



## Improving Efficiency of Steel Use in Reinforced Concrete Buildings in Nigeria: A Case Study of a Building in Abuja

Imran Rufai<sup>1</sup>, Muhammad Sani Aminu<sup>2</sup>

<sup>1</sup>Department of Civil Engineering, Baze University, Abuja, Nigeria

<sup>2</sup>Department of Engineering and Image Processing,  
National Space Research and Development Agency, Kano, Nigeria

### ABSTRACT

Reinforced concrete is one of the world's major types of structural frames. In Nigeria, it is by far the most popular. There have been growing concerns over the cost of reinforced concrete structures; both financially, and to the environment. By all accounts, it is desirable to reduce the use of material, wherever possible. Steel is the major structural component of reinforced concrete, so it is especially important to scrutinise its use. Recognising that construction practices vary widely, a case study of a typical building structure in Abuja, Nigeria, has been carried out. The structural calculations and drawings of the as-built structure were obtained and subjected to scrutiny. With the aid of the software, Protastructures 2018, it was found that up to 29% of the steel could be saved with a slightly modified design. The key savings were in slabs, where 10mm reinforcement was found sufficient for most cases; and then in the link in both beams and columns, where 8mm links were found sufficient. It was found that employing extra labour for better quality control is cheaper than the overly conservative design practices currently widespread in Nigeria. Hence, there is a lot of room in Nigeria for more efficient designs, which could save a large amount of material, cost less, be more environmentally friendly, and employ more labour.

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### INTRODUCTION

Reinforced concrete (RC) is one of the most widely used structural frames in the world. Its annual production globally is more than 10 billion cubic meters [1]. RC consumes significant amounts of natural resources and hence contributes considerably to the pollution of the environment [2]. Concrete and steel reinforcement are the major constituents contributing to the total weight of RC structures. Therefore, attempts have been made internationally in the past few decades to optimize different kinds of RC structures and RC components, aiming to minimize the demand for concrete and steel reinforcement as exhaustively documented by [3]. However, construction is an industry where each locale has its distinct prevalent practices, so there is a need to study each locale to provide tailor-made solutions. Of the 348 studies reviewed in [3], not

one of them involved a study of construction in Nigeria.

The aforementioned problems are prevalent in Nigeria, with the problem of high construction costs especially becoming prominent [4-6]. Accompanying effects such as cost overruns often cause rifts between project management consultants, owners, and contractors [7]. At least part has been attributed to the improper design of structures. [8] explored how poor designs, unrealistic contract durations, lack of experience, inadequate planning and scheduling, poor site management and supervision and mistakes during construction as the most significant factors leading to construction cost overruns.

Several studies have been made on the causes of high costs of construction in Nigeria, as by [4, 8-11] but these studies have not researched the technical aspects of the reinforced concrete design of these structures. The cost of building

materials in the total expenditure on housing constitutes about 60% [12]. This further buttresses the importance of a proper reinforced concrete design in cost savings. Our aim in this study is to undertake an investigation on the structural design of a typical building in Nigeria and look for structural design inefficiencies that may lead to high construction costs, whilst maintaining structural integrity. To achieve this, a case study of a building that has been built in Abuja, Nigeria's capital, has been carried out. The structural design of the building is compared to a more optimum design, and the material cost savings are computed.

### Description of Building

The structure under investigation is a 3-storey (2 suspended floors) reinforced concrete building in Abuja, Nigeria. It has undergone all necessary regulatory checks, and several units of it have already been built. Both suspended floors have the same plan, which is shown in figure 2.1. The roof plan is shown in Figure 2.2. The structure is symmetrical about the middle, between axes 10 and 11.

The following are the dimensions of the structural elements as designed and built:

1. 16 slab panels are 150mm thick, while 12 panels are 175mm thick.
2. All beams in the suspended floors are 230 x 450 mm, as is common practice in Nigeria.
3. All roof beams are 230 x 300 mm.
4. All columns are 230 x 230 mm and floor to floor heights are 3m.

The following were the working assumptions of the structural design:

1. Permanent Floor Load = 2 kN/m<sup>2</sup>
2. Imposed Floor Load = 1.5 kN/m<sup>2</sup>
3. Wall Loading on all beams = 9.37 kN/m
4. Characteristic Steel Strength,  $f_{yk} = 460$  MPa
5. Characteristic Concrete Cube Strength,  $f_{ck} = 20$  MPa
6. Slab Cover = 20mm
7. Beam Cover = 25mm
8. Column Cover = 25mm

The British Standards were used to design the structure.

