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Analysis and Design of Building's Structural Members (Slabs and Beams) using Microsoft Excel and AUTOCAD Software: A Case Study of MARCGSO' Building

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Abstract

The frequent collapse of concrete structures (Buildings, Bridges and Culverts) these days in the global construction industries has led to claiming of many innocent lives. From the literature perspective, the observed major causes of this failure are the errors developed from the programmed structural software; the method used in running the software, its usage error during the analysis and design of structural members; and possibly, error committed by unskill personnel while using the structural software. Allowing the continuity of these errors in the construction industries will cause greater damages to lives and properties globally, thus; a more accurate and reliable design software has to be developed to eradicate errors occurrence in structural design. The results of this investigation proved that Microsoft Excel sheet is accurate for structural members' analysis and design; good for accurate calculation in designing, it can be access quick; so reliable, and error free. Its application in construction industries will bring accuracy and stability to designed structures, and more lives will be saved. As a case study, the architectural plans of Maryland Catholic Grammar School, Ogbomoso (MARCGSO)'s principal lodge building was used as a prototype to show how efficient is Microsoft Excel in structural analysis. At MARCGSO, this has been tested and found reliable. During the investigation, the structural details of the designed concrete structural members were carried out using AUTOCAD software. Analysis and design of members were carried out from the basic principle of structural design using BS 8110 part 1:1999. The result shows that, Microsoft Excel and BS 8110 part 1:1999 code are the best design tools needed for analysis and design of structural members. It is very fast, accurate and error free. Also, the output of analysis carried out using Microsoft Excel are traceable, amendable and reliable, thus, its application in designing will prevent sudden structural failure. Likewise, it is very easy for young and structural engineers to operate, thus, its application can be done by: open a fresh Microsoft Excel sheet, get BS 8110 part 1:1999 code of structural design, prepare a general arrangement of architectural plan of structure to design, then follow the step by step of designing stated in this study. It required no application download or software purchase. In conclusion, the use of Microsoft Excel in structural analysis and designing will save many lives and prevent sudden collapse of structures resulting from wrong code or software error.

Keywords: Microsoft Excel, Structural analysis, Design code, Design error, Structural members

1. Introduction

A reinforced concrete is a concrete with series of connected bents jointed by slabs and beams (Mrema, Gumbe, Chepete, & Agullo, 2012). It consists of aggregates like: cement, sand, granite and admixtures together with steel bars (Kilani, Adeleke, & Fapohunda, 2022). Structural design is defined as a process of setting tools or methods in use, to determine the specifications that are safe and economical for a structure in order to develop a sufficient strength to carry its intended load (E-SUB Construction Software, 2018). It also involves the production of structural layout of the proposed structures (like buildings, culverts and bridges), structural dimensioning, production of architectural plans, analysis and design of structural elements, and production of details of design calculations of structural members (Structural Design, 2023). A structural member is a load bearing element of a facility. Examples of structural members are: load bearing walls, columns, slabs and beams (Law-Insider, 2021). Structural members are mainly classified into element, types, structural system, overall shape, form, application and material (Civil Engineering X, 2022). All these seven classes were grouped into two based on their capacities for load bearing, that is, strong and weak members. Strong members are strong stiff load bearing member of a structure while the weak members are non – load bearing members of a structure (Fire Engineering, 2010). Examples of strong members of a structure are: columns, beams and slabs while the weak structural members are: ceilings and non-load supporting walls (Mrema et al., 2012). Columns and beams are the main two members of a structure that bear the building's structural weight and make it stable from slab to foundation of the building. Beams are members of a building's that carries the weights of roof ceilings and floor slabs; transferring them to a perpendicular frame work load bearing member in order to withstand the stacked walls' loads and shear the carried loads heavier for them to carry. Columns are the vertical building's members which were purposely constructed to reinforce (support) some other heavily loaded members of a structure like: beams and slabs (Ram, 2020). Recently, unexpected collapsing of structures like: buildings, culverts and bridges are increasing in our environment. This has claimed many lives of inmates. One of the major sources of these is poor structural designs and errors made by human or by using programmed software for structural analysis. Errors in design are failures made unavoidably when information were applied incorrectly or make the information pertinent inaccessible (Reichart, 1988). Also, errors in design is defined as mistakes made in design, omission of essential data in design and conflicts (Lopez, Love, Edwards, & Davis, 2010). The errors made through the human mistake in design could be from inaccurate mode of designing and insufficient time constraints. This causes inconsistencies in measurement, deviation in actual values and inaccurate in measuring precision (De Quiros, Lopez, Aranda-Mena, & Edwards, 2008). Most of the errors made in structural design are from electrical, mechanical and plumbing (EMP) design systems. To achieve the accurate construction of structures with high safety of inmates, these errors need to be avoided, especially during the structural design (Peansupap & Ly, 2015). Errors in structural design are the sources of many catastrophic accidents that front the injury and death of construction workers, and buildings' inmates as traced by the previous structural scholars (Musa & Obaju, 2016). Harle (2017) designed and analyzed a building structure the use of one language programming software for the analysis and design of its members. Author used STAAD PRO. and MATLAB analysis software to generate and analyzed the loads on building structural members. These two software were used to create accurate design calculations of the concrete reinforcing areas required at a specified area of a structural member like: beam, column and slab, using the maximum bending moment and shear force values gotten from the analyzed members of a building using Staad Pro. Design programming software. Harle (2017) has shifted to the use of Excel sheet (MS) for structural design recently, while the MATLAB software was used for structural programming by the author. These two soft-wares were produced and run in one programming language code, but the programming of these two software in other languages would have contributed to the quick design and analysis performance of the software which is the current limitation of this programming. This could have contributed to the better design output if implemented initially.

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Time Error 9 Error in Orion CSC Run software is an error that normally occurs as a result of misconfiguration of file codes system in the computer operating windows system. It is a hexadecimal error format that occurs as a result of wrong operating windows used for computer operation together with its other compatible driver and software. This Orion 9 Error usually surface when the system operating windows files are damaged. It was observed that files error come into existence through the incomplete processes of software uninstall, inaccurate deletion of hardware, inadequate installation and recovery of a computer system from being affected by virus. All these might have lead to the corruption of Orion file in the computer operating system (Survey Developer, 2023). In the investigation conducted by Ondrej (2011) on SAP2000 software, the errors developed through the use of SAP 2000 structural design software were categorized into three: codes and windows error; errors of analysis; and other perspective error. Author said, these errors were developed from the use of inadequate virtual and graphic memories, use of no joint memories software, and refilling of formatted database. Navaee (2003) solved the problem of statistical indeterminate and determinate beams using Microsoft Excel. During the process, the analysis and design of a loaded building's beam members were done using Microsoft Excel to generate bending moment and shear force diagrams. The deflections and slopes of the beams were analyzed using Microsoft Excel also. To determine the deflections, slopes, bending moments and shear force of the spanning beams, four standard formulas were developed in B4 to E4 Excel cells. These formulas formed were capable of analyzing the accurate values of beams' deflections, slopes, bending moments and shear forces. The beams analyzed were suggested to the end concentrated loads and were uniformly distributed. Also, author made use of Hardy Cross's method of structural analysis from the theorem of moment distribution method (MDM), to analyze the uniformly distributed loads of the loaded beams, and the moments at the fixed ends were determined from the analysis. Also, the beams factors of loads distribution in the beam members were determined using MDM. At the stages of designing and analyzing the beam with the use of MDM, the ends spans of the beam were clamped while its end moments were fixed to counter balanced moments for the beams' joints perfect equilibrium. At that point, the end spans were unclamped to give room for rotation to distribute the moments that were initially computed. These distributed moments were then carried (over) to the opposite end. The unclamping and clamping processes were repeated until sufficient values of distributed moment were formed. This method of designing and analysis used was prone to error making at the stages of designing. Having considering the design errors developed through the use of existed structural design software that were commonly caused sudden collapsing of the buildings as explained earlier, this paper focuses on cancellation of these design errors resulted from the: installation of design software, use of structural design software, manual design calculations of building structural members (beams, slabs and columns), and building structural details using a simple error free Microsoft Excels calculation sheets for the design and provision of accurate steel bars for accurate member reinforcement.The software (Microsoft Excel spread sheet) is easy to compute and can be operated upon by any structural design engineer. The aim of this study is to develop a simple and standard design platform for structural members' (beams, slabs and columns) analysis and design using Microsoft Excel and AutoCAD. The aim is achieved through the following objectives: (i) to upgrade the level of structural design from manual to that of using Microsoft Excel for designing (ii) to encourage the use of structural design codes such as British Standard (BS 8110:1997)) among engineers for structural designs (iii) to eradicate the problem of building failures normally caused by software and human errors during structural design stages (iv) to develop an accurate and reliable platform for the design of structural members (beams, slabs and columns) using Microsoft Excel sheet. (v) to produce the accurate design details of analysis carried out from Excel platform using AutoCAD software.

