Cost Analysis of Cantilever Retaining Wall Design: British Standard and Eurocode

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Abstract- This study conducted a cost analysis of Cantilever retaining wall design using British standards vs Eurocode for a 3.3m high retaining wall. Utilizing Tekla Tedds Software, separate analysis and design were performed for each design code, focusing on the area of reinforcements required, provided and compared the cost analysis of the Area of reinforcements provided, with British standards serving as the control. Results indicate that British standards yielded a higher area of reinforcements required, averaging 39.8%, and an Area of reinforcements provided averaging 32.1%, compared to Eurocode. Additionally, the cost analysis of the Area of reinforcements provided showed that Eurocode is more economical, with an average percentage of 66%. these findings suggest that Eurocode offers a more cost-effective design approach for cantilever retaining walls than British standards.

Indexed Terms- British Standards, Cost analysis, Cantilever retaining wall, Eurocode, Tekla Tedds.

I. INTRODUCTION

In the ever-evolving world of civil engineering, the quest for designing cost-effective and structurally sound Cantilever retaining walls is a critical challenge faced by engineers worldwide. As urban landscapes expand and infrastructure demands grow, the efficiency and economic viability of these structures become paramount. Choosing between the British Standards and Eurocode (EC) for designing Cantilever retaining walls is not merely a technical decision but one that has far reached implication on project costs and resource allocation globally. Understanding the nuances1 of these standards and their design implications can lead to substantial savings and enhanced structural integrity.

Cantilever retaining walls are integral to civil engineering, playing a critical role in supporting various infrastructure projects such as roadways (Mohammad & Ahmed, 2018) Constructed typically from reinforced, bridges, and buildings concrete. Serving as a crucial barrier that hold back soil in terrains with significant elevation changes. It generally consists of a base slab and a vertical stem, which are further divided into two key sections: the heel slab and toe slab. All three components function as one-way cantilever slabs. The stem serves as a vertical cantilever, resisting lateral earth pressure, while the heel slab and toe slab act as a horizontal cantilever, countering the resulting soil pressure (Gawnar & Sapate, 2022) necessitating adherence to stringent design standards and codes to ensure safety, durability, and cost-effectiveness. The design of these walls requires meticulous attention to detail to ensure stability, safety and economic viability. Historically, The British Standards, maintained by the British Standards Institution (B.S.I), have long been the foundation of engineering practices in the U.K and many Commonwealth countries. The British Standards, particularly BS 8002 and BS 8110, have provided a robust framework for the design of retaining structures, offering detailed and reliable guidelines on earth retaining structures and concrete use (British Standards Institution, 1985). Although, it has been superseded by the Eurocode, developed by the European Committee for Standardization (C.E.N), which aims to harmonize structural design standards across Europe, enhancing safety and reliability while facilitating international trade within the European Union (Nwoji & Ugwu,2017), Eurocode 2 and Eurocode 7 provides the guidelines for the design of concrete structures, and the principles and requirements for geotechnical design, addressing the safety and serviceability of geotechnical structures respectively. Eurocode presents a modern, comprehensive set of standards emphasizing higher safety factors and detailed structural analysis (European Committee for Standardization, 2004). As a member of the Commonwealth and lacking its own set of codes, Nigeria has traditionally utilized the design codes established by the United Kingdom, hence the selection between British Standards and Eurocode significantly impacts project costs, influencing decisions on material procurement, construction methods, and overall feasibility.

This article presents a comprehensive comparative cost analysis of a cantilever retaining wall design using British Standards and Eurocode, for a 3.3m high retaining wall. By employing Tekla Tedds software, focusing on three pivotal aspects of cantilever retaining wall design: the Area of reinforcements required, Area of reinforcements provided and the cost of the reinforcements provided. By evaluating these factors under the BS 8110 and EC2, this study seeks to identify which standard offers a more cost effective and efficient solution.

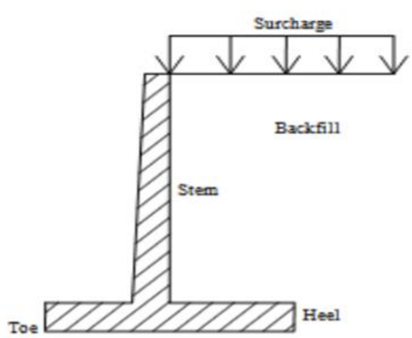

Fig. 1 Typical Parts of a Cantilever retaining wall

II. METHODOLOGY

2.1 Design Parameters

Table 1: Material data

Parameter	British Standard	Eurocode
Grade of Steel	460N/mm^2	460N.mm^2
Grade of Concreate	C25	C25/30
Concrete cover	30mm	30mm

Table 2: Retained Soil details

Moist density	17.5kN/m^3
Saturated density	20.4kN/m^3
Characteristic effective shear resistance angle	28^0
Characteristic wall frictional angle	14^0