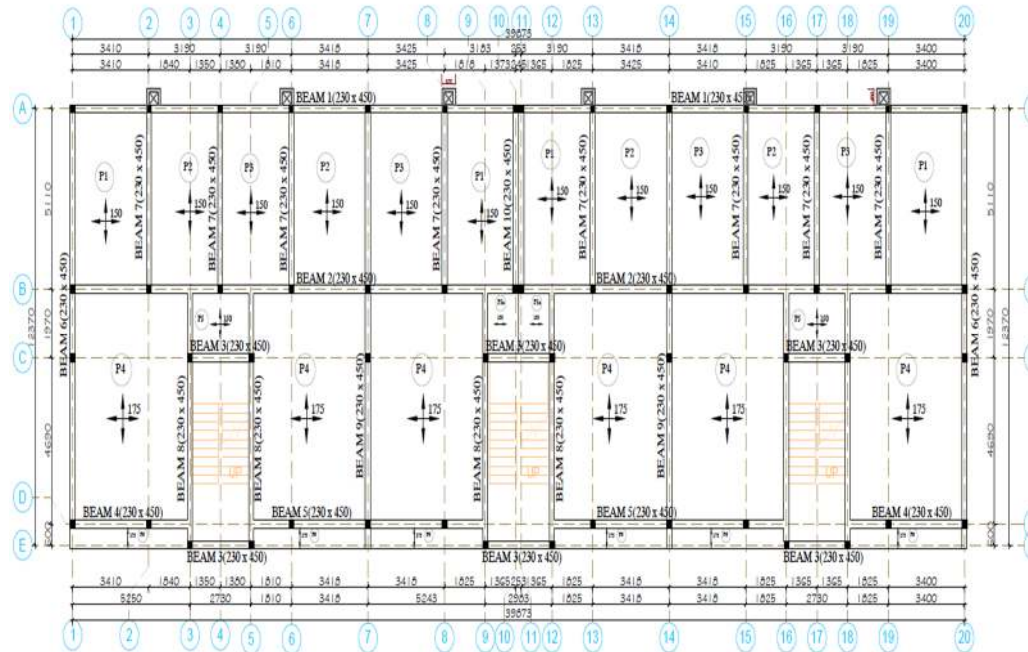


Figure 2.1: Plan for both suspended floors of the building. All dimensions are in millimetres.

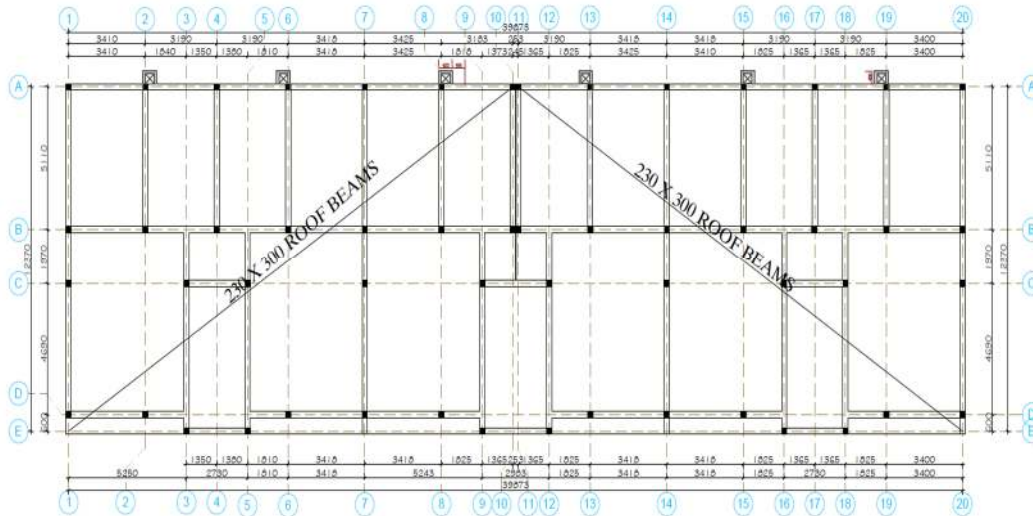


Figure 2.2 Roof Plan. All dimensions are in millimetres.

### METHODOLOGY

Structural calculations and drawings were obtained for the 3-storey building described above. The structure was originally designed using the software CSC Orion 18. For the study, the structural layout, elemental details and loading conditions of the building were recreated on

ProtaStructure 2018, a software closely resembling Orion 18. The model is shown in Figure 3.1. Structural design results for all elements were obtained which matched those obtained by the building's original designers. After this, the process of trying to get a more optimum design was begun.

