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Structural Analysis and Design of University of Eldoret School of Medicine

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Abstract: Health care providence is a critical aspect in any community or country worldwide. In most countries, the health docket is assigned a ministry on its own that is accountable for ensuring proper healthcare is provided, challenges are solved and money is allocated to finance healthcare providence in purchasing of drugs and paying the health practitioners. The basic foundation of proper healthcare providence is through the employment of competent healthcare workers that fully understand what is expected of them in their respective areas of expertise. Competent health practitioners are birthed at school during training. A conducive environment with proper training and resources is therefore a step in the right direction in providing competent health workers. At the fore front of health practitioners are the doctors. Their role is providence of essential medical care, prescription of medication, performance of surgeries and offering preventive measures in maintenance of health. The doctors therefore play a vital role in enhancing the healthcare sector and subsequently, their training is crucial in gearing the health docket in the right direction. With the projected increase in population, there will be need for more doctors and concurrently construction of more training institutions for the doctors. This study involved the design of a medical school which would support the education of doctors and production of detailed drawings and specifications of the facility according to accepted codes and standards. The school will be helpful in alleviating the doctor to patient ratio and decreasing the pressure imposed on the few available school of medicine in Kenya which currently admitmore students than their capacity.

Keywords: School of medicine, Structural analysis and Design, Eurocodes standards, ProtaStructure, TeklaTedds

1. Introduction

The first school of medicine established that worked towards training of medical practice was achieved by a man called Hippocrates of Kos around 400 BCE. He is called the father of divination to date as he did studies of each of his patients teaching illnesses were caused by problems in the human body and not by demons and witchcraft as people had believed. The Hippocratic School of medicine used the ancient Greek medicine and established it as a field on its own separating it from the fields of theurgy and philosophy and therefore establishing medicine as a profession[1].

Pre colonization, Africa practiced traditional medicine. The system was based on three levels of specialty: divination, spiritualism and herbalism. Illnesses were believed to have both natural and supernatural causes hence both physical and spiritual methods were used to cure illnesses. The system lacked advanced machinery and research needed to cure complex bacterial and viral illnesses and as a result, the mortality rate was high for diseases that are now proven curable. The first school of medicine established in Africa was University of Cape Town incepted in the year 1920 by a professor known as Professor A W Falconer from Scotland[2]. This was the inception of the first actual research and medical training institution in Africa that incorporated complex technology in health care providence. It was not until 1965-1967 that Kenya had its own school of medicine, The University of Nairobi school of medicine, established by Dr NjorogeMungai, the then Minister of Health[3].

Currently, Kenya has a total of twelve schools of medicine from both private and public universities with only one of them, Moi University Medical School, being in UasinGishuCounty[4]. University of Eldoret was upgraded fromChepkoilel University College, a constituent ofMoi University in 2013 and given its own chatter by the then president MwaiKibaki. The University has currently been able to establish nine schools with approximately thirty four departments and a total student population of 14,000[5]. It has plans of establishing its own college of health sciences with several schools, one of them being the school of medicine.

According to [6], Kenya currently has a doctor to patient ratio of 1:17000 which is far from the recommended ratio of 1:1000 as per the World Health Organization. The shortage of the doctors has resulted in the long working hours for the doctors without leaves which eventually makes them unable to attend to the patients appropriately.The solution to the problem is by increasing the number of doctors which can be done by increasing the number of graduate doctors each year. The available universities offering the course have a specific capacity for intakes each year. Increasing the intakes beyond this capacity would be detrimental for appropriate learning hence necessitating the construction of more schools. This design and its subsequentconstruction will therefore eventually narrow the doctor to patient ratio gap being experienced in Kenya

Figure 1: Master plan of the UOE with several schools yet to be constructed amongst them School of medicine

Figure 2: Google map image of the proposed location of the school

2. Methodology

I. Preliminary research and planning

Visits were conducted to two school of medicine:

a. **Kisii medical school-** It is located in Kisii County, Kenya. The facilities in the school are Lecture rooms, multi-purpose hall, offices, Bio- Chemistry lab, pathology lab, anatomy lab, microbiology lab, skills/ demo lab, kitchen and toilets
b. **Moi University medical school-**It is located in UasinGishu County, Kenya. The facilities are Lecture rooms, histopathology lab, bio-chemistry lab, pathology lab, anatomy lab, microbiology lab, skills/ demo lab and a well-established cancer center.

