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Research Article

A Comparative Study of Rectangular Beam Depth Effects Under EBCS-1995 and ES EN-2015 Codes

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Abstract

To achieve structural integrity, serviceability, and economy of buildings, national and international building standards are used for dimensioning and proportioning of structural members. Building codes may be amended due to, the existence of new construction materials, technologies, and structures, and to improve earlier gaps. Ethiopia has experienced three building codes in the last 40 years. Those codes were the Ethiopian Standard Code of Practice, ESCP 1983-1995, Ethiopian Building Code of Standard, EBCS-1995, and the Ethiopian Standard, ES EN 2015. Design code compliance design and supervision of buildings is one of the major ways to achieve the planning, design, construction, service life as well as overall performance of projects. This study is conducted on the depth determination of an interior RC beam with different span and steel grades under EBCS-1995 and ES EN-2015 design codes. The result of this study proves that EBCS 1995 is uneconomical for shear and moment design for longer spans, and preferable for smaller spans, while ES EN 2015 provides smaller serviceable depth and deflection and maintains economical design for longer spans. Construction professionals need to understand the basic purpose of code amendment and should use the new design code as a major design reference and the earlier code accordingly.

Keywords

Effective Depth, Serviceability Depth, Ultimate Depth, Span-to-Depth Ratio, Design Code

1. Introduction

The structural strength, serviceability, as well as economy of a reinforced concrete structure, primarily depend on the geometric dimension of a member aligned with the quality of the material, the function of the structure, and the load expected to be resisted. According to [1] the influence of prestressing TRM on bearing capacity, fracture characteristics, and ductility 3 RC beam was studied experimentally and it was concluded that the crack load, yield load, and ultimate load can be significantly increased by prestressing TRM reinforcement, and the yield load can be increased by more than 30%. Based on the study [2] conducted numerical and experimentally investigation on the performance of reinforced concrete (RC) beams with unequal depths subjected to combined bending and shear and the results confirmed that geometric properties(shape and depth) affect the cracking, yielding level, ultimate load carrying capacity and mode of failure modes. The side effects on beams with small shear span-to-depth ratios less than 1.15 using finite element modeling technics are investigated and the results indicate for shear span-to-depth ratio less than 1.15, the size of the beam doesn't have effect [3]. The effect of beam depth on the performance of shear-deficient beams externally strengthened

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with carbon fiber–reinforced polymer composites was investigated on parameters like ductility, cracks, and failures, and the results showed that externally bonded carbon fiber-reinforced polymer increased the shear capacity of the beam [4]. The effect of various concrete grades on composite members of framed structures experimentally using rolled steel sections as reinforcement cast was studied. According to his findings the results of failure loads and deformations in flexure and axial compression show that, the use of rolled steel sections as reinforcement proves to be advantageous even for variations in grades of concrete [5]. The effect of Cross Section Dimensions on Stiffness and Deflection on Reinforced Concrete Beams using the Response-2000 application program was studied to determine deflection values, maximum load, crack width, and stiffness by modeling 10 beam specimens with dimensional variations but the same cross-sectional area. The results of the study show that beams with the same surface area but different shapes of different dimensions greatly affect the deflection value, maximum load, crack width, and stiffness [6]. The research study [7] indicates that the minimum thickness based on ACI recommendation for a fixed-ended beam under a given grade of steel and concrete is L/21. The authors studied the Comparison of design calculations of Deep beam design using three codes namely the Indian standard code, the American Concrete Institute code, and the Construction Industry Research and Information Association code. The author noted that, for structural members exposed to public view or environmental elements, the serviceability performance of the structure is arguably as significant as its strength. After a detailed comparison, he concludes that the Indian standard code gives the maximum total reinforcement which means for the same size and loading condition out of all the three codes and span-to-depth ratio,(l/D) is an important parameter to decide the amount of reinforcement in the three codes [8].

