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Comparative Study of British Standard (BS 8110) and Eurocode (EC 2) in Reinforced Concrete Design: A Case Study of a Single Storey Building Located at Akure

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Abstract

With more emphasis and focus on the relative advantages and disadvantages of Eurocode 2 and BS8110 under certain criteria which are loading, analysis as well as the cost effectiveness, this research was carried out to compare the use of the BS8110 and Eurocode2 in the design of structures. Therefore, the analysis and design of the main structural element in reinforced concrete building was undertaking using the two codes. A 2-storey framed building was loaded and analyzed using the two codes. In each case, the results obtained with the Eurocode values for maximum span moments and Shears were lesser than that obtained with the BS code for the same elements. The degree of variation in the percentages in the area of steel required for slab was about 12%, for beam: about 15%, for column: about 16% and for foundation: about 27%. It was also observed that as the loading increases down the structure, the percentages of the differences in the area of steel required increase down the structure. This implies that the percentages of the differences in the area required increase with depth. However, almost the same provisions were made. Eurocode embody the most recent research on many areas of structural behavior which is a way of simulating innovation in that their clauses are structured in a slightly different way.

Keywords

BS8110, Eurocode, design, moments and Shear

Article History

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1. Introduction

Reinforced concrete is a combination of two dissimilar but complimentary materials, namely concrete and steel (Morgan and Claydon, 2016). Concrete is produced by mixing cement, fine aggregates, coarse aggregate and water. Steel on the other hand, is a metal alloy that is composed principally of Iron and Carbon. While concrete has a high compressive strength but poor tensile strength, steel reinforcement having a high tensile strength, compliments the concrete in a reinforced concrete. Majority of structures in the world are constructed using reinforced concrete but such constructions are usually based on a national/international code of practice.

Design codes are guides that set out the design loads, load combinations and partial factors of safety which help ensure that prospective project qualities are achieved as expected. The BS codes and Eurocodes as applied in the design of reinforced concrete structures are examples of such guides. While the former is the British Standards structural design guides, the latter is the pan-European structural design guides.

After the determination of the arrangement and layout of the building by the architect comes the structural design aimed to provide safe, stable and durable structures which incorporate maximum possible economy (Mosley et. al., 2007).

Since April 2010, United Kingdom has adopted EC2 as their standard code for the design of reinforced concrete structures and the earlier BS8110-1997 has been withdrawn (Franklin and Mensah, 2011). However, BS8110 still continues to enjoy a large degree of prominence on the African continent. The major exception to this is in the Republic of South Africa where there has been a major shift towards full embrace of the EC2 design philosophy as well as provisions. The foregoing dichotomy or state of affairs has added impetus to the need for the present study. It is anticipated that fuller embrace of EC2 as well as other ECs will have some impact on the design of all types of structures on the African continent. Consequently, it is essential to publish the results of research and other data that narrow and focus on the scope of the new design methods on specific structural elements that practicing are directly involved with. Hence a design aided investigation and comparative study is necessary to highlight points of convergence and difference between EC2 and BS8110.

The purpose of this research work is to compare the cost and ease of use between BS8110 and Eurocode 2 in reinforced concrete design. This will be accomplished by carrying out a reinforced concrete design of a 2-storey building with the use of BS 8110 and Eurocode 2 respectively, investigating and comparing the efficiency in carrying out reinforced concrete design using British Standard, (Structural use of concrete) with Eurocode (Design of concrete structures) and verifying the more cost effective and time saving of the two methods of design, Eurocode2 and BS-code.

2. Materials and Method

Method and Building details

The BS8110 and EC2 are based on the limit state design philosophy. The analysis for design are given separately for each structural elements designed. These elements are slabs, beams, column and foundation of a decent two storey office complex which is 3m high from slab surface to slab surface for each floor. The floor plan is shown in figure 1 below. The critical panel of the slab was designed, a continuous beam, a column and a pad footing were also designed in suitable sizes using both codes. The focus during the design was on the similarities and differences between the BS code and Eurocode for each structural element.