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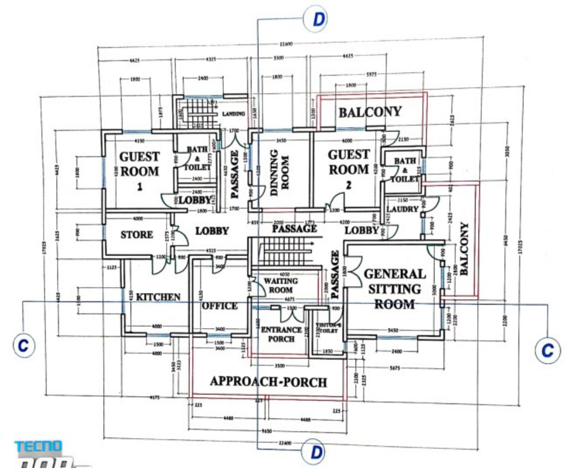
2. Materials and Methods

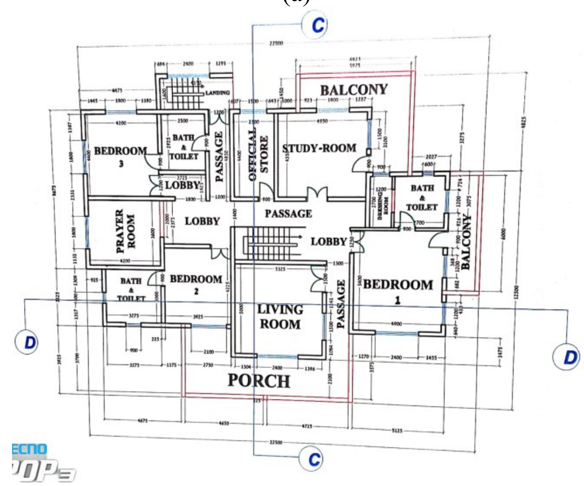
2.1 Materials

2.1.1 Architectural plans

In this study, the architectural plans of Maryland Catholic Grammar School, Ogbomoso (MARCGSO)'s principal lodge building was used as case study plans for the design of structural members with the aid of Microsoft Excel. The design of structural members with this type of platform (Microsoft Excel) was first implemented at MARCGSO. The results obtained at MARCGSO were so accurate and reliable. The plans used for the design were grouped into ground and first (upper) floor plans. The ground floor plan is of size 22,600 mm by 16,798 mm in length and breadth. It made up of two guest rooms together with their bath and toilet rooms, a waiting room, a general sitting room, two stair cases, two balconies, a dining room, an office, a kitchen and a store. This ground floor plan was design purposely to serve as guest house (floor) for the visiting priest of MARCGSO (see Figure 1). The first floor plan is of size 22,500 mm by 17,000 mm. Its breath is a little bit longer than the breadth of ground floor plan. The plan consists of a living room, three bedrooms with their bath and toilet rooms, a prayer room, two balconies, a porch, an official store, a dressing room and a study room (Figure 1). The first floor plan was design as a residential floor for the school principal, vice-principal and other school's official staff members. The roof plan, approach view; rear, right and left side elevations, cross – sectional views (Sections C-C and D-D), fences, and septic tank design plans were all projected from the ground and first floor plans as shown in Figure 2.



(a)



(b)

Figure 1. (a-b) Ground and first floor plans of a proposed principal's lodge.

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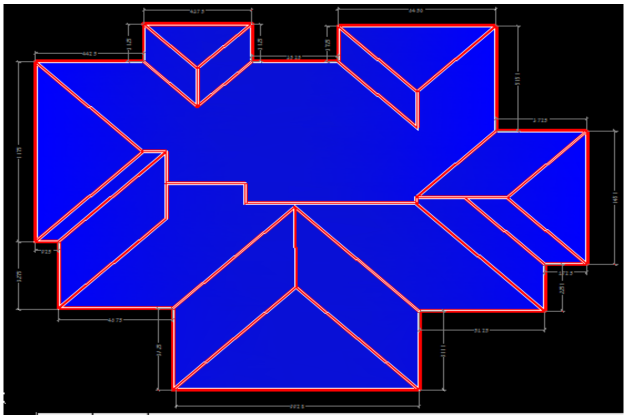
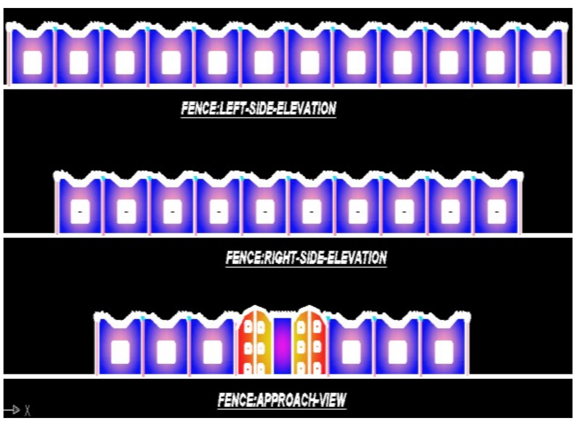


(a)



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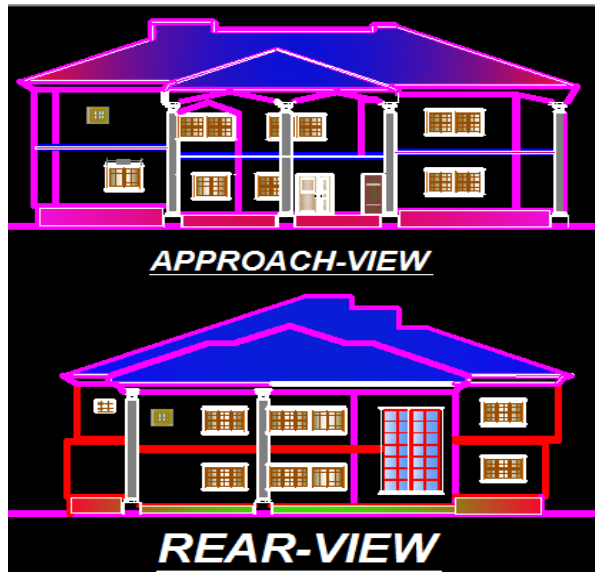
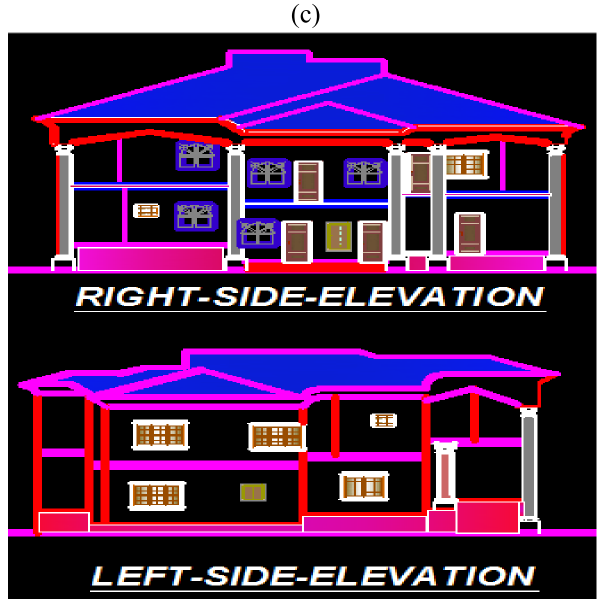