A computer program-based, analytical, and experimental study was conducted to investigate the effects of loading types and reinforcement ratio on the deflection and crack resistances of the beam, and the results from the three methods were agreed [9]. The experimental study on the effects of shear span-to-depth ratio on shear strength components of RC beams was investigated and the result at small shear span-to-depth ratio (a/d), Vc is much larger than Vcr, while it is the opposite for beams with a large and value [10]. According to the Analysis of Stress and Deflection of rectangular section Cantilever Beam subjected to three different loads point load, UDL load, and UVL independently, and also the study is validated by ANSYS. The analytical and finite element nodal stress and displacement values were calculated and showed minimum differences between the two methods [11]. In research conducted on mathematical modeling of a beam subjected to different loading conditions, the effects of the moment of inertia (I), Young's modulus (E), load (W), and compressive force (P) on deflection variation were formulated [12]. The effect of the shear span-to-depth (a/d) ratio on the shear behavior of steel reinforced grout (SRG)-strengthened reinforced concrete (RC) beams is experimentally investigated on Four critical shear spans corresponding to and ratios of 1.60, 2.10, 2.60, and 3.10 on twelve beams cast in four series of three specimens and the result reveals that the efficacy of the SRG significantly increased with an increase in a/d ratio in deep beams but deteriorated as and ratio increase in slender beams [13].

Reinforced concrete beams, slabs, and stairs are dimensioned to comply with the limits of span-to-depth ratio aimed at satisfying structural, architectural, and economical requirements. Design codes are well-structured documents and standards used as a reference for project work, and academic, and research purposes of a discipline under consideration. Ethiopia as a nation has experienced three national building codes in the last 40 years primarily based on Eurocodes norms with minor and major modifications. Those codes were the Ethiopian Standard Code of Practice, ESCP, 1983-1995, Ethiopian Building Code of Standard, EBCS, 1995-2015, and Ethiopian Standard, ES EN-2015-Onward. Different international building Codal standards recommend different formulas to determine the serviceability and ultimate depth of RC sections.

According to EBCS-2-1995, Section 5.2.2, the minimum effective depth of the beam to control deflection under the satisfaction of serviceability requirements is given as follows [14].

$$d \geq (0.4+0.6*fyk/400)*Le/\beta\alpha \quad (1)$$

Eqn. (1) can be written in the form of span-to-depth ratio as,

$$\frac{le}{d} = \frac{400\beta_\alpha}{160+0.6fyk}$$

Where,

d: minimum depth from serviceability requirement, mm

fyk: characteristics strength of reinforcement, Mpa

le: effective length, C/C distance between beam supports

βa: appropriate constant depending on the support condition

Table 1. *Coefficients Ba, to take into account support conditions.*

Beam type	Simply supported span	End Span	interior span	Cantilever span
Bα	20	24	28	10

Source: EBCS-2-1995, Table 5.1

According to ES EN 1992-1-1:2015 section 7.4 expression (7.16a), the minimum depth of the beam to control deflection under the satisfaction of serviceability requirements is given as follows [15].

$$l/d = k\ [11+1.5\sqrt{fck}*\rho o/\rho\ +3.2\sqrt{fck}*\ (\rho o/\rho\ -1)3/2],\ if\ \rho \le \rho o \quad (2)$$

Where l/d is the limit span/depth ratio

k is the factor to take into account the different structural systems;

ρo is the reference reinforcement ratio = $\sqrt{fck}*10^{-3}$;

ρ is the required tension reinforcement ratio at mid-span to resist moment due to design loads

fck is cylindrical characteristics compressive strength of the concrete in MPa units.

For another steel grade, multiply Equn-(2) by $\left(\frac{500}{f_{yk}\left(\frac{A_{st.req}}{A_{st,prov}}\right)}\right)$

If the span of the beam is greater than 7m multiply Eqn. (2) by $7/L_{eff}$

$A_{st,\ required}$ is assumed to be $A_{st,\ provided}$ and ρ is taken as 0.5% for slightly stressed concrete

Table 2. *Cofficients Ba, to take into account Support conditions.*

Beam Type	Simply Supported Span	End Span	Interior Span	Cantilever Span
K	1.0	1.3	1.5	0.4

ES EN 1992-1-1:2015, Table 7.4N

EBCS-1995 is the oldest version of Ethiopia's building design standard, which was used for 20years as a normative design reference for building structures in Ethiopia. However, due to the changes in building design parameters related to material, construction technologies, environmental, complexity of planning, and design requirements EBCS-1995 is no longer used beyond 2015. ES EN 1992-1-1:2015 is currently the adopted building design standard since 2015, which is based on European design norms with minor and major modifications intended to achieve the current and future planning, design, and construction requirements. Some comparative studies among international design codes and among different versions of national building codes have been conducted.

The confusion in not using the new codes effectively and old version codes accordingly causes various planning, designing and cost estimation dilemma and technical errors in current building works. There is wide literature gap that are justifying the gaps of earlier or current design codes and the reasons for design code amendments. The main objective of this comparative analytical study is to show the clear reason for the amendment of the design code considering the most frequent beam element which is interior beam. This codal comparative study will give international research, academic as well as design information importance.