Structural analysis

Structural analysis was done to obtain the internal moments and forces all through the structural element that are in unison with the design loads for the required loading combinations.

For the slab, the loading combinations are dead load which include self-weight (weight of concrete), partition, services, finishes and added dead load (masonry walls, etc.) in KN/m^2. The appropriate live load based on the use of the building is selected from the appropriate codes. Afterwards the total slab load is calculated as given in the codes. Then slab is analysed by using moment coefficients given in the relevant tables.

For the beam, the load from slabs are transferred to the beam using the method given in table 63 of Reinforced concrete designers manual by Reynolds et al. the beam self-weight and wall load (if applicable) are added. The beam is then analysed for different load cases as prescribed by the code to obtain the bending moment and shear force. Under design ultimate loads, any implied redistribution of forces and moments should be compatible with the ductility of the members concerned (Nwoji and Ugwu, 2017).

For the column load combination, the total load from the beam acting on the column as well as the column own load to get the overall load take-down(N). The load take-down (N) and moment (M) are then evaluated for the most critical load combination. The combination of biaxial load and moment is used for the study. While for the foundation, the load take-down to the footing supporting the column is calculated both ultimate and service load. The service load is used to size the pad plan section while the ultimate load is used in the section design.

Table 1: Some Design Terms in BS8110 and EC2

Parameters	BS 8110	EC 2
Ultimate moment	$M_u = 0.156fcubd^2$	$M_{Rd} = 0.167f_{ck}bd^2$
Area of tension reinforcement	As = M/0.95 fyZ	Asl = M/0.87fykZ
Lever arm	z = d[0.5 (0.25-K/0.9)] Where $K = M/f_{cu}bd^2$	z = d[0.5 (0.25-3K_o/3.4)] where $K_o = M/f_{ck}bd^2$
Area of compression reinforcement	Ac = M-M_u/0.95fy (d-d^1)	As_2 = M-M_{Rd}/0.87fyk (d-d_2)

The structure considered is a Single storey office building located in Akure, Ondo states South Western Nigeria.

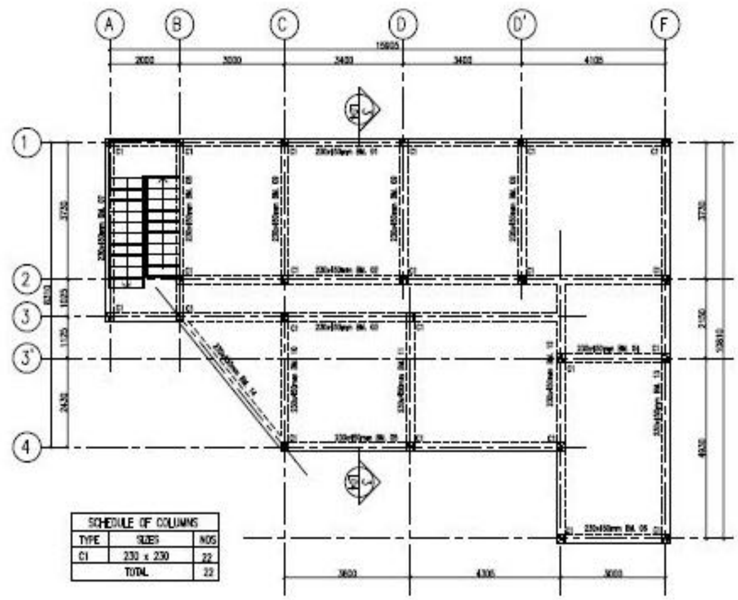


Figure 1: Structural plan of an Office complex located at Akure, Ondo State, Nigeria.

3. Result

Slab

Table 2 below gives the summary of the loading and analysis of the critical panel of the slab.