(c)



(d)

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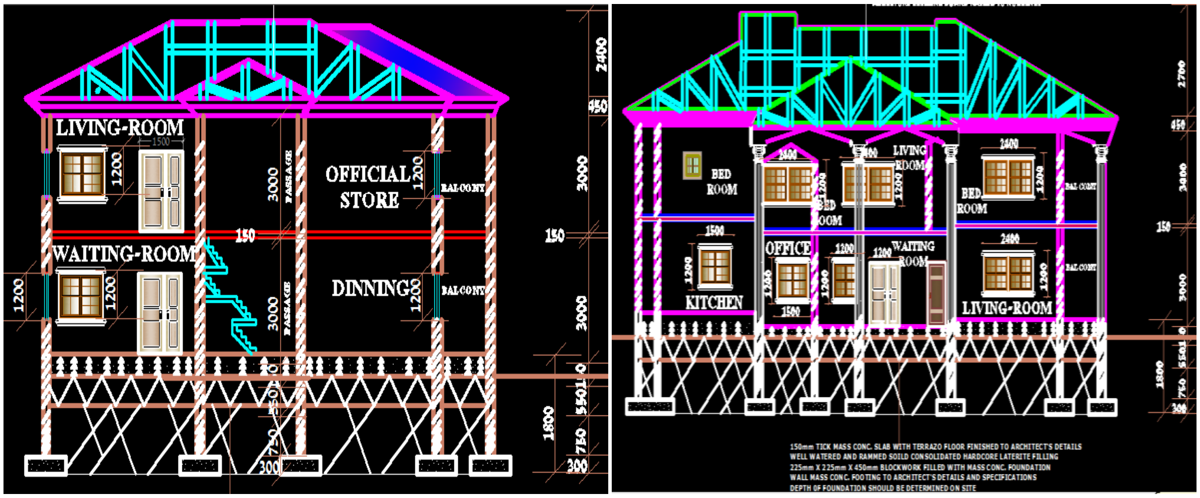

(e) (f)

Figure 2. (a) Building's roof plan (b) fence elevations (c) approach and rear elevations (d) right and left side elevations (e) cross-sectional view of section C - C (f) cross-sectional view of section D – D.

2.1.2 Structural members' arrangement

The structural layouts of the proposed building were generated from ground and first floor plans. The layouts consist of slab panels 1 to 22. All of these panels except that of panel 16, were in two ways spanning while that of panel 16 is one way slab. The slab panels 1 to 22 consist of different types of slab cases as specified by BS 8110 part1:1999 code of structural design (Navaee, 2003). The general arrangements (G.A) of building structural members were labeled from A to L and from 1 to 10 on G.A for easy identification of each structural member as shown in Figure 3. Likewise, the upper floor's G.A consist of 22 slab panels out of which six of them were one –way spanning slabs while others were two – ways spanning slabs. Also, the first floor's G.A shows the arrangement of beams and columns for the support of the building's roof and slabs. It was labeled from A to K and 1 to 8 as shown in Figure 3(a).

2.1.3 Microsoft Excel and AUTOCAD software

The Microsoft Excel programmed spread sheet was used for all the analysis and designs of structural members (beams, slabs) in this studies. While the AutoCAD software of version 2010 classical model was used for the production of architectural plans and structural details.

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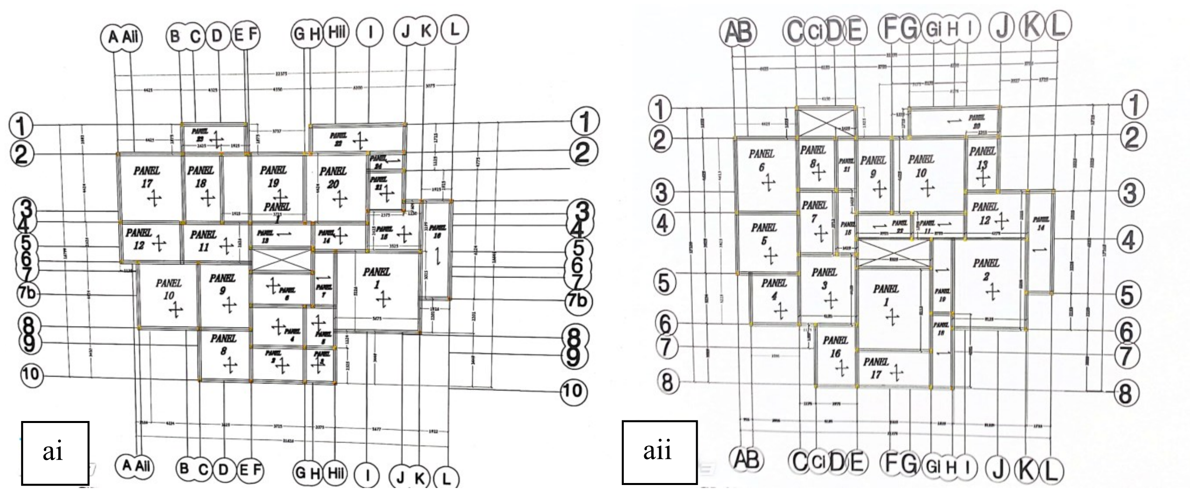

Figure 3(a). (i – ii): General layouts at ground and first floors.

2.2 Methodology

The steps used for the design and analysis of structural members (beams and slabs) in this study are explained as shown in Figure 3(b).