Online research was also conducted on two international medical schools:

a. **Queen's university school of medicine-** It is located in Ontario Canada. The facilities in the school are Leading edge classrooms, surgical and technical skills laband simulation labs, Informal learning spaces, Student study space, a state of the art clinical center and dedicated rooms for small group learning.[7]
b. **UMass Chan medical school-** It is located in Worcester, Massachusetts, United States of America. The facilities in the school are Faculty conference room located on the first floor, three amphitheaters located

in the third, fifth and seventh floor, Goff learning center that contains a number of meeting and classrooms that has advanced audio-visual capability located on the first and second floor. [8]

II. Architectural Design

It was done using the ArchiCADsoftware. A three-storey building with a flat roof that have solar panels was designed. The building's dimension was 30m by 27.2m. The ground floor contained the pathology lab, skills lab, anatomy lab, microbiology lab, bio-chemistry lab as well as both ladies' and gent's washrooms. The first and second floor contained three lecture halls, one study room, eight offices each with washrooms and a common staffroom. The third floor contained a multi-purpose hall, Dean's office with a washroom, the administrator's office with a washroom, one store room and ladies' and gent's washroom.

Figure 3: ArchiCAD architectural design of the school

III. Structural Layout

The layout was proposed and drafted using AutoCAD software showing the position of beams, columns and slab panels. The columns were placed aligned to the walls to avoid visibility and maneuverability problems within the rooms.

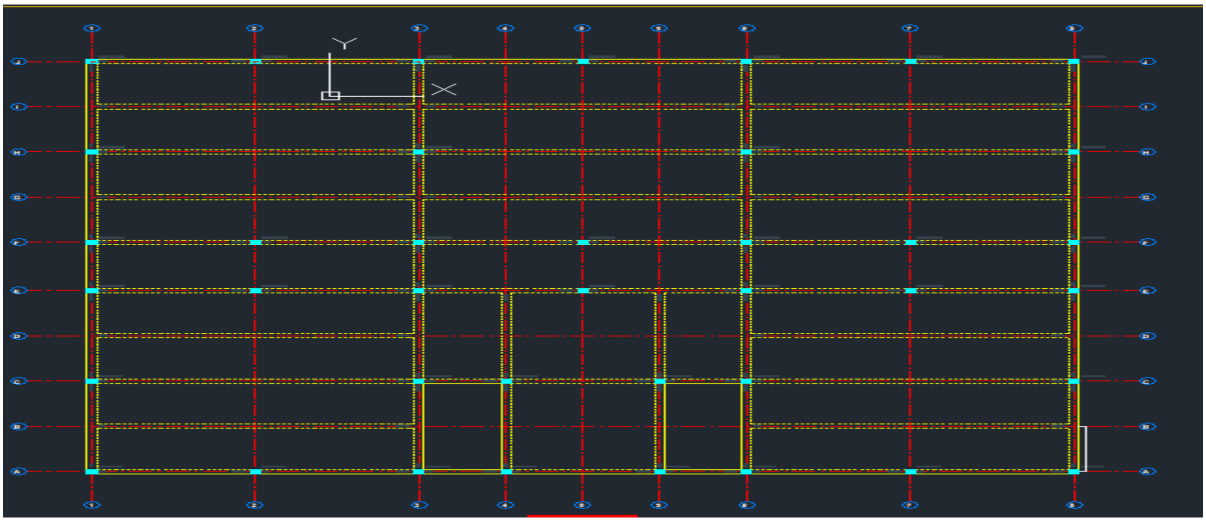


Figure 4: Structural layout drafted using AutoCAD

IV. Structural Design

Eurocodes standards were employed when designing the school. Prota Structure, TeklaTedds and hand calculations were used for the structural analysis and design of the structural concrete members.

a. **Prota Structure-** a model was designed from the structural layout drafted in AutoCAD for all the three floors. The following design parameters were used; wall thickness of 0.3m, wall height of 2.4m, wall unit weight of 3.71 KN/m^2, dead load 8.71KN/m, f_{yk} 500$N/mm^2$and f_{ck}25N/mm^2.

b. **TeklaTedds-** critical structural members were designed and included a critical slab of 10m by 3.2m, a three span continuous critical beam of 10m per span, a critical column of 0.3m by 0.4m and a critical column base supporting loads from the critical column with an assumed bearing pressure of 215 KN/m^2

c. **Hand Calculations-** critical structural members were designed.

3. Results and Discussion

Below is the critical beam as extracted from the ProtaStructure Software. The beam designed was a three span continuous beam whose dimension was 0.3*0.75m and spanning with 10m each span. The links provided were H8@200 center to center with a yield strength of 500N/mm^2. The reinforcement bars provided were 3H16, 3H20, 3H25 and 1H32 as shown in the figure with a yield strength of 500N/mm^2