Table 2: Summary of Loading and Analysis

	Loading (KN/m^2)	Moments (KNm)
BS8110	14.28	11.13
EC2	14.19	11.06
% difference	0.63	0.63

Beam

A summary of the beam from the slab load above and the beam own load as well as the span moments is shown in Table 3 while Figure 2 below gives the summary of the shears along the continuous beam.

Table 3: Differences in beam loading and moment.

	Loading (KN)			Moments (KNm)		
Span	BS8110	EC2	% difference	BS8110	EC2	% difference
2 – 1	44.67	43.54	2.53	58.16	78.89	-35.64
3 – 2	40.78	39.81	2.38	48.13	49.97	-3.82
4 – 3	49.55	43.54	12.13	98.81	94.04	4.83

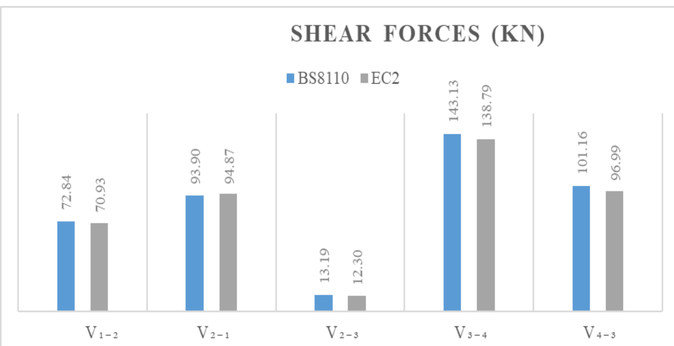


Figure 2: Difference in Shears along the continuous Beam.

Column

Table 4 shows the difference in column load (kN) for each floor level while table 5 gives a summary of biaxial loading on column and bending moments for both codes.

Table 4: Column load (kN) for BS 81110 and EC2

	BS8110 (KN)	EC2 (KN)	% Difference
2nd Floor – Roof level	63.34	65.23	-2.98
1st Floor – 2nd Floor	199.86	199.11	0.38
Ground Floor – 1st Floor	331.38	261.40	21.12

Table 5: Biaxial loading on column and bending moments for both codes.

	Loading			Moments (KNm)		
Section	BS8110	EC2	% Difference	BS8110	EC2	% Difference
X – X	19.03	18.82	1.10	19.07	11.63	39.01
Y –Y	17.92	21.16	-18.08	11.76	13.07	-11.14

Foundation

The chart below shows the differences in design load, moment and shear force for both codes.

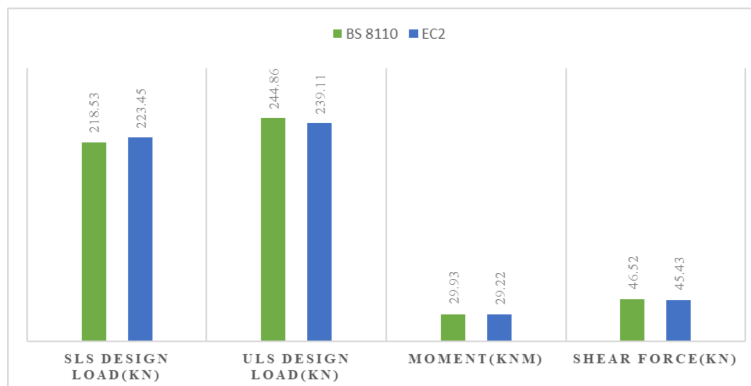
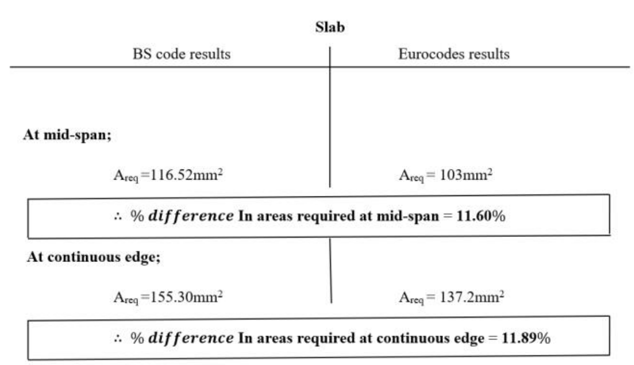


Figure 3: Differences in design load, moment and shear forces for BS code and Eurocode.