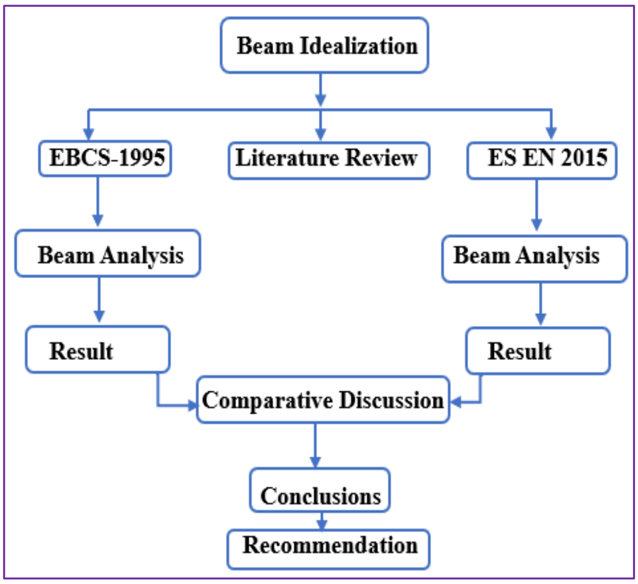

Figure 1. *Study Framework (source: Author 2024).*

2. Methods and Materials

This study is an analytical and comparative study in which the whole process is depicted in Figure 1 below.

2.1. Model Specification

A slightly reinforced concrete intermediate beam with a C/C effective span of 3m, 3.5m, 4m, 4.5m, 5m, 5.5m, 6m, 6.5m, 7m, 7.5m, and 8m made of steel grade fyk, 300Mpa, 400Mpa, 500Mpa, 600Mpa, and concrete grade fcu, 25mpa, longuditinal reinforcement, ϕ20mm, a shear reinforcement, ϕ8mm is considered for this study. The beam is supposed to carry LL of $4KN/m^2$ from the floor, its self-weight, DL and superimposed dead leadup of 8KN/m. The beam is analyzed based on linear elastic analysis with 0% moment redistribution considering the ultimate limit state, ULS and serviceability limit state, and SLS design philosophies. From Codal provision and design experience, the width of the beam is assumed D/2 to D/1.5, for this study the author assumes b = D/2, where D is the total depth and B is the width of the section. Assuming moderate weather conditions cover for beam 25mm based on EBCS-1995 and 30mm based on ES EN 2015.

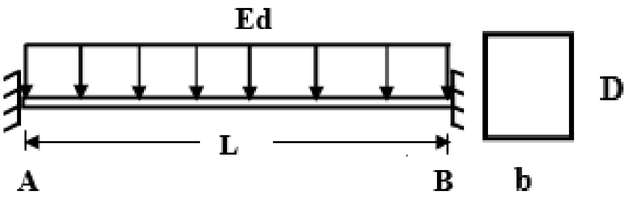

Figure 2. An ideal Model of intermediate beam.

2.2. Comparative Parameters

For comparative study of serviceability depth under the two-design code, the following parameters are used.

Table 3. Analytical and Comparative Codal Parameters.

Comparative Parameters		EBCS-1995	ES EN-2015
Span-to-depth ratio	L/d	400βα/(160+0.6fyk)	$K\ [11+1.5\sqrt{fck}*\frac{\rho o}{\rho}+3.2\sqrt{fck}*(\frac{\rho o}{\rho}-1)^{3/2}]$
Serviceable depth	D	L/(L/d)	L/(L/d)
Total depth	D	$d+CC+\phi_s+\phi_L/2$	$d+CC+\phi_s+\phi_L/2$
Total width	B	D/2	D/2
Dead load	DL	ϒc*D*b	ϒc*D*b
Live load	LL	Depends on building's function	Depends on building's function
Design load	W=Ed	1.3DL+1.3SUPDL+1.6LL	1.35DL+1.35SUPDL+1.5LL
Service load	w	DL+LL	DL+LL
Moment of inertia	I	$bD^3/12$	$bD^3/12$
Elastic Modulus	Ecm	$9.5(fck+8)^{1/3}$	$22((cm/10))^{0.3}$
Calculated Deflection	Δ_{cal}	$wl^4/384EI$	$wl^4/384EI$
Allowable Deflection	Δ_{all}	Le/200	Le/250
Maximum Moment	Max	$Wl^2/12$	$Wl^2/12$
Maximum Shear	Vmax	Wl/2	Wl/2
Critical design shear	Vcr	Vmax(L-2d)/L, d in m	Vmax(L-2d)/L, d in m
Flexural Depth	du	$\sqrt{Mmax/0.2952*b*fcd}$	$\sqrt{Mmax/0.2942*b*fcd}$

Source: (EBCS 1995 and ES EN 2015)

3. Model Analysis

All essential parameters related to beam depth were analyzed using an excel template under the recommendations of the two design codes. That parameter includes maximum eflection, allowable deflection, maximum shear, critical design shear, maximum moment, serviceability depth, and ultimate depth.