Bending

	1B29	L=	10000mm	1B30	L=	10000mm	1B31	L=	10000mm
B_w / H (mm)		300 / 750			300 / 750			300 / 750	
Flange B_f / H_f									
(Left)	---		---		---				
(Right)									
Top Edge									
M (kN.m)	89.2	0.0	390.4	390.0	66.0	389.6	390.0	0.0	89.2
d (mm)	709.0	709.0	701.0	701.0	709.0	701.0	701.0	709.0	709.0
K/K'	0.08	0.00	0.37	0.37	0.06	0.37	0.37	0.00	0.08
x (mm)	88.6	88.6	126.1	125.9	88.6	125.8	125.9	88.6	88.6
A_{sm} (mm^2)	125.9	88.6	88.6	125.9	88.6	88.6	125.9	88.6	88.6
A_{sv} (mm^2)	429.35	403.41	635.55	523.78	291.64	523.68	635.44	403.30	429.57
A_s (mm^2)	304.48	403.41	1380.02	1378.69	517.16	1377.23	1378.56	403.30	304.75
A_s' (mm^2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$A_{s,min}$ (mm^2)	355.03	355.03	351.03	351.03	355.03	351.03	351.03	355.03	355.03
Bottom Edge									
M (kN.m)	214.2	356.7	0.3	0.0	183.1	0.0	0.3	357.0	214.3
d (mm)	692.0	704.5	692.0	692.0	707.0	692.0	692.0	704.5	692.0
K/K'	0.21	0.33	0.00	0.00	0.17	0.00	0.00	0.33	0.21
x (mm)	86.5	113.7	86.5	86.5	88.4	86.5	86.5	113.8	86.5
A_{sm} (mm^2)	86.5	113.8	86.5	86.5	113.8	86.5	86.5	113.8	86.5
A_{sv} (mm^2)	429.35	403.41	635.55	523.78	291.64	523.68	635.44	403.30	429.57
A_s (mm^2)	1178.89	1244.78	636.43	523.78	626.98	523.68	636.39	1245.96	1179.40
A_s' (mm^2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$A_{s,min}$ (mm^2)	346.52	352.78	346.52	346.52	354.03	346.52	346.52	352.78	346.52

Shear And Torsion Design

V_d (kN)	149.3		221.0	182.2		182.1	221.0		149.4
v (MPa)	0.70		1.05	0.87		0.87	1.05		0.70
V_{Rdc} (MPa)	0.53		0.53	0.52		0.53	0.53		0.53
$V_{Rd,max}$ (MPa)	5.42		5.42	5.42		5.42	5.42		5.42
V_{Rd} (kN)			340.3			340.3			340.3
V_{nom} (kN)		356.5			356.5			356.5	
T_d (kN.m)		0.0 $\leq T_{Min}$			0.0 $\leq T_{Min}$			0.0 $\leq T_{Min}$	
T_{Min} (kN.m)		13.0			13.0			13.0	
$b_{support}$ (mm)	0.0		0.0	0.0		0.0	0.0		0.0
Links	1H8-200	1H8-200	1H8-200	1H8-200	1H8-200	1H8-200	1H8-200	1H8-200	1H8-200

Deflection Check

L/d	14.19 ≤ 21.44 ✓	14.14 ≤ 75.17 ✓	14.19 ≤ 21.41 ✓

Steel Areas (mm^2)

	LE9JR7VCZZIZJJCH (Fenerbahce_Do Not Use COMMERCIAL)
Beam Reinforcement Design Rev: 1	Calc. By: Checked By:

Required									
Top Edge	304.48	403.41	1380.02	1378.69	517.16	1377.23	1378.56	403.30	304.75
Bottom Edge	1178.89	1244.78	636.43	523.78	626.98	523.68	636.39	1245.96	1179.40
Supplied									
Top Edge	603.19	603.19	1407.43	1407.43	603.19	1407.43	1407.43	603.19	603.19
Bottom Edge	1472.62	1472.62	1472.62	942.48	942.48	942.48	1472.62	1472.62	1472.62
Steel Bars									
Hanger Bars		3H16			3H16			3H16	
Top Bars									
Top.Sup.Bars			1H32	1H32		1H32	1H32		
Bottom Bars		3H25			3H20			3H25	
Bottom Bars									
Bot.Sup.Bars									
Side Bars									

Figure 5: Critical beam from ProtaStructure

Below is the critical slab designed using TeklaTedds software. The slab was a 150mm slab whose dimension was 10m by 3.2m. The steel reinforcement provided was H10@175 center to center with a yield strength of 500N/mm^2.