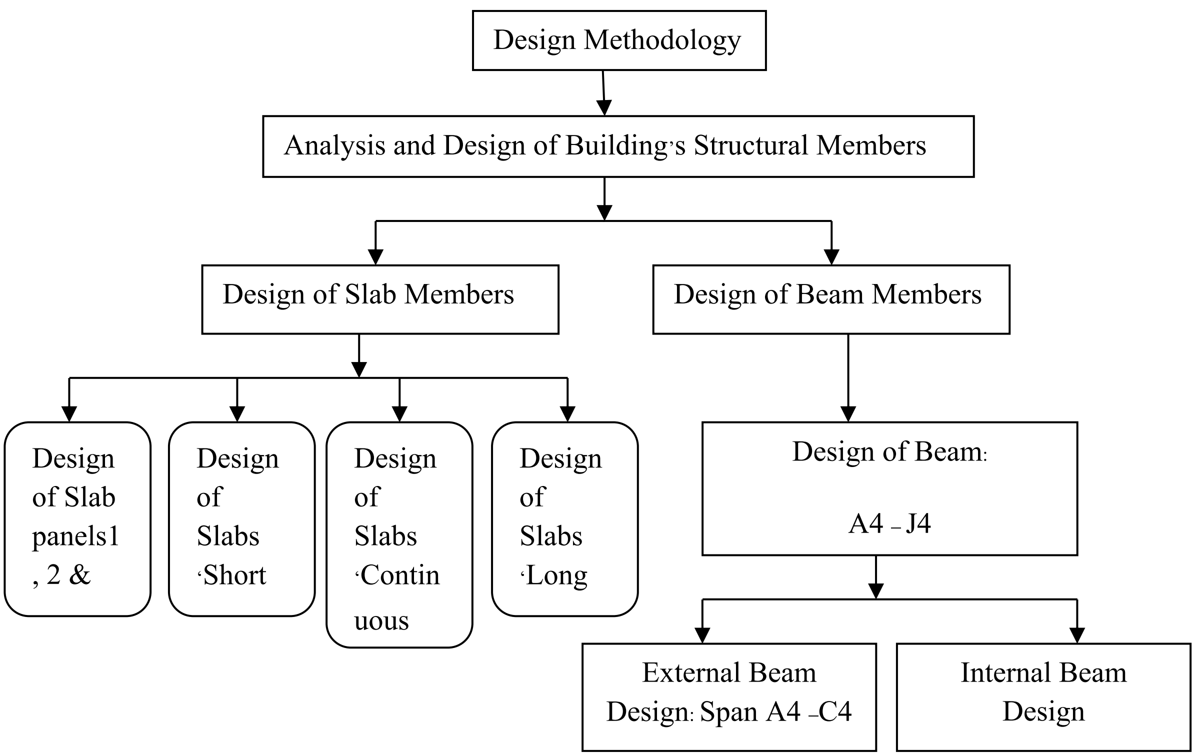

Figure 3(b). Slabs and beams design methodology.

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2.2.1 Analysis and design of building's structural members using Microsoft Excel

2.2.1.1 Design of slab members

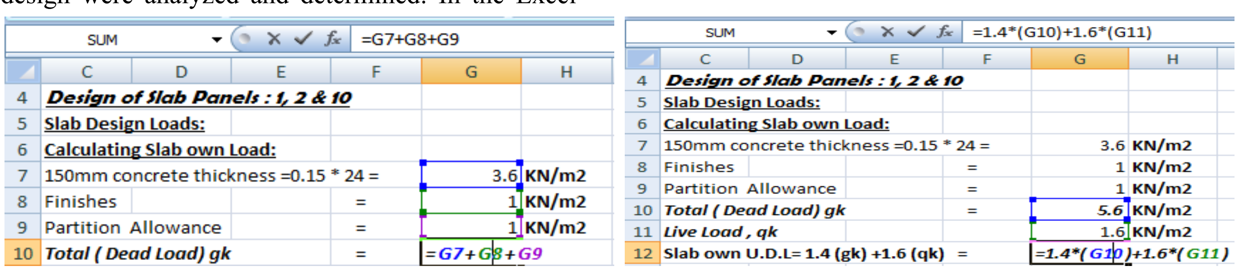
The pre-selection of the building's slab-types to design for was done in order to know if the selected slabs were one – way or two – way spanning slabs. The structural layout plans of the proposed building (both at ground and upper floors) were used for this selection. A selected slab-panel is said to be a one way slab if ly / lx ≥ 2.0 and is two – way slab if ly / lx ≤ 2.0 according to BS 8110 – 1:1997 page 35 for civil and builder engineers. For uniformity in design, the critical slab panels 1, 2 and 10 were selected for design and the details were used to predict the expected reinforcement of the other panels following the specification stated by BS 8110 – 1:1997 code.

(a) Design of Slab Panels 1, 2 and 10

The slab panels 1, 2 and 10 had the same dimensional arrangements; therefore, their designs and analysis were taken to be the same. Among the three panels, panel 1 was selected for reinforcement design which was detailed for the remaining slabs. At the initial stage of slab design, the loads on slab to design were analyzed and determined. In the Excel spread sheet, at cell C7 to F9, the self weight of concrete slab was determined by multiplying the thickness of the slab which is 150mm with the density of concrete which is 24KN/m^3. The computation of their result was done at cell G7 by imputing "=0.15*24 in the cell and press enter. The finishes and partition allowance on the slab was taken as 1KN/m^2 each, which were placed at cell G8 and G9 respectively. The total dead loads of concrete slab (g_k) was determined by adding the values gotten at cells G7, G8 and G9 together at cell G10 as shown in Figure 4 (a). Considering the live purpose of the building, the imposed (live) load (qk) of 1.6KN/m^2 suggested by BS 8110-1:1997 code was used for the design. This load was placed at cell G11. The Uniformly Distributed Load (UDL) on concrete slab was determined from the equation 1

$$\text{UDL} = 1.4(\text{gk}) + 1.6\ (\text{qk}) \qquad (1)$$

Where: 1.4 is the modification factor of concrete slab's dead load; gk is dead load; 1.6 is the modification factor of concrete slab's imposed load. The 1.4 (gk) value was determined at cell G10 and that of 1.6 (qk) at cell G11. Their UDL was calculated for at cell G12 as shown in Figure (4b).



(a) (b)

Figure 4. (a) Calculating the total dead load of slab (gk) (b) analysis of slab own (U.D.L).

The units of all the calculated loads were recorded at H7 to H12 cells. The effective depth of the slab were determined from the formula: Effective Depth (d) = Overall Depth (h) – cover – ½ of bar diameter, that is, d = 150 – 20 – ½ (12) =124 mm. Taking the exposure condition of the concrete slab as Mild and fire resistance as one hour, the concrete cover was given as 20mm and the slab breadth, 1000mm as indicated in Tables 3.3 and 3.4 of BS 8110-1:1997code of structural design page 21.

Considering the slab panel1, the ratio of ly to lx was determined at cell F20 which is 1.1, that is, ly/lx =1.1 ≤ 2.0 as shown in figure 5. It implied that, the slab under design is a two – way spanning slab. Using ly/lx = 1.1 values, the short and long spans coefficients of slab panel1 were determined from Table 3.14 of BS

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8110-1:1997 at interior panel column as: - 0.037 and 0.028 (for short span coefficients) and -0.032 and 0.024 (for long span coefficients) respectively as indicated in Figure 5.

	A	B	C	D	E	F	G	H	I	J
19			*Panel 1*	*ly*	*lx*	*ly/lx*	*ly/lx <2*			
20				5.55	5.225	=D20/E20	*1.1 <2*	*Hence, the Slab is two-way slab*		

21			***Short Span Coeff.***	-0.037	and	0.028
22			***Long Span Coeff.***	-0.032	and	0.024

Figure 5. First: **-** Ratio of long span to short span of the slab **(**Ly / Lx**)**; Second:**-**Long and short span coefficient of slab panel 1.

The additional loads on concrete slab were determined by multiplying the modification factor, wall weight, height of the building, and the addition of both long and short spans. The product was divided by the area (length x breadth) covered by the slabs. The outcome of the division gave the additional uniformly distributed load (UDL) in KN/m^2 on the slab panel 1. This analysis ranged from C14 to J14. The additional UDL was determined at cell K27 and that of Ultimate UDL (concrete own UDL + UDL from Additional partition load) of slab panel 1 was determined at cell L24 as shown in figure 6.

Additional partition Load:							
Mf	*wall wt.*	*Height of buildng*	*longspan*	*shortspan*	*L+S*	*LOAD*	*UNIT*
1.4	3.47	3.15	5.55	5.225	10.775	=I25*E25*D25*C25	

26		*length*	*breadth*	*Area =B*L*	*unit*		LOAD(KN)	Area	*Load/Area=U.D.L from point load*		
27	*Area*	5.55	5.225	*28.99875*	*m²;*	U.d.l =	164.8866	28.99875	*5.68599*	*KN/m²*	
28	*TOTAL u.d.l = Ultimate U.d.l + u.d.l from point load*					=	*10.4*	+	*5.68599*	=K28+I28	*KN/m²*

Figure 6. First: **-** Additional partition load on slab panel 1; Second:**-** Ultimate uniformly distributed load on slab panel 1.