4. Results and Discussions

The numerical values of comparative parameters for a given beam of different span and steel grade are computed using an Excel sheet with the respective design codes of ES EN-2015 and EBCS-1995. those tabular results are plotted in graphical form for clear comparison.

Table 4. Excel results for comparative parameters under EBCS 1995, for Fyk=300Mpa.

L(m)	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
L/d	33	33	33	33	33	33	33	33	33	33	33
d(mm)	91.07	106.25	121.43	136.61	151.79	166.96	182.14	197.32	212.50	227.68	242.86
D(mm)	134.07	149.25	164.43	179.61	194.79	209.96	225.14	240.32	255.50	270.68	285.86
b(mm)	67.04	74.63	82.21	89.80	97.39	104.98	112.57	120.16	127.75	135.34	142.93
DL(KN/m)	0.22	0.28	0.34	0.40	0.47	0.55	0.63	0.72	0.82	0.92	1.02
LL (KN/m)	4	4	4	4	4	4	4	4	4	4	4
Ed (KN/m)	17.09	17.16	17.24	17.32	17.42	17.52	17.62	17.74	17.86	17.99	18.13
w (KN/m)	12.22	12.28	12.34	12.40	12.47	12.55	12.63	12.72	12.82	12.92	13.02
I (mm4)	1E+07	2E+07	3E+07	4E+07	6E+07	8E+07	1E+08	1E+08	2E+08	2E+08	3E+08
Δall(mm)	15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40
Δcal(mm)	6.60	8.00	9.31	10.53	11.67	12.74	13.73	14.67	15.56	16.41	17.21
Mmax(KNm)	12.82	17.52	22.99	29.23	36.28	44.16	52.87	62.45	72.93	84.33	96.68
Vmax(KN)	25.64	30.03	34.48	38.98	43.54	48.17	52.87	57.65	62.51	67.46	72.51
Vcr(KN)	24.08	28.21	32.39	36.61	40.90	45.25	49.66	54.15	58.72	63.37	68.11
du(mm)	239.11	264.94	289.12	311.98	333.75	354.62	374.73	394.21	413.15	431.63	449.72

Table 5. Excel result for comparative parameters under ES EN 2015, for fyk=300Mpa.

L(m)	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
L/d	44.27	44.27	44.27	44.27	44.27	44.27	44.27	44.27	44.27	41.32	38.74
d(mm)	67.77	79.06	90.35	101.65	112.94	124.24	135.53	146.82	158.12	181.51	206.52
D(mm)	115.77	127.06	138.35	149.65	160.94	172.24	183.53	194.82	206.12	229.51	254.52
b(mm)	57.88	63.53	69.18	74.82	80.47	86.12	91.77	97.41	103.06	114.76	127.26
DL(KN/m)	0.17	0.20	0.24	0.28	0.32	0.37	0.42	0.47	0.53	0.66	0.81
LL (KN/m)	4	4	4	4	4	4	4	4	4	4	4
Ed (KN/m)	17.03	17.07	17.12	17.18	17.24	17.30	17.37	17.44	17.52	17.69	17.89
w (KN/m)	12.17	12.20	12.24	12.28	12.32	12.37	12.42	12.47	12.53	12.66	12.81
I (mm4)	7.5E+6	1.1E+7	1.5E+7	2.1E+7	2.8E+7	4E+7	4.7E+7	6.0E+7	7.5E+7	1.2E+8	1.7E+8
Δall(mm)	12.00	14.00	16.00	18.00	20.00	22.00	24.00	26.00	28.00	30.00	32.00
Δcal(mm)	11.43	14.64	17.82	20.92	23.92	26.80	29.56	32.20	34.73	30.07	26.05
Mmax(KNm)	12.77	17.43	22.83	28.99	35.91	43.61	52.11	61.41	71.53	82.92	95.43
Vmax(KN)	25.54	29.88	34.25	38.65	43.09	47.58	52.11	56.68	61.31	66.33	71.57
Vcr(KN)	24.39	28.53	32.70	36.90	41.15	45.43	49.75	54.12	58.54	63.12	67.88

