid understanding of engineering principles and hands-on experience through various lab work and internships. These experiences have enhanced my technical skills, problem-solving abilities, and teamwork. Additionally, I have developed strong skills in estimation and costing, and I am proficient in software like Infraworks, AutoCad, StaadPro, MS Excel,etc.

I am enthusiastic about working on challenging projects that positively impact society and the environment. I continuously seek opportunities to expand my expertise and stay at the forefront of advancements in civil engineering.

Prathamesh Naik

I'm Prathamesh Naik, a final-year B.Tech Civil Engineering student at VIT Vellore. My journey in civil engineering has been driven by a deep interest in construction management, design, and project management. I am passionate about utilizing my skills to develop innovative solutions and ensure effective project outcomes.

My academic background has equipped me with a strong grasp of engineering fundamentals, complemented by practical experience gained through diverse projects and internships. I am proficient in key software tools such as Infraworks, AutoCAD, StaadPro, MS Excel, and Revit, which have enabled me to approach design and management tasks with both precision and creativity. I am particularly excited about opportunities that allow me to apply my technical expertise to projects with meaningful impacts on society and the environment. As I prepare to transition into the professional realm, I am committed to continually expanding my knowledge and contributing to advancements in civil engineering.

Dr. Prasanna Venkatesan R

Experienced faculty with a demonstrated history of working in the engineering education industry. Research interests include Lean Construction, Construction Techniques, Construction Project Management, Building Information Modeling (BIM) and Construction Health & Safety. Strong educational background with a Ph.D. in Civil Engineering.