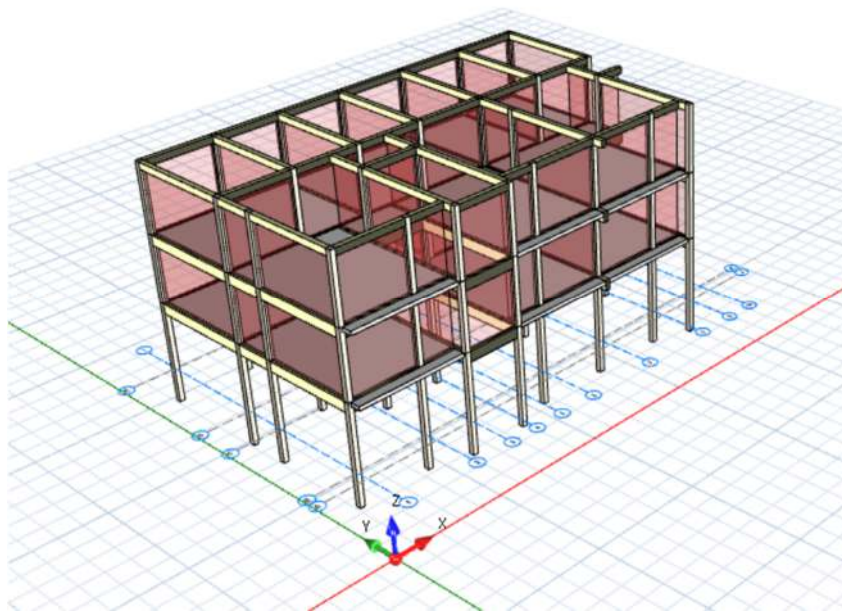


Figure 3.1: A completed model of the building's superstructure. Due to symmetry, only half of the building is shown.



Firstly, the Eurocode was used to redesign the structure. The Eurocode is known to be slightly more economical than the British Standards [13]. The steel reinforcement for all members was then progressively reduced until the most efficient amount of steel allowable by the Eurocode was obtained. For constructability purposes, these bar sizes and spaces were then modified to conform to best practices using [14]. These bar sizes and spacings are:

1. Slabs: Minimum diameter of 10mm and minimum spacing of 250mm
2. Beams: Minimum longitudinal bar diameter of 12mm

3. Beams: Minimum link diameter of 8mm and maximum link spacing of 300mm
4. Columns: Minimum longitudinal diameter of 16mm
5. Columns: Minimum link diameter of 8mm and maximum link spacing of 230mm.

The more efficient amounts of steel obtained were then compared to those of the original design. The total weight of steel in the original and modified design was then tabulated and compared. The working assumptions of the comparison are shown in Table 3.1.

**Table 3.1:** Mass [15] and Costs of Steel Bars in Abuja<sup>1</sup>

Reinforcement Diameter (mm)	Mass (kg/m)	Cost/tonne (Naira)
8	0.395	450,000
10	0.617	450,000
12	0.889	450,000
16	1.58	450,000

## RESULTS AND DISCUSSION

### Slabs

The results of the slab analysis and design are shown in Table 4.1. The original total amount of reinforcement used is 15.43 tonnes, but the more optimised result shows a total of 9.54 tonnes. The major difference is primarily due to the use of 10mm bars wherever applicable in this study, as opposed to 12mm reinforcement used

throughout the slab members as built. Figure 4.2 shows a sample of the detailed design differences between the two designs. It can be seen that even taking the original design alone, 452 mm<sup>2</sup> was provided in cases where 221 mm<sup>2</sup> and 226 mm<sup>2</sup> was required. Thus, the provided area is over 100% more than the required area, which, to say the least, is wasteful.



