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Comparative Study of BS 8110 and Eurocode 2 for Sustainable Reinforced Concrete Building Elements Using Protastructure Software

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ABSTRACT : *Eurocode 2 is a modern standard that harmonizes structural concrete design across Europe and has been shown in several studies to be more cost-effective than BS8110. This study outlines a structured procedure for designing reinforced concrete columns, beams, slabs, and isolated pad footings using BS8110-1997 and Eurocode 2 within Protastructure software for a three-storey twin two-bedroom residential building. The investigation compares load effects, bending moments, reinforcement requirements, and cost implications to promote sustainable structural design. The structural layout was produced from the building plan, and axes were created and dimensioned using the* orthogonal *axes generator. All structural components, including their end conditions, were accurately modelled using appropriate tools. Storey operations were applied to insert and edit storeys, while load combinations and model checks ensured reliable results. Analysis and design outputs for loads, moments, reinforcement areas, and costs were recorded and evaluated. Column design showed a 3.9% increase in bending moment under Eurocode 2 depending on load intensity. Beam design, however, demonstrated a 15.6%–17.7% reduction in reinforcement and cost under Eurocode 2, while slab design showed an 11.1% reduction. At higher loads, Eurocode 2 produced small increases of 0.4% in load and 0.1% in moment but resulted in a 54.5% rise in reinforcement and cost. Conversely, lower loads produced a 7.0% reduction in moment and a 36.0% decrease in reinforcement and cost. Overall, the study concludes that Eurocode 2 promotes more sustainable and efficient structural design by optimizing material use and reducing costs, demonstrating its advantages for modern engineering practice.*

KEYWORDS: *Eurocode 2, BS8110, Sustainable Design, Protastructure Software, Cost Efficiency*

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I. INTRODUCTION

The pressing urgency for sustainable construction practices has in recent years driven structural engineers to reconsider not just materials, but the efficiency of structural design itself — including optimization of reinforcement, concrete usage, and long-term durability. In reinforced concrete (RC) design, the choice of design code can significantly influence the amount of steel and concrete required, which in turn affects material consumption, embodied energy, carbon emissions, and overall sustainability. In this context, comparing traditional and modern design codes — specifically BS 8110 and Eurocode 2 (EC2) — is not only academically relevant but also of practical importance, particularly for regions (such as Nigeria) where BS 8110remains widely used but moves toward EC2 adoption are ongoing.BS 8110 has long been the backbone of RC design in many countries. However, EC2 offers more comprehensive provisions, greater flexibility in material properties, and often more economic design outcomes. Previous studies have demonstrated that EC2 can result in reduced reinforcement quantities compared to BS 811
10 — a factor with direct implications for material efficiency and sustainability. For example, in a recent comparative study of a two-span continuous beam in Cameroon, EC2 (with appropriate national annex) yielded lower longitudinal reinforcement areas than BS 8110, implying less steel consumption and less steel congestion in beams (Che et al 2023) Moreover,

shear design provisions show notable differences: a 2023 experimental review showed that under low shear reinforcement, EC2 tends to be conservative, but BS 8110 produced better agreement with experimental and Chinwuba, 2023). These findings point to trade-offs: while EC2 may economize on steel in flexural design, BS 8110 may — in certain contexts — better predict shear capacity. This tension motivates the need for comprehensive comparative study using modern design tools (finite element or structural design software) that can highlight code-driven differences in design efficiency, safety, and sustainability. Adopting software like Protastructure permits rigorous modeling and analysis under both codes, enabling a more systematic evaluation than manual hand calculations.

Another dimension to this comparison is serviceability and deflection control, especially for slabs and continuous beams. A recent analytical study comparing bending and deflection in simply supported one-way slabs found differences in span-to-depth (L/d) ratio limits between BS 8110 and EC2, indicating that slab thickness and reinforcement design could diverge significantly depending on the code used — with potential impacts on concrete volume, cracking, and long-term performance.(Ahamed, 2021)

Moreover, as environmental concerns mount, structural design optimization is increasingly viewed through sustainability lens. Some recent work proposes holistic workflows that combine concrete mixture design and structural analysis under uncertainty, aiming to minimize environmental impact (e.g., global warming potential) while satisfying structural code constraints (Agrawal, et al.,2023). Such integrated approaches align well with the goals of sustainable RC design and underscore the value of choosing efficient code-driven designs.