(b) Design of slab's short span mid span design

The mid span reinforcement design of concrete slab is the main reinforcement design of steel bars needed to bear the weight of dead and imposed loads on the slab. In the analysis, the number of mid span reinforcement bars were calculated for through the area of steel bars gotten using the formulas:

$$As = \frac{M}{0.95fy.la.d^2} \tag{2}$$

Where M is the maximum bending moment of the concrete slab, la is the lever arm, which was calculated from the formula:

$$la = 0.5 + \sqrt{\left(0.25 - \frac{k}{0.9}\right)} \leq 0.95 \tag{3}$$

And K was determined from:

$$K = \frac{M}{fcu.bf.d^2} \leq 0.156 \tag{4}$$

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Where *f*cu is the characteristic strength of concrete which was taking as 20N/mm² and 'd'is the effective depth of the concrete slab for tension reinforcement as shown in BS 8110-1:1997 code of structural design page 25 to 26. In Excel spread sheet, the data were input from cell F30 to J31 to determine the value of M. The ultimate UDL value of the slab calculated early was placed at cell F31 called F (cell F30), then, the θx value was calculated at cell G31, followed by Lx at cell H31 and I31 while the value of M was calculated by multiply the values of F, θx and L²x at cell J31. At cell J31, "= I31*H31*G31*F31" were inputted and 'enter' key of computer keyboard was pressed onceto calculate the value of M in J31 cell (Figure 7). In the calculation of K, the input data in the formula$K = \frac{M}{fcu.bf.d^2} \leq 0.156$ were placed at cell D33 to H33 while the actual value of K was determined at cell I33. At Cell I33,'= D33/(H33*F33*E33)" was input and pressed 'enter' key to calculate the value of K as shown in Figure 7.

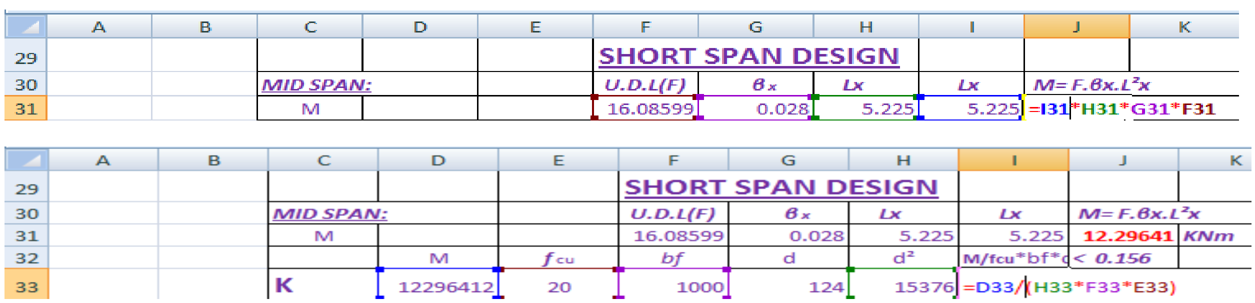
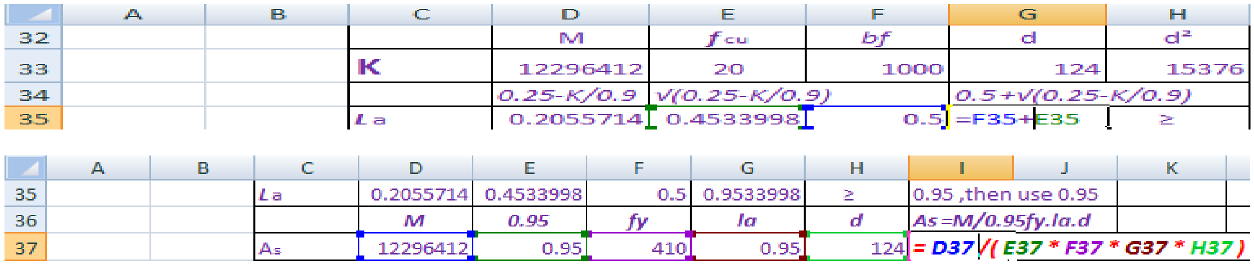


Figure 7. First:- Calculating of maximum bending moment (M) on slab; Second:- Calculating of K value.

The lever arm of the reinforcement design of concrete slab was also calculated from cell D35 to G35. In the calculation, the values of: 0.25 – K / 0.9; √ (0.25 – K / 0.9); and $la = 0.5 + \sqrt{\left(0.25 - \frac{k}{0.9}\right)}$ were determined at cell D35, E35 and G35 respectively (see figure 8). The areas of the steel required for the concrete slab reinforcement using the formula:$As = \frac{M}{0.95fy.la.d^2}$was calculated at cell I37. This was conducted by input "=D37 / (E37*F37*G37*H37) at cell I37 and press "Enter" button from the keyboard of a computer system in the Excel sheet as a shown in figure 8. The area gotten from the calculation was used to provide the spacing in between the steel bars for concrete slab's reinforcement. Also, structural details of the slab were produced with calculated results.



	A	B	C	D	E	F	G	H
32				M	*f* cu	*bf*	d	d²
33			K	12296412	20	1000	124	15376
34				*0.25-K/0.9*	*√(0.25-K/0.9)*		*0.5+√(0.25-K/0.9)*	
35			*La*	0.2055714	0.4533998	0.5	=F35+E35	≥

	A	B	C	D	E	F	G	H	I	J	K
35			*La*	0.2055714	0.4533998	0.5	0.9533998	≥	0.95 ,then use 0.95		
36				*M*	*0.95*	*fy*	*la*	*d*	*As =M/0.95fy.la.d*		
37			As	12296412	0.95	410	0.95	124	*= D37/(E37 * F37 * G37 * H37)*		

Figure 8. First:- Calculating lever-arm value; Second:- Calculating the area of steel bars (As).

(c) Design of continuous edge of slab panel 1

The negative coefficient of short span of the slab that was gotten earlier was substituted in the formulas used for the design of the mid-span of the slab panel1's short edge for the calculation of the continuous edges. This was done from calculating the Moment at tensile zone of the concrete slab to the calculation of steel bars' areas. The steel bars areas gotten were used to produce the slab reinforcement details

(d) Long span design

The formulas and steps used in the short span design were adopted for the design of slab panel1's long span reinforcement using coefficients of -0.032 and 0.024 for mid-span and continuous edges respectively. The slab's deflection check was done to check the effectiveness of the slab by following the above calculation methods using the formula shown in equation 5.

$$\text{Mf} = 0.55 + \frac{477 - fs}{120\left[0.2 + \frac{M}{(bf * d^2)}\right]} < 2.0 \quad (5)$$

2.2.1.2 Design of beam member

(a) Design of beam A4 – J4

The floor beams were designed based on general arrangement. From BS 8110 -1997 code of structural design, by considering the structural function to be performed by the beams, the size of the beam selected was 450 by 225 mm. The procedure of using Microsoft Excel sheet for the reinforcement design of building's floor beams adopted for floor beam A4 to J4 will be explain while the design of other beam members were done by following the calculating steps of the designed beam A4 -J4. For proper loading and accurate analysis, the beam A4 – J4 design loads were calculated for. During load calculations, the beam own load was calculated from the multiplication of modification factor (1.4), length and breadth of the beam (0.45 m and 0.225 m) with density of concrete (24KN/m^3) plus the finishes of 1.2 KN/m^2 (suggested from BS 8110 – 1997 code) and the results were inputted at cells E163 to I163 respectively as shown in Figure 9.

The Wall / Partition Loads on beam A4 – J4 were calculated by multiplying the modification factor (1.4); wall – weight and height of the building; plus finishes (1.2 KN/m^2). The calculated value was placed at cells F165 to I165 under the load weights (W1 –W4) (Figure 9).