**Table 4.1: Slab Design Results**

Constructed Building Details (Slabs)					Optimised Building Details (Slabs)				
Reinforcement	Number	Length (m)	kg/metre	Mass (kg)	Reinforcement	Number	Length (m)	kg/metre	Mass (kg)
12mm @ 200	400	7.52	0.889	2674.11	10mm @ 250	324	7.52	0.617	1503.31
12mm @ 250	192	4.44	0.889	757.85	10mm @ 250	192	4.44	0.617	525.98
12mm @ 250	320	1.54	0.889	438.10	10mm @ 250	320	1.54	0.617	304.06
12mm @ 250	36	1.54	0.889	49.29	10mm @ 250	36	1.54	0.617	34.21
12mm @ 250	28	3.38	0.889	84.13	10mm @ 250	28	3.38	0.617	58.39
12mm @ 250	144	6.76	0.889	865.39	10mm @ 250	144	6.76	0.617	600.61
12mm @ 200	312	9.56	0.889	2651.64	10mm @ 250	240	9.56	0.617	1415.64
12mm @ 250	252	1.16	0.889	259.87	10mm @ 250	252	1.16	0.617	180.36
12mm @ 200	104	8.4	0.889	776.63	10mm @ 250	80	8.4	0.617	414.62
12mm @ 250	40	6.86	0.889	243.94	12mm @ 250	36	6.86	0.889	219.55
12mm @ 250	108	7.92	0.889	760.42	12mm @ 250	68	7.92	0.889	478.78
12mm @ 250	40	3.86	0.889	137.26	10mm @ 250	40	3.86	0.617	95.26
12mm @ 250	104	7.33	0.889	677.70	10mm @ 250	80	7.33	0.617	361.81
12mm @ 250	40	5.21	0.889	185.27	12mm @ 250	36	5.21	0.889	166.74
12mm @ 200	108	6.47	0.889	621.20	12mm @ 250	68	6.47	0.889	391.12
12mm @ 250	108	8.89	0.889	853.55	10mm @ 250	80	8.89	0.617	438.81
12mm @ 200	40	5.21	0.889	185.27	12mm @ 250	36	5.21	0.889	166.74
12mm @ 250	108	6.47	0.889	621.20	12mm @ 250	68	6.47	0.889	391.12
12mm @ 250	40	2.8	0.889	99.57	10mm @ 250	40	2.8	0.617	69.10
12mm @ 250	48	2.7	0.889	115.21	10mm @ 250	48	2.7	0.617	79.96
12mm @ 250	84	1.74	0.889	129.94	10mm @ 250	84	1.74	0.617	90.18
12mm @ 250	64	4.44	0.889	252.62	12mm @ 250	64	4.44	0.617	175.33
12mm @ 250	28	1.35	0.889	33.60	12mm @ 250	28	1.35	0.617	23.32
12mm @ 250	48	2.51	0.889	107.11	10mm @ 250	48	2.51	0.617	74.34
12mm @ 250	84	1.74	0.889	129.94	10mm @ 250	84	1.74	0.617	90.18
12mm @ 250	16	2.12	0.889	30.15	12mm @ 250	16	2.12	0.617	20.93
12mm @ 250	28	0.97	0.889	24.15	12mm @ 250	28	0.97	0.617	16.76
12mm @ 250	48	2.51	0.889	107.11	10mm @ 250	48	2.51	0.617	74.34
12mm @ 250	84	1.83	0.889	136.66	12mm @ 250	84	1.83	0.617	94.85
12mm @ 250	48	2.8	0.889	119.48	12mm @ 250	48	2.8	0.617	82.92
12mm @ 250	64	4.44	0.889	252.62	10mm @ 250	64	4.44	0.617	175.33
12mm @ 250	200	2.12	0.889	376.94	10mm @ 250	200	2.12	0.617	261.61
12mm @ 250	64	4.54	0.889	258.31	10mm @ 250	64	4.54	0.617	179.28
12mm @ 250	48	2.8	0.889	119.48	12mm @ 250	48	2.8	0.617	82.92
12mm @ 250	84	1.74	0.889	129.94	12mm @ 250	84	1.74	0.617	90.18
12mm @ 250	48	2.7	0.889	115.21	10mm @ 250	48	2.7	0.617	79.96
12mm @ 250	32	1.16	0.889	33.00	10mm @ 250	32	1.16	0.617	22.90
12mm @ 250	16	1.16	0.889	16.50	12mm @ 250	16	1.16	0.617	11.45
<b>Total Mass (kg)</b>				<b>15,430.34</b>	<b>Total Mass (kg)</b>				<b>9,542.97</b>
Mass (Tonnes)				15.43	Mass (Tonnes)				9.54
Cost per tonne (N)				450,000	Cost per tonne (N)				450,000
<b>Total Cost (N)</b>				<b>6,943,652</b>	<b>Total Cost (N)</b>				<b>4,294,337</b>

**Table 4.2: Sample detailed design differences between the original and optimised design of slab**

Design Type	Slab Strip	Type	d/h	g	L1	L2	C-sup	M-sup	C-span	M-span	Req/Sup	As	STEEL BARS
		(mm)	(mm)	(kN/m <sup>2</sup> )	(mm)	(mm)	(kN.m)	(kN.m)	(kN.m)	(kN.m)	(mm <sup>2</sup> )	(mm <sup>2</sup> )	
Original Design	Y5 -- Storey: 1												
	IS1A	6	112/150	5.600	5110.00	3190.00	0.0000	1.1	0.0440	162.36/214.16	221.4/452.39	221.4/452.39	Top:T12-250(T1) Bottom: T12-250(B2)
													Support Mc = 0.75Support As = 226.19/452.39 Support Mc = 8.1Support As = 226.19/452.39
Optimised Design	Y8 -- Storey: 1												
	IS1A	4	110/150	5.600	5110.00	3190.10	0.0450	4.5	0.0240	162.36/214.16	162.36/214.16	162.36/214.16	SupTop: T10- StrBot: T10-
													Support Mc = 0.55Support As = 162.36/214.16



### Beams

The total reinforcement used in the original design for beams is 9.95 tonnes, as opposed to 7.76 tonnes obtained in this study, as shown in Table 4.3. The difference in reinforcement is less than that obtained in slabs because in many cases, the reinforcement diameter of 16mm longitudinal reinforcement used in the original design was optimal. The only fairly consistent source of reduction in usage is shear links, where 8mm links at 300mm spacing are

used in the optimised structure in all but one instance, while 10mm links at 200mm spacing were used throughout in the original structure. Figure 4.1 shows a sample - Beam 7 in the original design - of the structural design of both sets of design. It should be noted that even though 300mm link spacing was calculated in the original design, 200mm spacing was used in the drawings as shown in Figure 4.2, probably as a safety precaution. This, however, leads to an unnecessarily less optimal design.