Area of steel requirement



As can be observed, the % $difference$ at both span is about 12%

Beam (F)

BS code results	Eurocodes results
For span 4-3;	
A_{req} =661mm^2	A_{req} = 563.27mm^2

∴ % $difference$ **In areas required for the span 4-3 = 14.70%**

BS code results	Eurocodes results
At support 3;	
A_{req} =764.5mm^2	A_{req} = 650.90mm^2

∴ % $difference$ **In areas required at continuous edge = 14.86%**

Also, the % difference in the required areas at the span and the support is about 15% for the same beam **F**

Column F1

BS code results	Eurocodes results
A_{req} = 470.81mm^2	A_{req} = 396.75mm^2

∴ % $difference$ **In areas required = 15.57%**

Similarly, the % difference in the required areas for the same column **F1** being about 16%.

Foundation

BTA

BS code results	Eurocodes results
At mid-span;	
A_{req} = 253.56mm^2	A_{req} = 185mm^2

∴ % $difference$ **In areas required = 27.03%**

Similarly, the % difference in the required areas for the same footing (BTA) being about 27%.

Discussion

It can be seen from the Tables 1 – 4 that the BS8110 gave higher values for the loading and even in the moment except for the moments along the span of the continuous beam. This is as a result of the different method of evaluating design load adopted by both codes. This includes the difference in partial factor of safety to loads at the ultimate limit state. This difference is presented in Table 6 below. One of the reasons for that is the difference in steel strength adopted by both codes.

Table 6: Partial factor of safety for limit state loading

Span	BS8110	EC2
Loaded span	1.4DL+ 1.6LL	1.35DL + 1.5LL
Unloaded span	1.0DL	1.35DL

There are obviously many more differences between these two codes in design philosophy which resulted to the differences in design calculations. Some significant differences between EC2 and BS 8110 are identified and explained as below:

1. The Loads in BS 8110 have been replaced by Actions in EC 2. Similarly, in EC 2, dead and live loads in BS 8110 are now permanent actions and variable actions. Bending moments and shear forces in BS 8110 have been replaced by internal moments and internal stresses in EC 2.

2. The British Standard (BS 8110) includes separate chapters on the design of beams, slabs, columns, and bases, among other things. However, the Eurocode (EC 2) classifies the material based on structural action, such as bending, shear, deflection, torsion, and so on, which can apply to any element.

3. It can also be observed that the Eurocode gave lesser values from steel requirement for all structural elements. Unlike BS 8110, the design rules in EC 2 apply to steel reinforcement with a characteristic yield strength of 400 - 600 N/mm2. EC 2 prohibits the use of round mild steel with a characteristic strength of 250 N/mm2 that was useful in BS 8110.

4. BS 8110 is based on characteristic cube strength, whereas EC 2 is based on characteristic cylinder strength at 28 days. In general, cylinder strength is about 0.8 times cube strength.

5. The partial factor for ultimate limit states in EC 2 has a single value of 1.5, whereas in BS 8110, it is usually determined by the stress type under consideration.

Conclusion

With strict adherence to the BS8110 and EC2, the various parts of the structure were designed to achieve a stable structure and from the obtained results of the selected parts designed with the Eurocodes and compared with the respective parts designed with the British Standard, it was observed that both methods are limit state methods and that many of the Eurocode rules are based on the same principle as the British Standards. However, Eurocodes embody the most recent research on many areas of structural behavior which is a way of simulating innovation in that their clauses are structured in a slightly different way.

Both methods are very okay as the differences in the obtained results were very slight or minimal but for economic purpose, the use of Eurocode should be encouraged as it is more up to date in research, more extensive and less restrictive.

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