Tekla Tedds	Project				Job Ref.	
	Section				Sheet no./rev. 1	
	Calc. by H	Date 5/1/2024	Chk'd by	Date	App'd by	Date

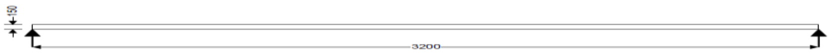
RC SLAB DESIGN

In accordance with EN1992-1-1:2004 incorporating corrigendum January 2008 and the UK national annex

Tedds calculation version 1.0.22

Design summary

Description	**Unit**	**Provided**	**Required**	**Utilisation**	**Result**
Support 1					
Span 1					
Tension reinf.	mm^2/m	449	317	0.705	PASS
Tension bar spacing	mm	175	193	0.905	PASS
Allow. span-to-depth ratio		26.67	37.15	0.718	PASS
Support 2					
Cover					
Min cover bottom	mm	25	20	0.800	PASS



Slab definition

Slab reference name	**CRITICAL ONE WAY SLAB**
Overall slab depth	h = **150** mm
Number of spans	N_{spans} = **1**
First support	**Simple**
Last support	**Simple**
Nominal cover to bottom reinforcement	c_{nom_b} = **25** mm
Loading	
Ratio of quasi-permanent to ultimate load	r_q = **0.800**
Concrete properties	
Concrete strength class	C25/30
Characteristic cylinder strength	f_{ck} = **25** N/mm^2
Partial factor (Table 2.1N)	γ_C = **1.50**
Compressive strength factor (cl. 3.1.6)	α_{cc} = **0.85**
Design compressive strength (cl. 3.1.6)	f_{cd} = **14.2** N/mm^2
Mean axial tensile strength (Table 3.1)	$f_{ctm} = 0.30\ N/mm^2 \times (f_{ck} / 1\ N/mm^2)^{2/3}$ = **2.6** N/mm^2
Maximum aggregate size	d_g = **20** mm
Reinforcement properties	
Characteristic yield strength	f_{yk} = **500** N/mm^2
Partial factor (Table 2.1N)	γ_S = **1.15**
Design yield strength (fig. 3.8)	$f_{yd} = f_{yk} / \gamma_S$ = **434.8** N/mm^2
Concrete cover to reinforcement	
Nominal cover to bottom reinforcement	c_{nom_b} = **25** mm
Fire resistance period to bottom of slab	R_{btm} = **60** min
Axis distance to bottom reinft (Table 5.8)	a_{fi_b} = **20** mm

Tekla Tedds	Project				Job Ref.	
	Section				Sheet no./rev. 2	
	Calc. by H	Date 5/1/2024	Chk'd by	Date	App'd by	Date

Max bar diameter in bottom	ϕ_{max_b} = **10** mm
Min. btm cover requirement with regard to bond	$c_{min,b\_b} = \phi_{max\_b}$ = **10** mm
Reinforcement fabrication	**Not subject to QA system**
Cover allowance for deviation	Δc_{dev} = **10** mm
Min. required nominal cover to bottom reinft	$c_{nom\_b\_min} = \max(a_{fi\_b} - \phi_{max\_b} / 2, c_{min,b\_b} + \Delta c_{dev})$ = **20.0** mm

PASS - There is sufficient cover to the bottom reinforcement

Bending design checks

Redistribution ratio	δ = **1.0**
Limiting value of K	$K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208**

Reinforcement design at midspan of span 1 (cl.6.1)

Length of span 1	l_1 = **3200** mm
Design bending moment	M_{p1} = **15.7** kNm/m
Reinforcement provided	**10 mm dia. bars at 175 mm centres**
Area provided	A_{sp1} = **449** mm^2/m
Effective depth to tension reinforcement	$d_{p1} = h - c_{nom\_b} - \phi_{p1} / 2$ = **120.0** mm
K factor	$K = M_{p1} / (b \times d_{p1}^2 \times f_{ck})$ = **0.044**

K < K' - Compression reinforcement is not required

Lever arm	$z = \min(0.95 \times d_{p1}, d_{p1} / 2 \times (1 + \sqrt{1 - 3.53 \times K}))$
	z = **114.0** mm
Area of reinforcement required for bending	$A_{sp1\_m} = M_{p1} / (f_{yd} \times z)$ = **317** mm^2/m
Minimum area required	$A_{sp1\_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{p1}$ = **160** mm^2/m
Area of reinforcement required	$A_{sp1\_req} = \max(A_{sp1\_m}, A_{sp1\_min})$ = **317** mm^2/m

PASS - Area of tension reinforcement provided is adequate (0.705)

Check reinforcement spacing

Reinforcement service stress	$\sigma_s = (f_{yk} / \gamma_S) \times \min((A_{sp1\_m}/A_{sp1}), 1.0) \times r_q$ = **245.3** N/mm^2
Maximum allowable spacing (Table 7.3N)	s_{max_p1} = **193** mm
Actual bar spacing	s_{p1} = **175** mm

PASS - The reinforcement spacing is acceptable

Shear design checks

Shear resistance constant (cl. 6.2.2)	$C_{Rd,c} = 0.18\ N/mm^2 / \gamma_C$ = **0.12** N/mm^2