Table 3: Base soil details

Soil density	18.9kNm^3
Characteristic effective shear resistance angle	32.6^0
Characteristic wall friction angle	16.3^0
Characteristic base friction angle	30^0
Bearing Capacity	295kN/m^2

(Ibrahim et al, 2022)

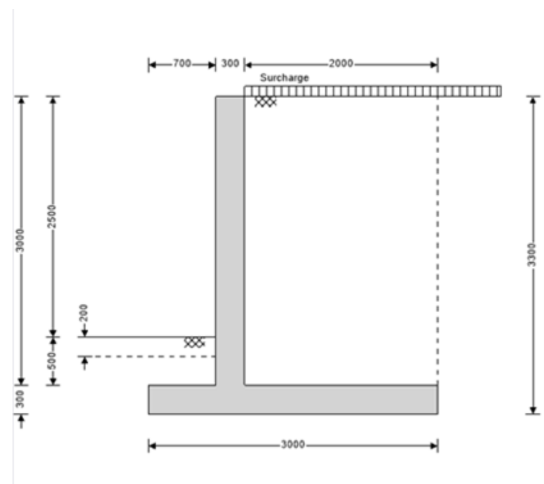

Fig. 2: Cantilever retaining wall

2.2 Tekla Tedds Design Procedures

Tekla Tedds is a robust structural analysis and design software simplifies engineering workflows. Renowned for its ease of use and robust capabilities, Tekla Tedds automates repetitive hand calculations. It offers a comprehensive library of multi-material element designs and the availability of different codes for use. The general design procedure after opening the Tekla Tedds environment is as follows

1. Launch the software and create a new project document.
2. Define Project Parameters:
3. Enter the project title and select the design standard (British Standards or Eurocode).
4. Input Material Properties:

5. Define concrete and reinforcement properties, including grades, densities, and strengths.
6. Define Wall Geometry:
7. Input the height (3.3 meters), base width, thickness, and backfill slope of the wall.
8. Load Input:
9. Enter parameters for earth pressures, surcharge loads, and seismic loads (if applicable).
10. Perform Structural Analysis:
11. Set up the analysis, define boundary conditions and load cases, and execute the analysis to determine internal forces.
12. Design Reinforcement:
13. Calculate required reinforcement areas, ensuring compliance with the selected standard. Define bar sizes, spacing, and anchorage.
14. Stability Checks:
15. Verify sliding stability, overturning stability, and bearing capacity.
16. Generate Design Outputs:
17. Produce detailed calculation reports and drawings for reinforcement and general arrangement.
18. Review and Optimization:
19. Review design results and optimize as necessary for cost-effectiveness and efficiency.

III. RESULTS AND DISCUSSION

After performing the analysis and design, the results were compared based on three factors. They are the Area of reinforcements required, Area of reinforcements provided and Cost of reinforcements provided. Table (4) shows the Area of reinforcements required for the cantilever retaining wall according to the different design codes. From this table and its graphical representation, it can be seen that area of reinforcements provided is the least in Eurocode.

Table 4: Comparison based on the Area of reinforcements required (mm^2/m)

	BS8110	EC2	Difference (%)
Stem rear face flexural reinforcement.	1122 mm^2/m	552.9 mm^2/m	50.72
Base top face flexural reinforcement.	894 mm^2/m	386.9 mm^2/m	56.72
Base bottom face flexural reinforcement.	390 mm^2/m	379.8 mm^2/m	2.82
Transverse stem reinforcement	390 mm^2/m	300 mm^2/m	23.07
Transverse base reinforcement	390 mm^2/m	134.0 mm^2/m	65.65
Average			39.8

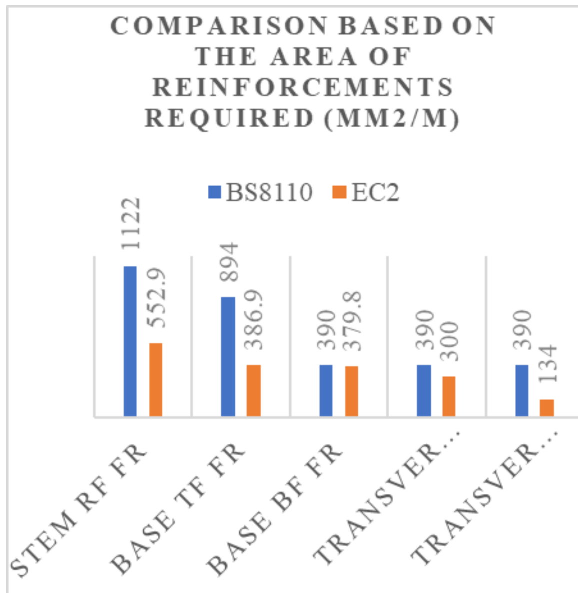

Figure 4: Comparison based on the Area of reinforcements required (mm^2/m)

Table (5) compares the Area of reinforcements provided for the Cantilever retaining wall according to the different design codes. This table and its graphical representation in figure 5 shows the Area of reinforcements provided and is the least in the Eurocode for the Cantilever retaining wall.