Despite the growing body of work, there remains a relatively small number of recent studies that explicitly compare BS 8110 and EC2 within the same structural model — especially using advanced design software and considering sustainability metrics (materials, reinforcement volumes, ease of design, etc.). This gap is particularly pronounced in the context of African countries (such as Nigeria) where BS 8110 remains widespread, but there's interest in transitioning to EC2. Although an older study compared BS 8110 and EC2 for a medium rise building design, using traditional analysis software to examine shear, moment, and column loads, the study concluded that EC2 is "logical and organized, less restrictive and more extensive" than BS 8110, recommending adoption of EC2 by practicing engineers.(Nwoji and Ugwu, 2017).Reinforced concrete (RC) remains the world's dominant structural material because of its versatility, cost and shear strength for stirrup-reinforced beams (Ayodeji and Chinwuba, 2023)

Cement availability: yet its environmental footprint — largely from cement production — drives strong interest in sustainable design approaches that reduce embodied carbon and life-cycle cost while meeting safety and serviceability criteria (Flower & Sanjayan, 2007).

International and national structural codes (e.g., BS 8110 and Eurocode 2) provide the rules by which structural engineers size RC members (beams, columns, slabs, footings). Although both codes aim to ensure safety, they differ in partial safety factors, load combinations, detailing rules, and assumptions about material behavior; those differences lead to systematic variations in required steel area, concrete grade, cover, and ultimately material quantities — which in turn influence both cost and embodied carbon of elements (De'nan, 2020; Ng, 2008).

Code differences that commonly affect material quantities include design values for characteristic strengths and partial safety factors for materials and loads; different minimum/maximum reinforcement limits; treatment of load combinations and factors for permanent/live loads; and detailing/cover rules that affect durability requirements and bar sizes/spacing. Several comparative studies report that Eurocode 2 tends to produce lower required reinforcement areas for many typical flexural members compared with BS 8110, with varying results depending on national annex choices and assumed steel grades — producing potential material (cost and carbon) savings when Eurocode 2 is applied carefully (Nwoji & Ugwu, 2017; Ng, 2008; comparative work summarized in De'nan, 2020).

Sustainability assessment requires moving beyond initial material cost: life-cycle assessment (LCA) metrics such as Global Warming Potential (GWP) quantify impacts across cradle-to-gate or cradle-to-grave boundaries and can reveal tradeoffs (higher-strength concrete may reduce cross-section/mass but sometimes increase embodied carbon per m^3) (Flower & Sanjayan, 2007; Manso-Morato et al., 2024). Modern sustainability-aware design combines structural design codes with LCA and cost optimization: multi-objective optimization strategies minimize cost and carbon emissions (or combine them into a single cost-focused sustainability objective), subject to code constraints and constructability/durability constraints (Negrín et al., 2023; So, 2025).

Because codes differ in reinforcement area and concrete grade selections, a straightforward code-to-code comparison should tabulate quantities (m^3

concrete, tonne steel), unit costs, and resulting initial (capital) cost and embodied carbon per element and per building frame (De'nan, 2020; BAEL/BS studies summarized in regional comparisons). Cost modeling must use realistic unit prices and national annex parameters.

Partial safety factors, minimum cover (affecting durability and required concrete volume), minimum reinforcement, and the adopted steel yield strength (e.g., 250/460/500 MPa) are all impactful. In many comparisons Eurocode 2's treatment of material factors yields smaller reinforcement areas for common spans and loading conditions, but results depend on the selected national annex and limit-state checks (Ng, 2008; Nwoji & Ugwu, 2017).

Coupling code-derived quantities to LCA databases (e.g., Ecoinvent) yields embodied GWP per element. LCA studies show cement is the dominant contributor to concrete's CO2; cement substitutions (GGBS, FA, LC3) and optimized reinforcement detailing (less congestion, lower steel mass) consistently reduce embodied carbon (Flower & Sanjayan, 2007; Manso-Morato et al., 2024; Sahab, 2005).

Modern studies use metaheuristics, surrogate models, or hybrid algorithms to minimize cost and/or CO_2 subject to structural constraints. Multi-criteria optimization literature demonstrates the feasibility and benefit of automated searches that trade cost vs carbon vs constructability (Negrín et al., 2023; Salimi et al., 2022; recent MDPI studies on cost-efficient beam design and GA/ANN approaches). These approaches are directly applicable when integrating a design tool such as Protastructure into an automated workflow to produce design variants under BS 8110 and Eurocode 2 and evaluate cost+LCA metrics. Protastructure (commercial BIM/analysis/design package) supports automated quantity take-off and code-based design workflows for RC elements; combining automated extraction of reinforcement and concrete quantities from Protastructure with parametric LCA and cost databases creates a transparent and reproducible pipeline for comparing codes on both financial and environmental metrics. Prota (the vendor) publishes application notes and white papers demonstrating automated take-off and design-to-drawing workflows suitable for this kind of comparative study, though peer-reviewed validation combining Protastructure with LCA datasets is limited in the literature and represents a methodological contribution (ProtaSoftware, product docs & technical white papers).