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	C	D	E	F	G	H	I	J
160	LOADING							
161	ITEMS			W1	W2	W3	W4	UNIT
162	Beam own Weight							
163	1.4((0.45*0.225*24)+1.2)=4.602			4.602	4.602	4.602	4.602	KN/m

	C	D	E	F	G	H	I	J
160	LOADING							
161	ITEMS			W1	W2	W3	W4	UNIT
162	Beam own Weight							
163	1.4((0.45*0.225*24)+1.2)=4.602			4.602	4.602	4.602	4.602	KN/m
164	Wall/Partition LOAD							
165	1.4((3.47*3.0)+1.2)=16.25KN/m			16.25	16.25	16.25	=F165	KN/m

Figure 9. First:-Beam A4 – J4 own weight calculating method; Second:- Wall / Partition load on beam A4 – J4 calculating method.

The loads from the two slab panels that were attached to each span of the beam A4 – J4 were analyzed and placed at the cells F166 to I167. Addition of all the loads from cells F163 to F167 was determined at cell F168 as W1, that of W2 was determined at cell G168 (from addition of cells G163 to G167), for that of W3, the span load was calculated at cell H168 (from addition of cells H163 to H167) and that of W4 was calculated for at cell I168 (from addition of cells I163 to I167) as shown in Figure 10.

	C	D	E	F	G	H	I	J
160	LOADING							
161	ITEMS			W1	W2	W3	W4	UNIT
162	Beam own Weight							
163	1.4((0.45*0.225*24)+1.2)=4.602			4.602	4.602	4.602	4.602	KN/m
164	Wall/Partition LOAD							
165	1.4((3.47*3.0)+1.2)=16.25KN/m			16.25	16.25	16.25	16.25	KN/m
166	Slab Own LOAD ON Beam 1			50.64	22.61	21.03	22.66	KN/m
167	Slab Own LOAD ON Beam 2			41.04	42.51	8.46	3.46	KN/m
168	TOTAL LOAD			112.532	85.972	50.342	=I163+I165+I166+I167	

	C	D	E	F	G	H	I	J	K	L	M
169											
170	MOMENT	W	L	L	WL²/8	M i-ii	M ii-i	AV.M i-ii/2		M=(M - M av	Unit
171	M A4-C4	112.532	4.225	4.225	251.09582	0	219.17	109.585		141.5108	KNm
172	M C4-F4	85.972	4.75	4.75	242.46791	219.17	103.15	161.16		81.30791	KNm
173	M F4-G4	50.342	4.275	4.275	115.00394	103.15	89.64	96.395		18.60894	KNm
174	M G4-J4	46.972	4.425	4.425	114.96764	89.64	0	44.82		=G174-J174	

Figure 10. First:- Calculating total load on beam A4 – J4; Second:- Calculating beam A4 – J4 span moments.

External Beams Design: Span A4 – C4

Here the external span method is showed and procedure is repeated for all other span of Beam A4 – J4. The breadth flange of the external span of the beam was calculated from the formula *bf* = bw+ Lx/10 and that of internal span from *bf* = bw + Lx/5 where b_w is the width of the beam and Lx is the span of the beam. During the Excel calculations, the value of b_w was inputted in the cell D187 and that of Lx/10 was computed at cell G187 while the value of *bf* was calculated at cell H187 as shown in figure 11. Effective depth (d) was calculated from = Total Beam depth (h) – cover – ½Ø – Ø. The value of K was determined for the calculation of the area of steel bars for beam span A4 – CA from cells D191 to I191. The calculated values of M (moment at span A4 – C4 of the beam) was inputted at cell D191, that of f_{cu}, bf and d² were placed at cell E191, F191 and H191 respectively. The value of K used was calculated at cell I191. In the cell I191, the value of M at cell D191 was divide by multiplication of fcu, bf and d² which were computed as H191*F191*E191 to get the value of K as shown in Figure 11.

Available online at https://li02.tci-thaijo.org/index.php/ssstj

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	C	D	E	F	G	H	I
184	EXTERNAL BEAMS DESIGN						
185	Span A4-C4		M =	141.5108	KNm		
186		bw	L	Lx	Lx/10	bf=bw+Lx/10	
187	bf	230	4225	3591.25	359.125	=D187+G187	

	C	D	E	F	G	H	I	J	K
188		h	C	1/2ø	ø'	d=h-C-1/2ø-ø'			
189	Depth(d)	450	25	10	10	405	mm		
190		M	fcu	bf	d	d²	M/fcu.bf.d² < 0.156		
191	K	141510817	20	589.125	405	164025	=D191/(H191*F191*E191)		

Figure 11. First: -Calculating the value of beam's flange breadth; Second:-Calculating the value of K.

Having gotten the value of K, the K value was substituted in equations (3) and (2) to calculate for the area of steel.

3. Results and Discussions

3.1 Result of the design of slab panel 1, (2 and 10)

The value of the uniformly distributed load (UDL) of the slab panel1 owns weight was determined to be 10.4 KN/m^2. Compared with that of manual design, it is more effective than that of the manual (hand calculations). It is error free, and if any error is noticed, the error is traceable and can be fix easily. The ultimate UDL was calculated to be 16.085994 KN/m^2 and displayed in red as shown in Figure 12. The effectiveness of this method is that, all the calculated values were initiated by the designer and the output can be seen as they are being generated. Not like Orion and Staadpro software that were only generating the ultimate UDL with showing how it was calculated.

	C	D	E	F	G	H	I	J	K	L	M
16											
17	Design of Slab Panel 1 :The same design calculations and Details is provided for Panels 2 &10										
18	INPUT				CALCULATION					OUTPUT	
19	Panel 1	ly	lx	ly/lx	ly/lx <2						
20		5.55	5.225	1.062201	1.1 <2	Hence, the Slab is two-way slab					
21	Short Span Coeff.		-0.037	and	0.028						
22	Long Span Coeff.		-0.032	and	0.024						
23	Additional partition Load:										
24	Mf	wall wt.	Height of buildng		longspan	shortspan	L+S	LOAD	UNIT		
25	1.4	3.47	3.15	5.55		5.225	10.775	164.8866	KN		
26		length	breadth	Area =B*L	unit		LOAD(KN)	Area	Load/Area=U.D.L from point load		
27	Area	5.55	5.225	28.99875	m²;	U.d.l =	164.8866	28.99875	5.68599	KN/m²	
28	TOTAL u.d.l = Ultimate U.d.l + u.d.l from point load				=		10.4	+	5.68599	16.08599	KN/m²

Figure 12. Ultimate uniformly distributed load (U.U.D.L) on slab panel 1.

Considering the results of short span designs of panel1, both at the mid span and continuous edge, the calculated areas of slab steel reinforcement were 267.994 mm^2 and 358.908 mm^2 respectively (see Figure 13). As suggested in the BS 8110-1:1999, the areas of the steel bars provided were Y12@300mm c/c at the bottom with A_s prov. of 377 mm^2; and Y12@250mm c/c at the top with A_s prov. of 452 mm^2 based on the initial areas gotten through calculations. These design outputs are very clear, safe and more economical. Its output calculation can be traceable and fix any error if applicable easily not like that of STAAD Pro and Orion software of which their calculations steps were untraceable (Saha, Ali, Chisanga, & Yasin, 2021). Considering the design of a multistory building, the slab loads analysis and design, as well as their output were generated by STAAD PRO programmed software itself in a vertical sheet (Figure 14) which could developed errors. But, in this study, the computation of design parameters was done one by one in each speculated cell determine each parameter (s) which is far better than the programmed one.