**Table 4.3: Beam Design Results**

Constructed Building Details (Beams)							Optimised Building Details (Beams)						
Beam	Diameter (mm)	Type	Quantity	Length(m)	kg/metre	Weight (kg)	Diameter(mm)	Type	Quantity	Length(m)	kg/metre	Weight (kg)	
Beam 1	10	Links	408	1.2	0.617	302.08	8	Links	272	1.2	0.395	128.93	
	16	Bottom	12	20.2	1.58	382.99	12	Bottom	12	20.2	0.889	215.49	
	16	Top Long	8	20.2	1.58	255.33	12	Top Long	8	20.2	0.889	143.66	
	16	Top Short	20	1.6	1.58	50.56	12	Top Short	20	1.6	0.889	28.45	
Beam 2	10	Links	408	1.2	0.617	302.08	8	Links	272	1.2	0.395	128.93	
	16	Top & Bot	24	20.2	1.58	765.98	12	Top & Bot	24	20.2	0.889	430.99	
Beam 3	10	Links	56	1.2	0.617	41.46	8	Links	40	1.2	0.395	18.96	
	16	Top & Bot	16	3.1	1.58	79.13	12	Top & Bot	20	3.1	0.889	55.65	
Beam 4	10	Links	136	1.2	0.617	100.69	8	Links	76	1.2	0.395	36.02	
	16	Top & Bot	20	5.7	1.58	178.54	12	Top & Bot	24	5.7	0.889	120.55	
	16	Top	8	2.84	1.58	35.90	12	Top	8	2.84	0.889	20.20	
Beam 5	10	Links	272	1.2	0.617	201.39	8	Links	144	1.2	0.395	68.26	
	16	Top & Bot	24	10.9	1.58	413.63	12	Top & Bot	20	10.9	0.889	193.94	
	16	Top	8	7.28	1.58	92.02	12	Top	8	7.28	0.889	51.78	
Beam 6	10	Links	240	1.2	0.617	177.70	8	Links	164	1.2	0.395	77.74	
	16	Top & Bot	20	12.2	1.58	384.57	16	Top & Bot	20	12.2	1.58	384.57	
	16	Bot	4	5.31	1.58	33.56	16	Bot	4	5.31	1.58	33.56	
	16	Top	8	4.37	1.58	55.24	16	Top	8	4.37	1.58	55.24	
Beam 7 (x4)	10	Links	104	1.2	0.617	308.01	16	Top & Bot	20	5.31	1.58	33.56	
	16	Top & Bot	28	5.5	1.58	975.05	8	Links	72	1.2	0.395	136.51	
	10	Links	148	1.2	0.617	328.74	16	Top & Bot	28	5.5	1.58	975.05	
Beam 8 (x3)	10	Links	20	7.66	1.58	726.17	8	Links	104	1.2	0.617	231.00	
	16	Top & Bot	8	5.27	1.58	199.84	16	Top & Bot	20	7.66	1.58	726.17	
	16	Top	8	5.27	1.58	199.84	16	Top	8	5.27	1.58	199.84	
Beam 9	10	Links	252	1.2	0.617	186.58	10	Links	252	1.2	0.617	186.58	
	20	Top & Bot	20	12.77	2.47	630.84	20	Top & Bot	20	12.77	2.47	630.84	
	20	Bot	4	5.31	2.47	52.46	20	Bot	4	5.31	2.47	52.46	
	20	Top	8	4.37	2.47	86.35	20	Top	8	4.37	2.47	86.35	
	20	Top	4	1.95	2.47	19.27	20	Top	4	1.95	2.47	19.27	
Beam 10	10	Links	104	1.2	0.617	77.00	8	Links	76	1.2	0.395	36.02	
	16	Top & Bot	20	5.51	1.58	174.12	16	Top & Bot	20	5.51	1.58	174.12	
Roof	10	Links	902	1.06	0.617	589.92604	8	Links	451	2.12	0.395	377.67	
	16	Top and Bot	8	134.96	1.58	1705.894	16	Top and Bot	4	269.92	1.58	1705.89	
						<b>Total Mass (kg)</b>							<b>Total Mass (kg)</b>
						9,946.65							7,764.24
						Mass (Tonnes)							7.76
						450,000							450,000
						<b>Total Cost (N)</b>							<b>Total Cost (N)</b>
						4,475,993							3,493,909