Table 5: Comparison based on the Area of reinforcements provided (mm^2/m)

	BS8110	EC2	Difference (%)
Stem rear face flexural reinforcement.	1340 mm^2/m	670 mm^2/m	50
Base top face flexural reinforcement.	905 mm^2/m	452 mm^2/m	50.1

Base bottom face flexural reinforcement.	452 mm²/m	452 mm²/m	0
Transverse stem reinforcement	449 mm²/m	314 mm²/m	30.1
Transverse base reinforcement	449 mm²/m	314 mm²/m	30.1
Average			32.1

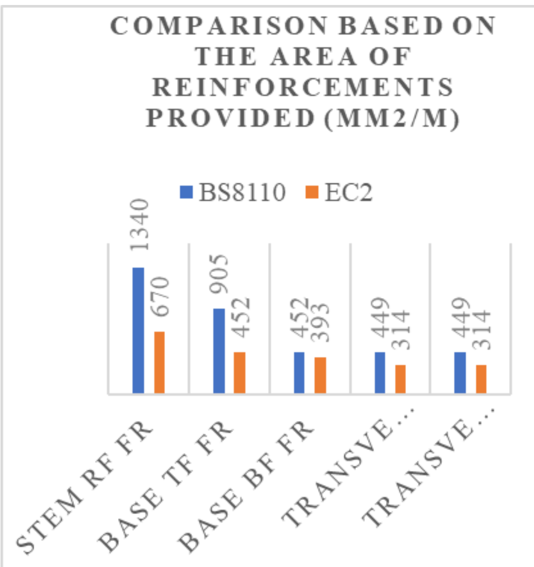

Figure 5: Comparison based on the Area of reinforcements provided (mm^2/m)

Table (6) shows the Area of reinforcements provided and the cost comparison for the Cantilever retaining wall according to the different design codes. This table and its graphical representation in figure 6 shows that the Area of reinforcements provided and the cost is the lowest in the Eurocode for the Cantilever retaining wall.

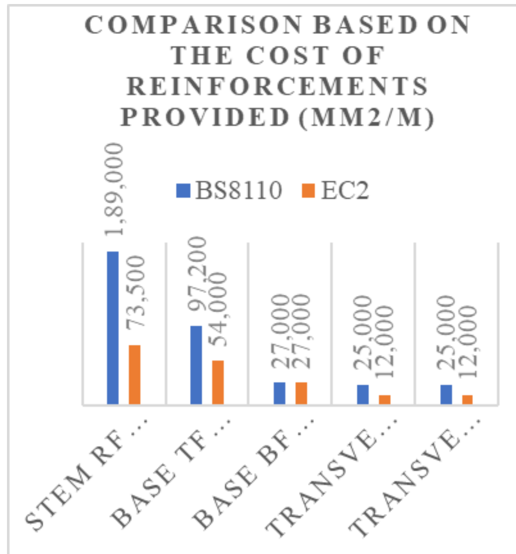

Figure 6: Comparison based on the Cost of reinforcements provided

Table 6: Comparison based on the Cost of reinforcements provided

	BS8110 AR provided	No of Rebar	Unit Price (Naira)	Total Price (Naira)	EC2 AR provided	No of Rebar	Unit Price (Naira)	Total Price (Naira)	Difference
Stem rear face flexural reinforcement.	Y16@150	9	21,000	189,000	Y16@300	2.5	21,000	46,200	
Base top face flexural reinforcement.	Y12@125	7.5	13,500	101,250	Y12@250	2	13,500	27,000	
Base bottom face flexural reinforcement.	Y12@250	2	13,500	27,000	Y12@250	2	13,500	27,000	
Transverse stem reinforcement	Y10@175	2.5	10,000	25,000	Y10@300	1.5	10,000	15,000	

Transverse base reinforcement	Y10@175	2.5	10,000	25,000	Y10@300	1.5	10,000	15,000	
TOTAL				367,250				130,200	237,050 (65%)

(Prices adopted; April,2024)

CONCLUSION

From the results of this study the following can be concluded:

1. EC2 yields less Area of reinforcements required for the Cantilever retaining wall with an average of 39.8% less for the total area of reinforcements required than BS8110.
2. EC2 yields less Area of reinforcements provided with an average of 32.1% less for the total Area of reinforcements provided than BS8110.

EC2 is the most economical based on the total price of reinforcements provided for the cantilever retaining wall, with an average of 66% less for the total price of reinforcements provided than BS8110.

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