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	C	D	E	F	G	H	I	J	K
28	*TOTAL u.d.l = Ultimate U.d.l + u.d.l from point load =*						*10.4*	+	*5.68599*
29				**SHORT SPAN DESIGN**					
30	***MID SPAN:***			*U.D.L(F)*	*βx*	*Lx*	*Lx*	*M= F.βx.L²x*	
31	M			16.08599	0.028	5.225	5.225	**12.29641**	***KNm***
32		M	*f*cu	*bf*	d	d²	M/fcu*bf*d² < *0.156*		
33	**K**	12296412	20	1000	124	15376	0.039986	< 0.156	**Okay**
34		*0.25-K/0.9*	*√(0.25-K/0.9)*		*0.5+√(0.25-K/0.9)*				
35	*La*	0.2055714	0.4533998	0.5	0.9533998	≥	0.95 ,then use 0.95		
36		***M***	***0.95***	***fy***	***la***	***d***	***As =M/0.95fy.la.d***		
37	As	12296412	0.95	410	0.95	124	***267.994***	**mm²**	
38	***PROVIDE Y12mm@300mm c/c (As prov.=377mm²) @ BTM of the Slab***								
39	***CONTINUOUS EDGES:***			**U.D.L(F)**	**βx**	**Lx**	**Lx**	**M= F.βx.L²x**	
40	M			16.08599	0.037	5.225	5.225	**16.24883**	***KNm***
41		M	*f*cu	*bf*	d	d²	**M/fcu*bf*d²** < *0.156*		
42	**K**	16248830	20	1000	124	15376	0.052838	< 0.156	**Okay**
43		*0.25-K/0.9*	*√(0.25-K/0.9)*		*0.5+√(0.25-K/0.9)*				
44	*La*	0.1912908	0.437368	0.5	0.937368	not ≥	0.95 okay		
45		***M***	***0.95***	***fy***	***la***	***d***	***As =M/0.95fy.la.d***		
46	As	16248830	0.95	410	0.937368	124	***358.908***	**mm²**	
47	***PROVIDE Y12mm@250mm c/c (As prov.=452mm²) @ TOP of the Slab***								

Figure 13. Output of slab panel 1's short span design.

Slabs	Direction		No.of Bars	Spacing mm	Spacin g mm	Direction		No.of Bars	Spacing mm c/c	Spacing mm
Slab F1	Short	M con	6φ12	161.3866	150	Long	M con	6 φ12	158.1555	150
		M dis	3 φ12	314	300		M dis	3 φ12	314	300
		M +	5 φ12	215.9392	200		M +	5 φ12	211.7531	200
Slab F2	Short	M con	5 φ12	194.8882	200	Long	M con	5 φ12	195.569	200
		M con	5 φ12	194.8882	200		M dis	3 φ12	314	300
		M +	4 φ12	260.948	250		M +	4 φ12	260.9136	250
Slab F3	Short	M con	4 φ12	252.2731	250	Long	M con	3 φ12	314	300
		M con	4 φ12	252.2731	250		M dis	3 φ12	314	300
		M +	3 φ12	314	300		M +	3 φ12	314	300
Slab F4	Short	M con	5 φ12	215.9775	200	Long	M con	4 φ12	260.5498	250
		M con	5 φ12	215.9775	200		M dis	3 φ12	314	300
		M +	3 φ12	291.448	300		M +	3 φ12	314	300
Slab F5	Short	M con	5 φ12	198.6024	200	Long	M con	5 φ12	209.3954	200
		M con	5 φ12	198.6024	200		M dis	3 φ12	314	300
		M +	4 φ12	266.5324	250		M +	4 φ12	279.191	300
Slab F6	Short	M con	4 φ12	238.1305	250	Long	M con	3 φ12	314	300
		M dis	3 φ12	314	300		M dis	3 φ12	314	300
		M +	3 φ12	314	300		M +	3 φ12	314	300

Figure 14. Outputs of slabs analysis and design using Staad Pro software (Gupta, 2021).

3.1.2 Slab panel 1 deflection check result

The results of deflection check of slab panel 1 show that, the designed slab panel 1 is safe against deflection as shown in Figure 15. The value slab's depth calculated was greater than that of the required depth by 84.49%, this means, the designed slab is safe against deflection. Compare this with that of Gupta (2021) and Harle (2017) output, the safety of their design output could not be evaluated or ascertained, it was only determined by mere STAAD PRO analysis which could contain errors.

	C	D	E	F	G	H	I	J	K	L
70										
71	DEFLECTION CHECK									
72	M=	12296412	Nmm	As req.=	267.99436	mm²	As prov.=	377	mm²	
73	fs	2fy	As req.	2fy.As.req	3.As prov	2fy.As.req/3As prov.				
74	fs=	820	267.99436	219755.4	1131	194.3018				
75	Mf	0.55	477-fs	120(0.2+(M/(bf. d²)))		0.55+ [(477-fs)/ 120(0.2+(M/(bf. d²)))]				
76	Mf	0.55	282.69817	119.9658		2.906491	> 2,then, use Mf=2.0			
77		bf	26*Mf	bf/26*Mf						
78	d req.=	1000	52	19.23077	≤ d actual=124mm,then,The Slab is saved against deflection					

Figure 15. Slab panel 1 deflection check.

3.2 Result of design of beam A4 – J4

Beam-Span A4 – C4

The results of Beams analysis and Design were presented as shown in figures 16 to 17. From the results of the loads calculations for Beam A4 – J4, the ultimate load at each span of the beam A4 – J4 were determined to be 112.532 KN/m for W1; 85.972 KN/m for W2; 50.342 KN/m for W3 and 46.972KN/m for W4 respectively as shown in figure 16. Also, in the figure 16, the moments in each span of A4–C4, C4-F4, F4-G4 and G4-J4 of beam A4 – J4 were determined to be 141.5108 KNm, 81.30791 KNm, 18.60894 KNm and 70.14764 KNm respectively.

	C	D	E	F	G	H	I	J	K	L	M
157			DESIGN OF BEAMS								
158		FLOOR-BEAMS DESIGN									
159	Reinforcement Design Of Beam A4-J4										
160	LOADING										
161	ITEMS			W1	W2	W3	W4	UNIT			
162	Beam own Weight										
163	1.4((0.45*0.225*24)+1.2)=4.602			4.602	4.602	4.602	4.602	KN/m			
164	Wall/Partition LOAD										
165	1.4((3.47*3.0)+1.2)=16.25KN/m			16.25	16.25	16.25	16.25	KN/m			
166	Slab Own LOAD ON Beam 1			50.64	22.61	21.03	22.66	KN/m			
167	Slab Own LOAD ON Beam 2			41.04	42.51	8.46	3.46	KN/m			
168	TOTAL LOAD			112.532	85.972	50.342	46.972	KN/m			
169											
170	MOMENT	W	L	L	WL²/8	M i-ii	M ii-i	AV.M i-ii/2		M= (M - M av	Unit
171	M_{A4-C4}	112.532	4.225	4.225	251.09582	0	219.17	109.585		141.5108	KNm
172	M_{C4-F4}	85.972	4.75	4.75	242.46791	219.17	103.15	161.16		81.30791	KNm
173	M_{F4-G4}	50.342	4.275	4.275	115.00394	103.15	89.64	96.395		18.60894	KNm
174	M_{G4-J4}	46.972	4.425	4.425	114.96764	89.64	0	44.82		70.14764	KNm

Figure 16. Calculating the ultimate load on beam A4 – J4.

In the design of external beam spans A4-C4, the span moment 141.5108KNm was for the design. For A4-C4 span, the flange beam width (b_f) was obtained 589.125 mm and the area of steel (As) calculated for that span was 985.078 mm^2. With 985.078 mm^2 calculated, 4Y20 mm was provided for bottom reinforcement with steel area of 1260 mm^2 using BS8110-1:1997 code (Figure17). Gupta (2021) and Harle (2017), it was the Staad Pro and Orion softwares that predicted this which can be prone to errors.