Shear capacity check at support 1

Shear force	V_1 = **19.6** kN/m
Reinforcement provided	**10 mm dia. bars at 175 mm centres**
Area provided	A_{sd1} = **449** mm^2/m
Effective depth	$d_{d1} = h - c_{nom\_b} - \phi_{d1} / 2$ = **120.0** mm
Effective depth factor (cl. 6.2.2)	$k = \min(2.0, 1 + (200\ mm / d_{d1})^{0.5})$ = **2.000**
Reinforcement ratio	$\rho_l = \min(0.02, A_{sd1} / (b \times d_{d1}))$ = **0.0037**
Minimum shear resistance (Exp. 6.3N)	$V_{Rd,c\_min} = 0.035\ N/mm^2 \times k^{1.5} \times (f_{ck} / 1\ N/mm^2)^{0.5} \times b \times d_{d1}$
	V_{Rd,c_min} = **59.4** kN/m
Shear resistance (Exp. 6.2a)	$V_{Rd,c1} = \max(V_{Rd,c\_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1\ N/mm^2))^{0.333} \times b \times d_{d1})$
	$V_{Rd,c1}$ = **60.6** kN/m

Tekla Tedds	Project				Job Ref.	
	Section				Sheet no./rev. 3	
	Calc. by H	Date 5/1/2024	Chk'd by	Date	App'd by	Date

PASS - Shear capacity is adequate (0.324)

Shear capacity check at support 2	
Shear force	V_2 = **19.6** kN/m
Reinforcement provided	**10 mm dia. bars at 175 mm centres**
Area provided	A_{sd2} = **449** mm²/m
Effective depth	$d_{d2} = h - c_{nom\_b} - \phi_{d2} / 2$ = **120.0** mm
Effective depth factor (cl. 6.2.2)	$k = \min(2.0, 1 + (200\ mm / d_{d2})^{0.5})$ = **2.000**
Reinforcement ratio	$\rho_l = \min(0.02, A_{sd2} / (b \times d_{d2}))$ = **0.0037**
Minimum shear resistance (Exp. 6.3N)	$V_{Rd,c\_min} = 0.035\ N/mm^2 \times k^{1.5} \times (f_{ck} / 1\ N/mm^2)^{0.5} \times b \times d_{d2}$
	V_{Rd,c_min} = **59.4** kN/m
Shear resistance (Exp. 6.2a)	$V_{Rd,c2} = \max(V_{Rd,c\_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1\ N/mm^2))^{0.333} \times b \times d_{d2})$
	$V_{Rd,c2}$ = **60.6** kN/m
	PASS - Shear capacity is adequate (0.324)
Deflection checks	
Basic span-to-depth ratio deflection check span 1 (cl. 7.4.2)	
Reference reinforcement ratio	$\rho_0 = (f_{ck} / 1\ N/mm^2)^{0.5} / 1000$ = **0.0050**
Required tension reinforcement ratio	$\rho = \max(0.0035, A_{sp1\_m} / (b \times d_{p1}))$ = **0.0035**
Required compression reinforcement ratio	$\rho' = A_{scp1\_req} / (b \times d_{p1})$ = **0.0000**
Structural system factor (Table 7.4N)	K_δ = **1.0**
Basic span-to-depth ratio limit	$ratio_{lim1\_bas} = K_\delta \times [11 + 1.5 \times (f_{ck}/1\ N/mm^2)^{0.5} \times \rho_0/\rho + 3.2 \times (f_{ck}/1\ N/mm^2)^{0.5} \times (\rho_0/\rho - 1)^{1.5}]$
(Exp. 7.16a)	$ratio_{lim1\_bas}$ = **26.20**
Modified span-to-depth ratio limit	
	$ratio_{lim1} = \min(40 \times K_\delta, \min(1.5, (500\ N/mm^2 / f_{yk}) \times (A_{sp1} / A_{sp1\_m})) \times ratio_{lim1\_bas})$ = **37.15**
Actual span-to-depth ratio	$ratio_{act1} = l_1 / d_{p1}$ = **26.67**
	PASS - Span-to-depth ratio is acceptable (0.718)
Reinforcement summary	
Midspan in span 1	**10 mm dia. bars at 175 mm centres**
Discontinuous support 1	**10 mm dia. bars at 175 mm centres**
Discontinuous support 2	**10 mm dia. bars at 175 mm centres**

Figure 6: Critical slab designed in TeklaTedds

Structural analysis and design through hand calculations are as shown below. The steel reinforcement provided was 4H20 with a yield strength of 500N/mm². The design specifications used for example permanent and variable actions, cover specifications were as extracted from[9].