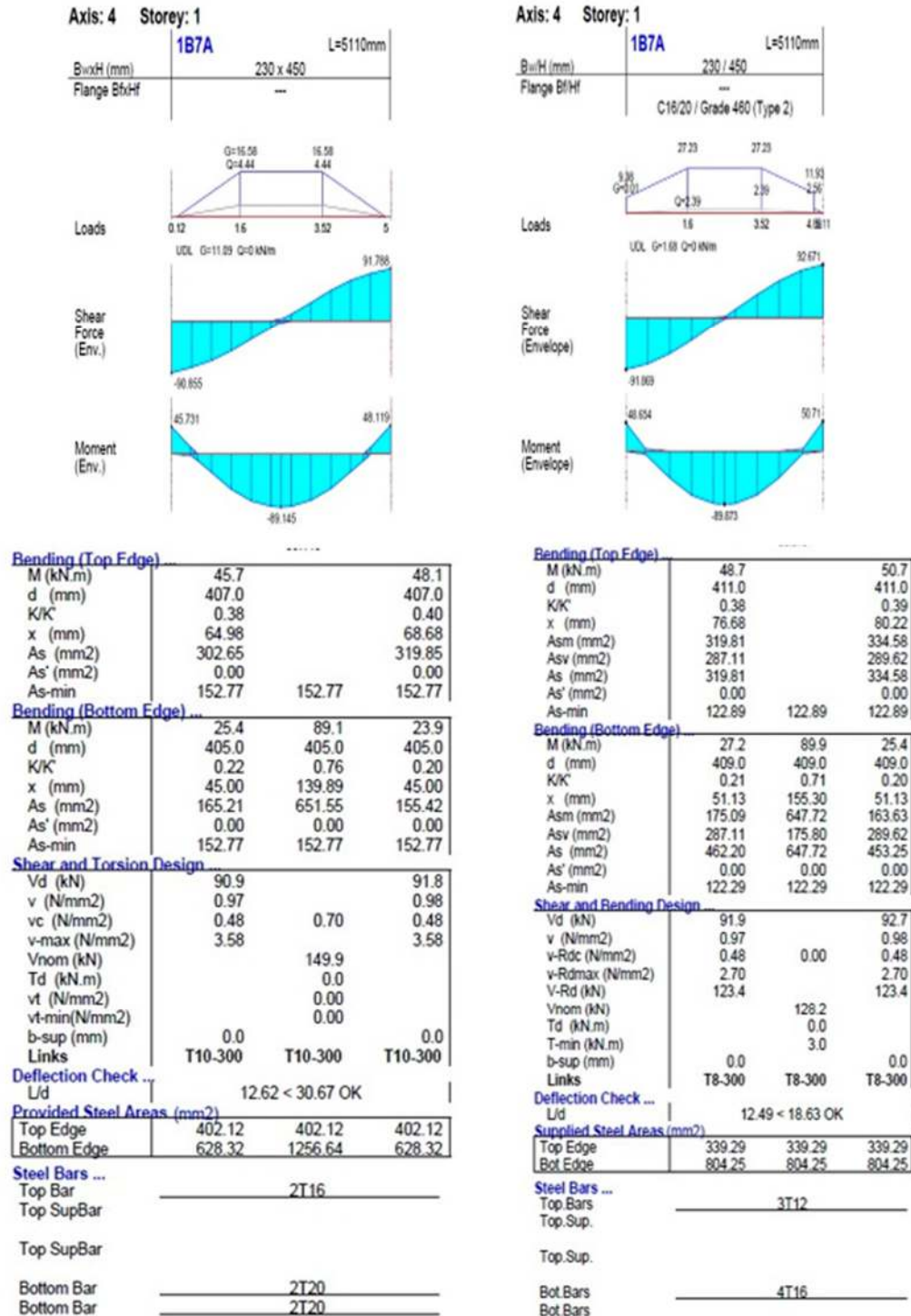


Figure 4.1: Original design (left) and more optimal design (right) of Beam 7

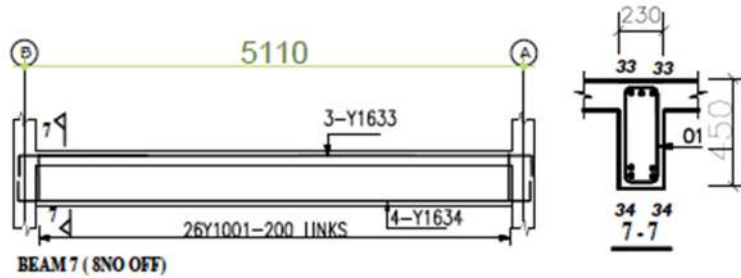


Figure 4.2: Original Provided Drawings of Beam 7

**Columns**

Savings are much less in column design. This is primarily due to the observance of the rule in [14], that the longitudinal reinforcement should be a minimum of 16mm. However,

reductions in the link spacing were found, with 10mm links at spacings of 175mm reduced to 8mm spacing at 225mm in all cases. Table 4.4 shows the column design results and the sample design is shown in Figure 4.3.