Code differences in cover and detailing change expected service life and therefore life-cycle cost; sustainable design should include maintenance and replacement scenarios (LCC) in addition to embodied carbon per initial build (Negrín et al., 2023; RILEM/LCA guidance).

Practical factors like bar congestion, labor productivity, local availability of high-strength steel or SCMs (supplementary cementitious materials) influence realized cost and carbon, especially in regions where BS 8110 remains in use or where national annexes to Eurocode adjust the rules.

Overview of Protastructure

Protastructure is an integrated structural analysis and design software widely used for modelling, analyzing, and detailing reinforced concrete and steel structures. It provides an intuitive 3D building modelling environment that allows engineers to create real-life structural systems and automatically apply relevant design codes. Its comprehensive set of analysis tools—including linear and nonlinear analysis, load combinations, automatic mesh generation, and member optimization—makes it highly suitable for academic and professional design studies. For this study, Protastructure is particularly important because it supports both BS 8110 and Eurocode 2, allowing the same building model to be analyzed under different design standards without reconstructing the structural model. This enables a uniform, unbiased comparison of the two codes using identical geometry, loading conditions, and structural configurations. Such consistency is essential for producing reliable comparative results based strictly on code provisions rather than modelling differences. The software also provides automated reinforcement detailing, concrete volume estimation, rebar scheduling, and material take-off (MTO). These outputs are critical for a cost-focused sustainability study because they allow accurate quantification of materials such as concrete, reinforcement steel, and formwork. By comparing the MTO results generated under BS 8110 and Eurocode 2, the study can objectively determine which code yields lower material consumption and therefore lower construction cost.

Protostructure's structural optimization features support sustainable engineering by enabling efficient design with minimal material use while still maintaining code-prescribed safety levels. The software's user-friendly interface and ability to run multiple design iterations quickly make it ideal for academic research requiring comparative analysis.

Protastructure serves as the central tool that integrates modelling, analysis, design, and material quantification, making it indispensable for evaluating the cost-effectiveness and sustainability differences between BS 8110 and Eurocode 2 in reinforced concrete building design. Although many studies compare BS 8110 and Eurocode 2, most focus on theoretical differences and structural safety rather than cost and sustainability. Only a few works use modern design software, and even fewer evaluate ordinary building elements using Protastructure. There is also limited evidence on actual material and cost savings when both codes are applied to the same building. Therefore, there is a clear research gap in providing a comprehensive, software-based, cost-focused comparison of BS 8110 and Eurocode 2 aimed at improving sustainability and affordability in reinforced concrete construction. No previous research combines code comparison, sustainability/cost analysis, and Protastructure modelling in one comprehensive study. The aim of this study is to carry out a cost-focused comparative assessment of reinforced concrete building elements designed using BS 8110 and Eurocode 2, using Protastructure software, to determine which code provides a more sustainable and economical design for typical building projects.

II. MATERIALS AND METHODS

Equipment/Tools

Protastructure software 2021 version 5.1.252. Architectural plans and section of proposed residential building, Laptop with specification not less than 4gig ram.

Description of building elements

A three-storey building with beam, column, slab and foundation elements were considered for design.

III. RESULTS AND DISCUSSION

In table 1, column C14 has a maximum load of 591.80kN for both design codes with increase in moment 6.7kNm to 11.8kNm at storey1. Column C21 recorded a minimum load of 43.90kN for both design codes with moment increase from 0.5kNm to 0.9kNm at storey3, as other parameters remain unchanged.