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	C	D	E	F	G	H	I	J	K
184	EXTERNAL BEAMS DESIGN								
185	Span A4-C4		M =	141.5108	KNm				
186		bw	L	Lx	Lx/10	bf=bw+Lx/10			
187	bf	230	4225	3591.25	359.125	589.125	mm		
188		h	C	1/2Ø	Ø'	d=h-C-1/2Ø-Ø'			
189	Depth(d)	450	25	10	10	405	mm		
190		M	fcu	bf	d	d²	M/fcu.bf.d² < 0.156		
191	K	141510817	20	589.125	405	164025	0.073222	< 0.156	OKAY
192			0.25-K/0.9	(0.25-K/0.9)^1/2		0.5 + (0.25-K/0.9)^1/2 <= 0.95			
193	La		0.1686421	0.410661		0.910661	<= 0.95	okay	
194			M	0.95	fy	la	d	As=M/0.95fy*la*d	
195	As		141510817	0.95	410	0.910661	405	985.078	mm2
196	USE 4Y20mm BARS@BTM(As pro.=1260mm²)								

Figure 17. Calculating the area of steel for external beam span A4-C4.

4. Details of Designs

4.1 Details of slab and beam designs

The details of slabs design is presented in Figure 18. Considering the design output of Slab panel 1, Y12mm steel bar was suggested for the design details. Also, the spacing among the steel rods of the slab was within 250 – 300 mm. The details of beam A4 – J4 designed is presented at figure 19. In the details, the external span of the beam was detailed with 5Y20mm and 5Y16 mm respectively starting from span A4 – C4 for bottom reinforcement

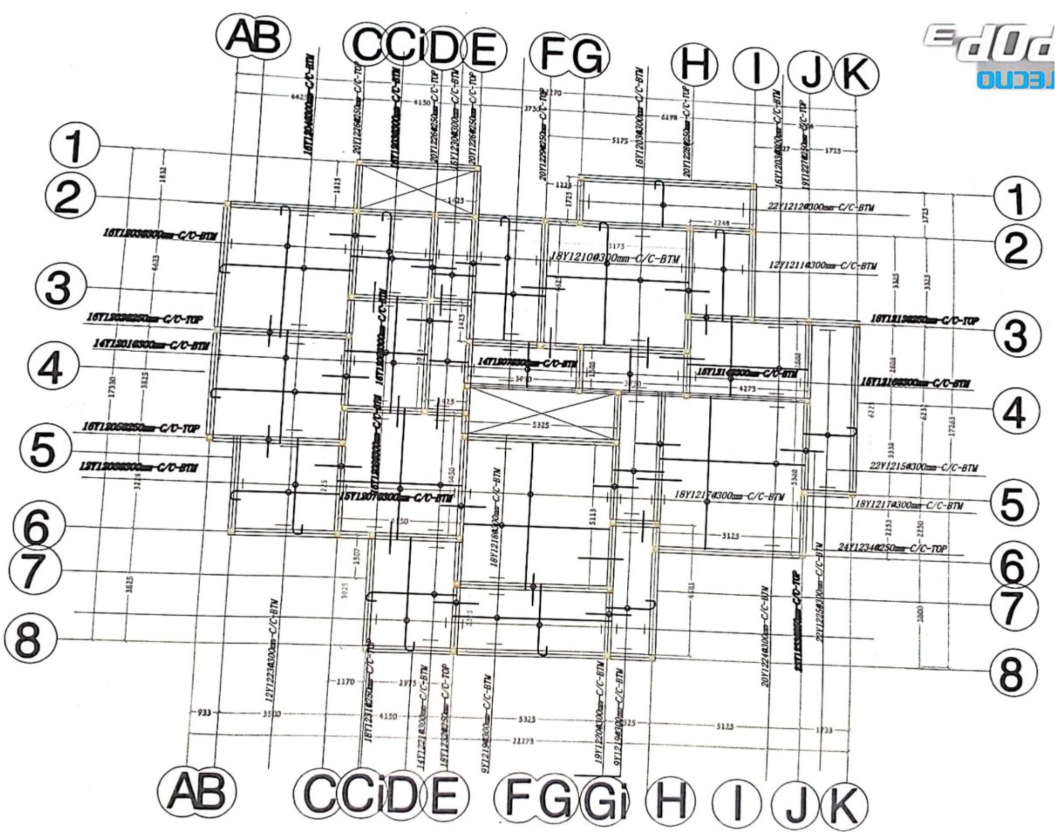

Figure 18. Slab details.

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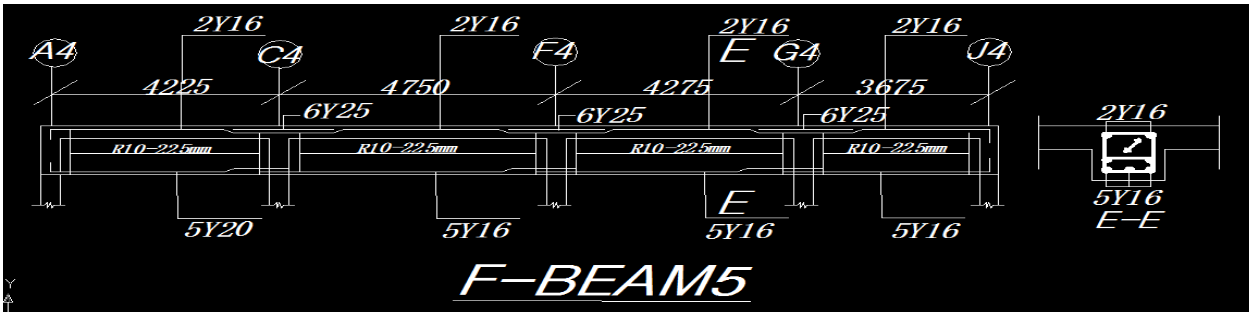

Figure 19. Floor beam A4 – J4 reinforcement details.

5. Significance of Design with Excel

This study has contributed to the knowledge in the sense that, structural member of a building can be design and details with the use of Microsoft Excel and AutoCAD together with BS8110-1:1997 code of structural design, and have a perfect analysis, design and detail results during the analysis. This method is error free and also traceable in case of any error or omission of vita data for quick correction. On like Orion, Staadpro, SAP 2000 software that were programmed with a coded binary algorithm by computer code analyst; the coding, installation, language and human errors using those software were excepted from the use of Excel platform for design. Its application can be done with easy. This program can be operated upon by any structural design engineers without consultation of any binary code programmer once the engineer or designer is a computer literate. Previous software are not reliable and dependable in terms of human, installation and omission errors. It will really assist the site engineers, lecturers and students to design structural members, especially, beams, slabs and columns with easy and error free.

6. Conclusion

As explained earlier in this study, with critical evaluation of design outputs and details of building members analyzed with Microsoft Excel, the following conclusions were made:

Manual analysis and design of structural members is too old for this 21st century. The application of this program as explained in this study (for structural design and analysis) will help in upgrading the existed manual design method. This program is safe, accurate, fast to operate, reliable and encourage the use of BS code for designing. It will help the beginners to make accurate design; also, it will assist engineers, students and lecturers to present clear steps of structural design and analysis together with their details of calculations. Application of this program will increase the rate of British Standard code (BS8110-1:1997) usage for structural design.

Likewise, this method will prevent the formation of design errors caused by software like Orion, StaadPro, SAP 2000 which were the major causes of frequent collapse of buildings in the globe nowadays. With application of this study's method, the quality of structural design and construction in the construction industries will improve. The service life span of structure will also prolong. In a nutshell, the use of structural design code is very important for structural stability and production of standard structures.

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Conflict of Interest

There is no conflict of interest.

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