References	CL03 DESIGN	Remarks
	CTITICAL COLUMN CALCULATIONS USING EC2	
EC2-1-1:2004 E	1. SPECIFICATIONS	
	Characteristic strength of concrete, f_{ck} = 30 N/mm²	
	X-stic strength of reinforcement, f_y = 500 N/mm²	
	The column is axially loaded	
Table 4.1	*Exposure conditions:* **XC1**	
Table 4.3N	Strength class : C30/37	
Table 4.4N	For structural class, S4: XC 1, Cmin ,dur =15 mm	
Cl 4.4.1.2	Cmin = Max (Cmin,b; Cmin, dur; 10mm)	
	Assume diameter of main steel = 20mm	
Table 4.2	Therefore Cmin,b =20 mm	
	Nominal cover to all reinforcement	
Cl 4.4.1.1	Cnom = Cmin + C dev	
Cl 4.4.1.3	Cdev = 10mm	
	Cmin =max (20mm; 15mm; 10mm)= 20mm	
	Cnom = 20mm + 10mm =30mm	Cnom= 30 mm
	1.2 Initial Proportioning	
	1.1.2. Floor Slab (150 mm thick)	
	Permanent Action	
	• Selfweight = (150/1000)m * 25kN/m³	
	= 3.75 kN/m²	
	• Finishes = 2.0 kN/m²	
	Total dead load = 5.8 kN/m²	
	Variable Action	
	Imposed Load = 3 kN/m²	
	Ultimate Action	
Table 2.1	Permanent and Variable action combination	
	= 1.35gk + 1.5 qk	
	= 1.35(5.75) + 1.5(3)	
	= 12.26 kN/m²	
	Area of slab acting on CL01; *l* = 5m	
	A = 5 * 3 *w* = 3m	
	= 15 m²	
	Total roof load = 12.26 * 15	
	= 183.9 kN	

1.2. Column Self Weight (Take dimension 300 X 300)

G_k = 0.3m*0.3m*2.4m*25kN/m^3
= 5.4 kN
F_d = 1.35(5.4)
= 7.29 kN

1.3. Beam Self Weight (750 x 300)

G_k = (750-150)/1000 * (300/1000) * (5 + 3) * 25
= 36 kN
F_d = 1.35(36)
= 48.6 kN

1.4. Wall Loads (300 mm wall)

G_k = 0.3*2.4*8*18
= 103.68 kN
F_d = 1.35(103.68)
= 139.97 kN

1.5. Total Loading

	Slab Load	Col swt	Beam swt	Walling	otal (kN)
Roof - 3rd Floor	183.9	7.29	48.6	0	**239.8**
3rd - 2nd Floor	183.9	7.29	48.6	139.97	**619.6**
2nd - 1st Floor	183.9	7.29	48.6	139.97	**999.3**
1st - Ground Floor	183.9	7.29	48.6	139.97	**1379**

NEd = 1379.07 kN

Cross Section :use equation below to size the column:
$n_u = 1 + \omega = 1 + A_s f_{yd}/A_c f_{cd}$

Cl.9.5.2 Percentage of longitudinal reinforcement,
As, should generally lie within the following limits
greater of 0 10N_{Ed}/ fyd and 0.002A_c < A_s < 0.04A_c
Assuming that the percentage of reinforcement is equal to, say, 2 per cent gives
A_{sc} = 0.02A_c

Substituting N_{Ed} into the above equation gives
*(1.379*10^6)/Ac(0.85*30/1.5)=1+ ((0.02 Ac(500/1.15))/Ac(0.85*(30/1.5)))*
81117.65/Ac= 1.51
Ac = 53720.3 mm²
For a square column b = h = √53720.3 = 231.77 mm — b= 300mm
Therefore a 300 mm square column is suitable. — h= 300mm

4. Structural Analysis

The column is braced
It is fixed at the top and bottom
Slenderness ratio
(a) Effective height

k beam A = 2(EI/L)A = (2*E*300*750^3)/(12*5000) = 4.22 × 10^6 E

k beam B = 2(EI/L)A = (2*E*300*750^3)/(12*5000) = 4.22 × 10^6 E

k column = EI/L = (E*300*300^3)/(12*2400) = 2.1825 × 10^5 E

$K_1 = K_2$

EC2: PD 6687 Cl 2.10 — k_G = kcolumn G/(kbeamA + kbeamB)= (2.1825*10^5)E/2(4.22*10^6)E = 0.033

k_H = 0.1 (since column is assumed to be fully fixed at the base)

lo= 0.5l sqrt{[1+k1/(0.45+k1)][1+k2/(0.45+0.1)]}
0.5*2400 sqrt{[1+0.1/(0.45+0.1)][1+0.1/(0.45+0.1)]} - 1845 mm

Radius of Gyration
i= sqrt(I/A)
sqrt[(bh^3 /12)/(bh)]= h/sqrt(12)= 300/sqrt(12) =
i= 86.60mm