Table 1: Column Reinforcement Design

BS 8110-97 - Column Reinforcement Design

Columns	Storey	b1 (mm)	b2 (mm)	Axial load (kN)	Moment (kNm) XX	Moment (kNm) YY	Steel Bars	Area of steel required(mm2)	Area of steel provided (mm2)
C1	1	225	450	196.90	7.8	22.5	6Y12	202.5	678.58
	2	225	450	121.70	8.9	32.4	6Y12	202.5	678.58
	3	225	450	52.70	4.7	0.7	6Y12	202.5	678.58
C2	1	150	450	388.80	24.0	15.3	6Y12	135.00	678.58
	2	150	450	191.70	34.6	8.7	6Y12	135.00	678.58
	3	150	450	62.80	19.4	1.9	6Y12	135.00	678.58
C5	1	225	225	325.30	3.7	4.8	4Y12	101.25	452.39
	2	225	225	195.10	2.2	7.5	4Y12	101.25	452.39
	3	225	225	53.90	1.8	8.9	4Y12	101.25	452.39
C7	1	225	450	336.60	6.7	35.7	6Y12	202.5	678.58
	2	225	450	248.10	5.0	64.5	6Y12	202.5	678.58
	3	225	450	89.60	6.5	1.0	6Y12	202.5	678.58
C9	1	225	450	382.40	18.0	36.6	6Y12	202.5	678.58
	2	225	450	234.80	32.0	61.0	10Y12	202.5	678.58
	3	225	450	80.60	19.7	0.9	6Y12	202.5	678.58
C10	1	225	225	557.60	6.3	6.3	4Y12	101.25	452.39
	2	225	225	335.30	9.9	3.8	4Y12	101.25	452.39
	3	225	225	98.50	13.3	1.8	4Y12	155.86	452.39
C13	1	225	450	312.00	6.2	33.1	6Y12	206.55	678.58
	2	225	450	189.50	3.8	50.1	8Y12	206.5	678.58
	3	225	450	75.70	14.9	0.9	6Y12	202.5	678.58
C14	1	225	225	591.80	6.7	6.7	4Y12	101.25	452.39
	2	225	225	345.20	6.3	3.9	4Y12	101.25	452.39
	3	225	225	97.10	5.6	3.5	4Y12	101.25	452.39
C15	1	225	225	486.20	5.5	7.1	4Y12	101.25	452.39
	2	225	225	295.30	3.3	9.4	4Y12	101.25	452.39
	3	225	225	88.40	3.8	9.2	4Y12	101.25	452.39
C19	1	225	450	172.30	5.0	19.5	6Y12	202.5	678.58
	2	225	450	120.30	2.4	31.4	6Y12	202.5	678.58
	3	225	450	44.40	8.0	1.0	6Y12	202.5	678.58
C20	1	450	225	346.90	33.4	28.7	6Y12	202.5	678.58
	2	450	225	246.20	64.0	10.1	10Y12	202.5	678.58
	3	450	225	83.30	0.9	2.7	6Y12	202.5	678.58
C21	1	225	225	205.30	3.5	19.7	4Y12	101.25	452.39
	2	225	225	126.40	32.9	2.5	8Y12	101.25	452.39
	3	225	225	43.90	0.5	0.5	4Y12	101.25	452.39