Table 4.4: Column Design Results

Constructed Building Details (Columns)							Constructed Building Details (Columns)						
Type	Diameter (mm)	Quantity	Length(m)	kg/metre	Weight (kg)		Type	Diameter (mm)	Quantity	Length(m)	kg/metre	Weight (kg)	
Column C1	Links	y10	60	0.92	0.617	34.0584	Column C1	Links	y8	46	0.92	0.395	16.7164
	Longitudinal	y16	4	11.1	1.58	70.152		Longitudinal	y16	4	11.1	1.58	70.152
	Longitudinal	y16	2	5.6	1.58	17.696		Longitudinal	y16	2	5.6	1.58	17.696
						Total (kg)		121.91					
					Number of C1	26						Number of C1	26
					Total of C1 (kg)	3,169.57						Total of C1 (kg)	2,718.67
Column C2	Type	Diameter (mm)	Quantity	Length(m)	kg/metre	Weight (kg)	Column C2	Type	Diameter (mm)	Quantity	Length(m)	kg/metre	Weight (kg)
	Links	y10	60	0.92	0.617	34.0584		Links	y8	46	0.92	0.395	16.7164
	Longitudinal	y16	4	11.1	1.58	70.152		Longitudinal	y16	4	11.1	1.58	70.152
						Total (kg)		104.21					
					Number of C2	28						Number of C2	28
					Total of C2 (kg)	2,917.89						Total of C2 (kg)	2,432.32
					<b>Total Mass (kg)</b>	<b>6,087.46</b>						<b>Total Mass (kg)</b>	<b>5,150.99</b>
					Mass (Tonnes)	6.09						Mass (Tonnes)	5.15
					Cost per tonne (N)	450,000						Cost per tonne (N)	450,000
					<b>Total Cost (N)</b>	<b>2,739,356</b>						<b>Total Cost (N)</b>	<b>2,317,945</b>

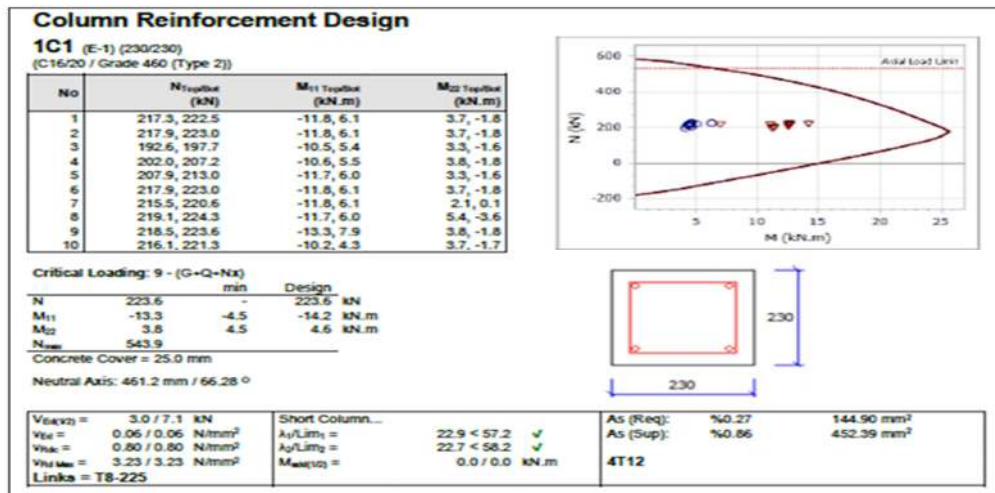


Figure 4.3: Sample optimum structural design of column





## CONCLUSIONS AND RECOMMENDATIONS

The analysis and computations above show remarkable savings from the original design. Table 5.1 below summarises these savings. A total saving of 29% was recorded for the superstructure, which is a considerable reduction. The greatest savings are from simply using 10mm reinforcement as longitudinal reinforcement in

slabs, instead of 12mm. Following this is the use of links in beams and columns, where 8mm links were found sufficient at spacings of 300mm and 230mm, instead of 10mm at 200 and 175 spacing respectively. The key achievement of this study is the observation and quantification of these simple issues which lead to the ballooning of costs.

**Table 5.1:** Summary of Design Result Differences

Element	Total Mass (t) (Designed)	Total Mass (t) (Optimised)	Total Mass Savings (t)	Cost Savings (N)	Percentage Savings
Slabs	15.43	9.54	5.89	2,649,315.33	38%
Beams	9.95	7.76	2.18	982,084.19	22%
Columns	6.09	5.15	0.94	421,410.60	15%
<b>Total Structure</b>	<b>31.46</b>	<b>22.46</b>	<b>9.01</b>	<b>4,052,810.12</b>	<b>29%</b>

Note: Costs are based on N450,000 per tonne of reinforcement

It is noted that engineers in Nigeria have good reasons for such extremely conservative designs. They include uncertainties with regards to actual rebar diameter, and rebar characteristic strength [16]. For this reason, there are caveats with implementing changes due to this study. These include:

1. Reinforcement must be checked to ensure its diameter is as specified.
2. Reinforcement to be used on-site must be tested to ensure its characteristic strength is at least as the figure assumed on the design.
3. Extra care must be taken on-site to ensure reinforcement is correctly placed.
4. Extra care must be taken on-site to ensure concrete mixes are of specified quality.
5. Member dimensions must conform to those assumed on the design.