Cl.5.8.3.2 **Slenderness ratio**
λ = lo/I = 1845/86.60 = 21.3

Critical Slenderness Ratio
Cl.5.8.3.1 λ_{lim} = 20 ABC*sqrt(n)
A = 0.7, B = 1.1, C = 1.7 − rm
C= 1.7 − (M_{01}/M_{02}) = 1.7 − (−29.4/58.8) = 2.2
n= $N_{Ed}/A_c f_{cd}$ = 1379.07 × 10^3 /300 × 300 × (0.85/1.5) × 30 = 0.9

λ_{lim} = 20 *0.7*1.1*2.2*sqrt(0.9) = 35.71
λ_{lim} > λ therefore column is not slender — (stocky) short braced column
and M = 0 kNm

5. Reinforcement
Effective depth,d = h - cover - Φlink - Φbar/2
300 - 30 - 8 - 20/2 = 252 mm — d= 252mm

Minimum design moment, M_{Ed}
M_{Ed} = Max(Mo<, eo N_{Ed})

Cl.6.1(4) All compression members are subjected to a minimum ecentricity
Minimum ecentricity, eo= h/30 = 300/30 = 10 mm < 20 mm take 20mm
Minimum design moment = eo N_{Ed} = (20/1000)* 137: 27.58 kNm
First order end moment, M_{02} = Max {|Mtop|,|M bottom|} + ei .NEd =
ei = lo/400 = 1845/400 = 4.6125
Mtop = 27.53*2 = 55.16

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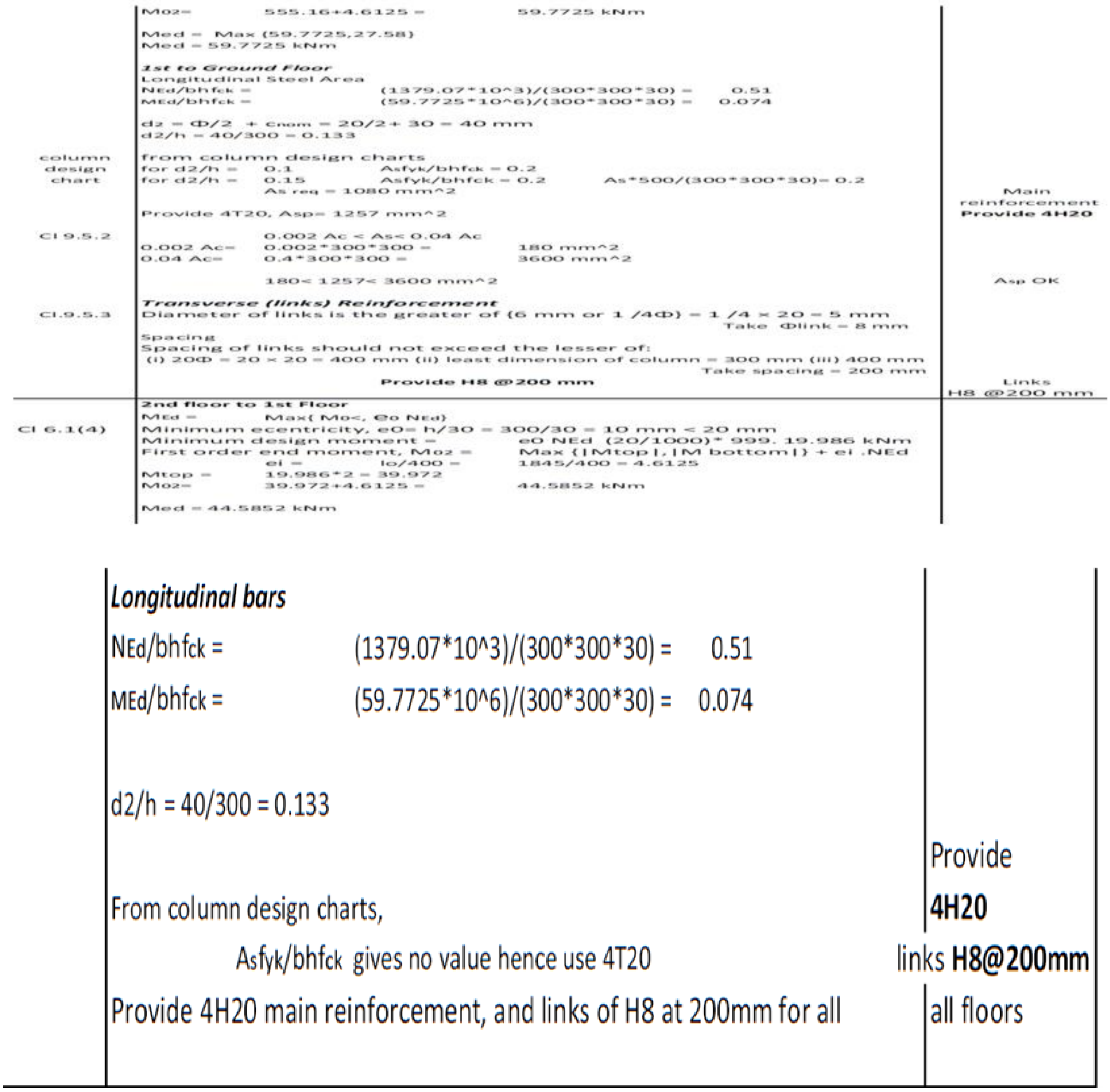