Eurocode2 - Column Reinforcement Design

Columns	Storey	b1 (mm)	b2 (mm)	Axial load (kN)	Moment (kNm) XX	Moment (kNm) YY	Steel Bars	Area of steel required (mm2)	Area of steel provided (mm2)
C1	1	225	450	228.10	6.1	4.6	6Y12	202.50	678.58
	2	225	450	141.40	10.2	2.8	6Y12	202.50	678.58
	3	225	450	52.70	5.1	1.1	6Y12	202.50	678.58
C2	1	150	450	386.80	25.8	7.7	6Y12	135.00	678.58
	2	150	450	226.70	42.2	4.5	6Y12	135.00	678.58
	3	150	450	62.80	19.8	1.4	6Y12	135.00	678.58
C5	1	225	225	325.30	6.5	6.5	4Y12	101.25	452.39
	2	225	225	195.10	3.9	8.3	4Y12	101.25	452.39
	3	225	225	54.70	2.0	7.8	4Y12	101.25	452.39
C7	1	225	450	399.60	8.0	8.0	6Y12	202.50	678.58
	2	225	450	248.10	5.0	5.0	6Y12	202.50	678.58
	3	225	450	89.60	7.0	1.8	6Y12	202.50	678.58
C9	1	225	450	382.40	19.9	7.6	6Y12	202.50	678.58
	2	225	450	234.80	34.2	4.7	6Y12	202.50	678.58
	3	225	450	80.60	20.1	1.5	6Y12	202.50	678.58
C10	1	225	225	557.60	11.2	11.2	4Y12	101.25	452.39
	2	225	225	335.30	11.3	6.7	4Y12	101.25	452.39
	3	225	225	98.50	13.7	2.2	4Y12	155.86	452.39
C13	1	225	450	359.30	9.4	7.2	6Y12	206.55	678.58
	2	225	450	219.10	6.2	4.4	6Y12	206.50	678.58
	3	225	450	75.70	15.3	1.5	6Y12	202.5	678.58
C14	1	225	225	591.80	11.8	11.8	4Y12	101.25	452.39
	2	225	225	345.20	8.0	6.9	4Y12	101.25	452.39
	3	225	225	97.10	6.1	3.9	4Y12	101.25	452.39
C15	1	225	225	486.20	9.7	9.7	4Y12	101.25	452.39
	2	225	225	295.30	5.9	10.6	4Y12	101.25	452.39
	3	225	225	100.10	2.0	9.0	4Y12	101.25	452.39
C19	1	225	450	189.90	6.3	3.8	6Y12	202.5	678.58
	2	225	450	117.60	2.4	2.4	6Y12	202.5	678.58
	3	225	450	44.40	8.3	1.3	6Y12	202.5	678.58
C20	1	450	225	406.00	8.1	8.1	6Y12	202.5	678.58
	2	450	225	246.20	4.9	11.3	6Y12	202.5	678.58
	3	450	225	83.30	1.7	3.2	6Y12	202.5	678.58
C21	1	225	225	205.30	4.6	5.1	4Y12	101.25	452.39
	2	225	225	126.40	3.7	3.7	4Y12	101.25	452.39
	3	225	225	43.90	0.9	0.9	4Y12	101.25	452.39

Table 2 indicated, beam E has a maximum load of 47.84kN for both design codes with moment 43.3kNm, area of steel provided 402.12mm2, 339.39mm2 for BS8110 and EC2 respectively at storey2.Beam 2 recorded a minimum load,11.440kN, 29.1kNm moment, for both design codes, 375.43mm2, 309.87mm2 area of steel required at storey3, as other parameters remain unchanged.

Table 2: Beam Reinforcement Design

BS8110-97 - Beam Reinforcement Design

Beam	Storey	B (mm)	H (mm)	Axial load Max (kN)	Moment Top,Botton Max(kNm)	Steel Bars	Area of steel required (mm2)T	Area of steel provided (mm2)
1	1	225	450	30.379	70.462, 47.941	2Y12, 3Y16	535.15 351.80	603.19, 402.12
	2	225	450	31.115	71.9, 49.2	3Y12, 3Y16	547.30 361.83	603.19, 402.12
	3	225	450	12.201	31.6, 20.5	3Y12, 3Y16	386.31 239.48	402.12, 402.12
2	1	150	450	43.986	79.2, 54.6	2Y16, 2Y16	658.38 446.99	804.25 628.32
	2	150	450	44.564	77.9, 55.6	2Y16, 2Y16	645.00 456.26	804.25 628.32
	3	150	450	11.440	29.1, 24.8	2Y16, 2Y16	375.43 310.90	402.12 402.12
3	1	150	450	42.051	53.2, 41.948	2Y16, 2Y16	393.66 305.20	402.12 402.12
	2	150	450	42.779	56.7, 44.3	2Y16, 2Y16	421.87 323.46	603.19 402.12
	3	150	450	12.346	29.6, 17.5	2Y16, 2Y16	298.82, 200.46	402.12 226.19
E	1	150	450	47.802	42.7, 41.3	3Y12 3Y12	311.17 299.94	402.12 402.12
	2	150	450	47.836	43.3, 41.1	3Y12 3Y12	315.78 299.00	402.12 402.12
	3	150	450	12.358	12.2, 11.8	3Y12 3Y12	139.54 134.28	226.19 226.19
B1	1	225	450	46.418	50.8, 47.8	3Y12 3Y12	374.46 350.45	402.12 402.12
	2	225	450	47.140	53.1, 48.8	3Y12 3Y12	369.34 358.32	402.12 402.12
	3	225	450	12.358	22.4, 12.6	3Y12 3Y12	374.46 350.45	402.12 402.12