All of these caveats could be reasonably met by the employment on-site of a single extra quality assurance engineer. With a site engineer's average salary of N107,000, a month [17] for ten months - a conservative duration for this project - that still works out to a cost saving of almost N3,000,000 (20%) from the reinforcement cost of this project. It is quite clear that a much more optimal design can be achieved, which is Eurocode compliant, cheaper, and employs more labour on site. It would even be faster, given that less material would be required.

## REFERENCES

- [1] S. Miller, A. Horvath and P. Monteiro, "Readily implementable techniques can cut annual CO<sub>2</sub> emissions from the production of concrete by over 20%", *Environmental Research Letters*, vol. 11, no. 7, p. 074029, 2016. Available: 10.1088/1748-9326/11/7/074029.
- [2] H. Van Damme, "Concrete material science: Past, present, and future innovations", *Cement and Concrete Research*, vol. 112, pp. 5-24, 2018. Available: 10.1016/j.cemconres.2018.05.002.
- [3] M. Afzal, Y. Liu, J. Cheng and V. Gan, "Reinforced concrete structural design optimization: A critical review", *Journal of Cleaner Production*, vol. 260, p. 120623, 2020. Available: 10.1016/j.jclepro.2020.120623.
- [4] D. Okpala and A. Aniekwu, "Causes of high costs of construction in Nigeria. Journal of construction engineering and management", *ASCE*, vol. 114, no. 1, pp. 233-234, 1988.
- [5] O. A. and R. D., "Infrastructure Delay and Cost Escalations: Causes and Effects in Nigeria.", in *Sixth international postgraduate research conference*, Delft University of Technology and TNO, 2006.
- [6] A. Elinwa and S. Buba, "Construction Cost Factors in Nigeria", *Journal of Construction Engineering and Management*, vol. 119, no. 4, pp. 698-713, 1993. Available: 10.1061/(ASCE)0733-9364(1993)119:4(698).



- [7] S. Murali and s. Yau, "Causes and effects of delays in the Malaysian construction industry", *International Journal of Project Management*, vol. 25, pp. 517-526, 2007. Available: 10.1016/j.ijproman.2006.11.007.
- [8] M. A.H., R. I.A and A. A.A., "Preliminary study on causative factors leading to construction cost overruns", *International Journal of Sustainable Construction Engineering and Technology*, vol. 2, no. 1, pp. 57-71, 2011.
- [9] P. Olayeni, P. Lawal and L. Amusan, "Developing Infrastructure in Nigeria: Why is the Cost so High?", *Mediterranean Journal of Social Sciences*, vol. 3, no. 11, 2022.
- [10] O. Aje, K. Odusami and D. Ogunyemi, "The impact of contractors' management capability on cost and time performance of construction projects in Nigeria", 2022.
- [11] G. Ojo and S. Odediran, "Significance of Construction Cost Estimating Risks in Nigeria", *International Journal of Civil Engineering and Construction Science*, vol. 2, no. 1, pp. 1-8, 2015.
- [12] A. Olotuah, "Recourse to earth for low-cost housing in Nigeria", *Building and Environment*, vol. 37, no. 1, pp. 123-129, 2002. Available: 10.1016/s0360-1323(00)00081-0.
- [13] T. Nwofor, S. Sule and D. BUDU Eme, "A comparative study of BS8110 and Eurocode 2 standards for the design of a continuous reinforced concrete beam", *International Journal of Civil Engineering and Technology*, vol. 6, no. 5, pp. 76-84, 2015.
- [14] B. Cresswell Riol, *Standard Method of Detailing Structural Concrete*, 3rd ed. London: Institution of Structural Engineers, 2007.
- [15] "Steel weight and unit weight of steel bars", Civil Guide, 2021. [Online]. Available: <https://civilsguide.com/what-is-the-unit-weight-of-steel-bars/>.
- [16] G. Bamigboye, O. Olaniyi, D. Olukanni, A. Ede and I. Akinwumi, "Diameter Inconsistency, Strength and Corrosion Characteristics of Locally-Produced and Imported Steel Reinforcing Bars in Ilorin, Nigeria", *International Journal of Engineering Research in Africa*, vol. 29, pp. 90-97, 2017. Available: 10.4028/www.scientific.net/jera.29.90.
- [17] "Civil Engineer Salary in Nigeria | PayScale", *Payscale.com*, 2022. [Online]. Available: [https://www.payscale.com/research/NG/Job=Civil\\_Engineer/Salary](https://www.payscale.com/research/NG/Job=Civil_Engineer/Salary).