Mo2= 555.16+4.6125 = 59.7725 kNm

Med = Max (59.7725,27.58)
Med = 59.7725 kNm

1st to Ground Floor
Longitudinal Steel Area
NEd/bhfck = (1379.07*10^3)/(300*300*30) = 0.51
MEd/bhfck = (59.7725*10^6)/(300*300*30) = 0.074

d2 = Φ/2 + cnom = 20/2+ 30 = 40 mm
d2/h = 40/300 = 0.133

column design chart | from column design charts
for d2/h = 0.1 Asfyk/bhfck = 0.2
for d2/h = 0.15 Asfyk/bhfck = 0.2 As*500/(300*300*30)= 0.2
As req = 1080 mm^2

Provide 4T20, Asp= 1257 mm^2 | Main reinforcement **Provide 4H20**

Cl 9.5.2 | 0.002 Ac < As< 0.04 Ac
0.002 Ac= 0.002*300*300 = 180 mm^2
0.04 Ac= 0.4*300*300 = 3600 mm^2

180< 1257< 3600 mm^2 | Asp OK

Cl.9.5.3 | *Transverse (links) Reinforcement*
Diameter of links is the greater of (6 mm or 1 /4Φ) = 1 /4 × 20 = 5 mm
Take Φlink = 8 mm
Spacing
Spacing of links should not exceed the lesser of:
(i) 20Φ = 20 × 20 = 400 mm (ii) least dimension of column = 300 mm (iii) 400 mm
Take spacing = 200 mm
Provide H8 @200 mm | Links H8 @200 mm

2nd floor to 1st Floor
MEd = Max(Mo<, eo NEd)
Cl 6.1(4) | Minimum ecentricity, e0= h/30 = 300/30 = 10 mm < 20 mm
Minimum design moment = e0 NEd (20/1000)* 999. 19.986 kNm
First order end moment, Mo2 = Max {|Mtop|,|M bottom|} + ei .NEd
ei = lo/400 = 1845/400 = 4.6125
Mtop = 19.986*2 = 39.972
Mo2= 39.972+4.6125 = 44.5852 kNm

Med = 44.5852 kNm

Longitudinal bars
NEd/bhfck = (1379.07*10^3)/(300*300*30) = 0.51
MEd/bhfck = (59.7725*10^6)/(300*300*30) = 0.074

d2/h = 40/300 = 0.133

From column design charts, | Provide **4H20**
Asfyk/bhfck gives no value hence use 4T20 | links **H8@200mm**
Provide 4H20 main reinforcement, and links of H8 at 200mm for all | all floors

Figure 7: Hand Calculation using Eurocodes Standards

The table below is a summary of the design of the critical members as carried out by hand calculation, TeklaTedds and ProtaStructure

Critical Element		Hand Calculation	TekklaTedds	ProtaStructure
SLAB	Area of steel required	316mm^2	317mm^2	200mm^2
	Area of steel provided	T10 @ 200C/C, Area= 393mm^2	T10 @ 175C/C Area=449mm^2	T10 @ 200C/C, Area= 392mm^2
BEAM (Highest moment was considered)	Area of steel required	1772 mm^2	2385mm^2	1381mm^2
	Area of steel provided	4H25 Area= 1963mm^2	3H25+2H25 2484mm^2	3H16+ 1H32 1407mm^2
COLUMN	Area of steel required	1080mm^2 N=1379 KN	N=1379KN	N=2007KN
	Area of steel provided	4H20 Area= 1257mm^2	6H16 Area=1206mm^2	6H20 Area=1886mm^2
COLUMN BASE	Area of steel required	1761mm^2	2607mm^2	3000mm^2

	Area of steel provided	H16@300C/C Area= $1809mm^2$ 2700*2700*600mm	H16@200C/C Area= $3016mm^2$ 2800*2800*600 mm	H16@ 200C/C Area= $3016mm^2$ 3000*3000*600 mm

4. Conclusion and Recommendation

In every design process, use of both software and hand calculations is encouraged. Software most especially BIM software save on time but should be complimented with hand calculations of at least the critical members to ascertain the accuracy of the software. For actualization of efficient, safe and economical structures, construction should be done in adherence to the design provided. The actualization and construction of this design will reap several benefits like increasing employment, increasing the doctor to patient ratio hence improving the health sector and decreasing the pressure imposed on the school of medicine available in Kenya.

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