Eurocode2 - Beam Reinforcement Design

Beam	Storey	B (mm)	H (mm)	Axial load Max (kN)	Moment Top,Botton Max(kNm)	Steel Bars	Area of steel required(mm2)	Area of steel provided (mm2)
1	1	225	450	30.379	70.462, 47.941	3Y12, 3Y16	531.68, 356.54	603.19, 402.12
	2	225	450	31.115	71.895, 49.215	3Y12, 3Y16	543.30 366.02	603.19, 402.12
	3	225	450	12.138	31.649, 20.502	3Y12, 3Y16	388.44 243.11	603.19, 339.29
2	1	150	450	43.986	79.2, 54.6	2Y16, 2Y16	631.18, 439.44	804.25 829.38
	2	150	450	44.473	77.9, 50.1	2Y16, 2Y16	619.47, 448.07	804.25 829.38
	3	150	450	11.440	29.091, 24.846	2Y12, 2Y16	205.53 309.87	402.12 402.12
3	1	150	450	42.051	53.1, 41.948	2Y16, 2Y16	395.09, 310.40	603.19 339.29
	2	150	450	42.779	56.747, 44.309	3Y12, 3Y16	419.97 327.88	603.19 339.29
	3	150	450	12.296	29.688, 17.501	3Y12, 3Y16	300.39, 207.52	603.19 339.29
E	1	150	450	47.802	35.9, 19.2	3Y12 3Y12	265.95, 235.63	339.29 339.29
	2	150	450	47.836	43.3, 41.1	3Y12 3Y12	320.53, 304.44	339.29 339.29
	3	150	450	12.358	14.7, 11.2	3Y12 3Y12	137.51, 132.24	339.29 339.29
B1	1	225	450	46.418	50.8, 47.8	2Y12 3Y12	377.91 355.25	603.19 402.12
	2	225	450	47.147	53.1, 48.8	3Y12 3Y16	377.91 355.25	603.19 402.12
	3	225	450	12.358	22.4, 22.1	2Y12 3Y12	265.50 262.33	339.29 339.29

In table 3, slab 1S13 has a maximum load of 6.3kN, moment 5.9kNm for both design codes. 254.40mm2, 226.19mm2 area of steel required at storey1 and 2 as other parameters remain unchanged

In table 4, pad footing F-1C14 supports maximum load of 649.36kN, 652.24kN, moment of 96.7kNm, 96.8kNm and 951.44mm^2, 1470.41mm^2 area of steel required for BS8110, EC2 respectively. Pad footing EC2 respectively was recorded. 1256.64mm^2, 804.25mm^2 area of steel provided was observed for BS8110, EC2 respectively.

F-1C19 with minimum load of 218.94kN for both design codes, moment of 18.5kNm, 17.2kNm for BS8110.

Table 3: Slab Reinforcement Design

BS8110-97 - Slab Reinforcement Design

Slab	Storey	L1 (mm)	L2 (mm)	Dead /Live load (kN)	Moment Suppot/ Span (kNm)	Steel Bars	Area of steel required (mm2) B	Area of steel provided (mm2) T
1S5	1	4750	3187	4.8 1.5	4.2 3.1	Y12-250 Y12-250	254.40	452.39
1S10	1	3075	3187	4.8 1.5	3.5 2.6	Y12-250 Y12-250	254.40	452.39
1S12	1	4125	3187	4.8 1.5	4.2 3.1	Y12-250 Y12-250	254.40	452.39
1S6	1	4225	3788	4.8 1.5	4.8 3.7	Y12-250 Y12-250	254.40	452.39
1S8	1	3075	3788	4.8 1.5	4.2 3.2	Y12-250 Y12-250	254.40	452.39
1S13	1	4225	3788	4.8 1.5	5.9 4.4	Y12-250 Y12-250	254.40	452.39

Eurocode2 - Slab Reinforcement Design

Slab	Storey	L1 (mm)	L2 (mm)	Dead /Live load (kN)	Moment Suppot/ Span (kNm)	Steel Bars	Area of steel required (mm2) B	Area of steel provided (mm2) T
1S5	1	4750	3187	4.8 1.5	4.2 3.1	Y12-250 Y12-250	226.19	452.39
1S10	1	3075	3187	4.8 1.5	3.5 2.6	Y12-250 Y12-250	226.19	452.39
1S12	1	4125	3187	4.8 1.5	4.2 3.1	Y12-250 Y12-250	226.19	452.39
1S6	1	4225	3788	4.8 1.5	4.8 3.7	Y12-250 Y12-250	226.19	452.39
1S8	1	3075	3788	4.8 1.5	4.2 3.2	Y12-250 Y12-250	226.19	452.39
1S13	1	4225	3788	4.8 1.5	5.9 4.4	Y12-250 Y12-250	226.19	452.39

Table 4: Pad Footing Reinforcement Design

Eurocode 2 - Pad Footing Reinforcement Design

Label	Depth	Lx	Ly	Axial load Σ(kN)	Moment (kNm) XX	Moment (kNm) YY	Steel bar XX	Steel bar YY	Area of Steel required (mm2) XX	Area of Steel required (mm2) YY	Area of Steel provided(mm2) XX	Area of Steel provided(mm2) YY
F-1C1	400	1000	1000	258.90	13.4	23.8	6ϕ16	6ϕ16.	831.99,	831.99,	884.67	884.67
F-1C2	600	1300	1300	431.37	31.1	56.4	7ϕ20	7ϕ20	1194.71	1194.71	1633.63	1633.63
F-1C5	500	1100	1200	357.74	36.1	31.9	6ϕ16	6ϕ16.	907.62	831.99	2/965.10	884.67
F-1C7	600	1300	1300	442.15	31.7	50.3	7ϕ20	7ϕ20	1194.71	1194.71	1633.63	1633.63
F-1C9	600	1300	1300	425.02	31.9	50.0	7ϕ20	7ϕ20	1194.71	1194.71	1633.63	1633.63
F-1C10	600	1500	1500	614.32	84.3	84.0	7ϕ20	7ϕ20	1378.51	1378.51	1378.51	1884.96
F-1C13	500	1200	1300	397.66	27.8	40.2	7ϕ16	6ϕ16	983.26	907.62	1045.52	965.10
F-1C14	600	1500	1600	652.24	96.8	88.8	8ϕ20	7ϕ20	1470.41	1378.51	2010.62	1884.96
F-1C15	600	1400	1400	535.64	66.7	66.9	8ϕ16	8ϕ16	1286.61	1286.61	1407.43	1407.43
F-1C19	400	1000	1000	218.94	.9.0	17.2	5ϕ16	5ϕ16	756.35	756.35	804.25	804.25
F-1C20	500	1300	1300	447.61	50.3	31.8	7ϕ16	7ϕ16	983.26	983.26	1045.52	1045.52
F-1C21	400	1000	1000	229.29	17.5	17.5	5ϕ16	5ϕ16	593.7	593.7	804.25	804.25

BS 8110 -97 - Pad Footing Reinforcement Design

Label	Depth	Lx	Ly	Axial load Σ(kN)	Moment (kNm) XX	Moment (kNm) YY	Steel bar XX,	Steel bar YY	Area of Steel required(mm2) XX	Area of Steel required(mm2) YY	Area of Steel provided(mm2) XX	Area of Steel provided(mm2) YY
F-1C1	500	1000	1000	218.94	9.8	18.5	5ϕ20	5ϕ20	624.76	624.76	1256.64	1256.64
F-1C2	400	1300	1300	429.34	31.6	57.0	7ϕ20	7ϕ20	609.14	609.14	1633.63	1633.63
F-1C5	400	1100	1200	356.95	36.0	31.9	6ϕ20	6ϕ20	562.29	515.43	1507.96	1382.30
F-1C7	400	1300	1300	440.12	31.6	50.2	7ϕ20	7ϕ20	609.14	609.14	1633.63	1633.63
F-1C9	400	1300	1300	423.00	32.4	50.5	7ϕ20	7ϕ20	609.14	609.14	1633.63	1633.63
F-1C10	400	1500	1500	611.62	84.2	83.9	7ϕ20	7ϕ20	829.10	825.68	1884.96	1884.96
F-1C13	400	1200	1300	396.72	29.3	29.3	7ϕ20	6ϕ20	609.14	562.29	1633.63	1507.96
F-1C14	400	1500	1600	649.36	96.7	88.6	8ϕ20	7ϕ20	951.44	871.92	2010.62	1884.96
F-1C15	400	1400	1400	533.29	66.6	66.9	7ϕ20	7ϕ20	656.00	658.24	1759.29	1759.29
F-1C19	500	1000	1000	218.94	9.8	18.5	5ϕ20	5ϕ20	624.76	624.76	1256.64	1256.64
F-1C20	400	1300	1400	449.72	57.5	34.3	7ϕ20	7ϕ20	656.00	609.14	1759.29	1633.63
F-1C21	400	1000	1000	229.29	17.5	17.4	5ϕ20	5ϕ20	468.57	468.57	1256.64	1256.64

In table 5, column C14 though the maximum load remains unchanged, the moment increased by 76.1% at storey1. Column 21minimum load was observed be constant with 80% increase moment from BS8110 to EC2 at storey3, as other parameters remain unchanged

Table 5: Comparison of column parameters

Code	Load kN	Percentage load %	Moment kNm	Percentage moment %	Area of Steel mm^2	Percentage Area of Steel %	Cost of Steel ₦	Percentage Cost of Steel %
Column C14								
BS8110	591.8	-	6.7	76.1	452.39	-	48,024	-
EC 2	591.8		.8		452.39		48,024	
Column 21								
BS8110	43.90	-	0.5	80.0	452.39	-	48,024	-
EC 2	43.90		0.9		452.39		48,024	

Table 6 showed beam E support maximum load of 47.84kN remain unchanged as area of steel, cost of steel was observed to have decreased by 15.6% at storey2. Beam 2 with minimum load of 11.44kN, 17.7% decrease in area of steel, cost of steel was observed at storey3 with other parameters remain unchanged..

Table 6: Comparison of beam parameters

Code	Load kN	Percentage load %	Moment kNm	Percentage moment %	Area of Steel mm²	Percentage Area of Steel %	Cost of Steel ₦	Percentage Cost of Steel %
Beam E								
BS8110	47.84	-	43.30	-	402.12	15.6	42,688:00	15.6
EC 2	47.84		43.30		339.39		36,029:00	
Beam 2								
BS8110	11.44	-	29.10	-	375.43	17.7	33,627:00	17.7
EC 2	11.44		29.10		309.87		27,755:00	

In table 7, at maximum load of 6.3kN, 11.1% decrease in cost of steel and area required at storey1 and 2 were recorded as other parameters remain unchanged.

Table 7: Comparison of slab parameters

Code	Lord kN	Percentage load %	Moment kNm	Percentage moment %	Area of Steel mm²	Percentage Area of Steel %	Cost of steel ₦	Percentage Cost of steel %
Slab 1S13								
BS8110	6.3	-	5.9	-	254.40	11.1	27,006:00	11.1
EC2	6.3		5.9		226.19		24,012:00	

From table 8, pad footing F-1C14 has percentage load increase of 0.4%. 0.1% increased moment and 54.5% increase in area of steel and cost of steel reinforcement. Pad footing F-1C19 though the load remains unchanged, 7.0% decrease in moment, 36.0% decrease in area of steel and cost of steel reinforcement were observed.

Table 8: Comparison of pad footing parameters

Code	Load kN	Percentage load %	Moment kNm	Percentage moment %	Area of Steel mm²	Percentage Area of Steel %	Cost of steel ₦	Percentage Cost of steel %
Pad Footing F-1C14								
BS8110	649.36	0.4	96.7	0.1	951.44	54.5	60,601:00	54.5
EC 2	652.24		96.8		1470.41		93,657:00	
Pad Footing F-1C19								
BS8110	218.94	-	18.5	7.0	1256.64	36.0	80,041:00	36.0
EC 2	218.94		17.2		804.25		51,226:00	

IV CONCLUSION AND RECOMMENDATION

4.1 CONCLUSION

In design of column, there was an increased moment of about 3.9% depending on load intensity with no visible change in other parameters using Eurocode2

Reduction of about 15.6% - 17.7% area of steel and its cost is expected in the design of reinforced concrete beam design to Eurocode2.

There is a reduction of 11.1% area steel and its cost in design of reinforced concrete slab according to Eurocode2.

At higher loads there is 0.4%, 0.1% increase in load and moment respectively, with more than half (54.5%) increase in area of steel and its cost. Lower loads result to no change, with 7.0% decrease in the moment and 36.0% reduction in area of steel including its cost when design is according to Eurocode2

The design data of Eurocode2 which were developed from that of BS8110 including dead and live loads,

areas of steel reinforcement and moment have contributed to the discrepancies in results of various parameters including cost of steel for building elements considered in reinforced concrete structural design.

Recommendations

i. For efficient reinforced concrete column structural design, engineers and other stakeholders in the design industry should adopt BS8110.

ii. Government agency saddled with the responsibility of ensuring sustainability in the design of reinforced concrete, with interest in beam should ensure that design consultants, carryout the task according to Eurocode2

iii. If sustainability in reinforced concrete slab is of priority, design should be to Eurocode2
iv. Individual and corporate organizations with responsibility in assessing reinforced concrete structural design documents for approval should mandate effective and efficient design of pad footing using BS8110, Eurocode2 for considerable higher and much lower load respectively.

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