L(m)	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
du(mm)	257.26	286.88	314.66	340.92	365.89	389.78	412.73	434.87	456.31	465.58	474.31

Similarly, for steel grade of 400mpa, 500mpa, and 600mpa all the comparative parameters are analyzed similarly using table 4 and table 5 formats based on the two codes. The results of basic comparative parameters are shown below in tabular and graphical descriptions. The depth from serviceability d_o, ultimate depth from flexure requirement d_{uo}, the calculated deflection under service load, $\Delta_{cal,o}$ and allowable deflection, $\Delta_{all,o}$, limiting span to depth ratio, $l/d_{(o)}$, the critical design shear, $V_{cr,o}$ and maximum design moments, $M_{max,o}$ based on EBCS 1995 and depth from serviceability dn, ultimate depth from flexure requirement dun, the calculated deflection under service load, Δcal,n and allowable deflection, Δall,n, limiting span to depth ration, $l/d_{(o)}$, the critical design shear, $V_{cr,o}$ and maximum design moments, $M_{max,o}$ based on ES EN 2015 are discussed as follow for comparison.

***Table 6.** EBCS 1995 Vs ES EN 2015 Comparative results for different grade of steel.*

For steel grade of fyk=300mpa

L(m)	do	duo	dn	dun	Δcal,o	Δall,o	Δcal,n	Δall,n	Vcr,o	Vcr,n	Mmax,o	Mmax,n
3	91.07	239.11	67.77	257.26	6.605	15	11.43	12	24.08	24.39	12.82	12.77
3.5	106.25	264.94	79.06	286.88	8.003	17.5	14.64	14	28.21	28.53	17.52	17.43
4	121.43	289.12	90.35	314.66	9.312	20	17.82	16	32.39	32.70	22.99	22.83
4.5	136.61	311.98	101.65	340.92	10.533	22.5	20.92	18	36.61	36.90	29.77	28.99
5	151.79	333.75	112.94	365.89	11.672	25	23.92	20	40.90	41.15	36.28	35.91
5.5	166.96	354.62	124.24	389.78	12.736	27.5	26.80	22	45.25	45.43	44.16	43.61
6	182.14	374.73	135.53	412.73	13.734	30	29.56	24	49.66	49.75	52.87	52.11
6.5	197.32	394.21	146.82	434.87	14.673	32.5	32.20	26	54.15	54.12	62.45	61.41
7	212.50	413.15	158.12	456.31	15.562	35	34.73	28	58.72	58.54	72.93	71.53
7.5	227.68	431.63	181.51	465.58	16.407	37.5	30.07	30	63.37	63.12	84.33	82.92
8	242.86	449.72	206.52	474.31	17.215	40	26.05	32	68.11	67.88	96.68	95.43

For steel grade of fyk=400mpa

L(m)	do	duo	dn	dun	Δcal,o	Δall,o	Δcal,n	Δall,n	Vcr,o	Vcr,n	Mmax,o	Mmax,n
3	107.14	226.44	90.35	236.00	4.219	15	5.64	12	23.91	24.14	12.87	12.84
3.5	125.00	250.42	105.41	262.03	5.015	17.5	6.94	14	28.05	28.28	17.62	17.56
4	142.86	272.91	120.47	286.45	5.748	20	8.18	16	32.24	32.48	23.15	23.04
4.5	160.71	294.21	135.53	309.55	6.424	22.5	9.35	18	36.51	36.72	29.49	29.31
5	178.57	314.55	150.59	331.57	7.049	25	10.46	20	40.85	41.03	36.66	36.39
5.5	196.43	334.12	165.65	352.69	7.631	27.5	11.50	22	45.28	45.41	44.70	44.29
6	214.29	353.04	180.71	373.06	8.176	30	12.49	24	49.80	49.85	53.63	53.05
6.5	232.14	371.44	195.77	392.79	8.691	32.5	13.42	26	54.41	54.37	63.48	62.68
7	250.00	389.40	210.83	411.98	9.179	35	14.31	28	59.13	58.98	74.30	73.22

L(m)	do	duo	dn	dun	Δcal,o	Δall,o	Δcal,n	Δall,n	Vcr,o	Vcr,n	Mmax,o	Mmax,n
7.5	267.86	407.00	242.02	420.34	9.645	37.5	12.16	30	63.97	63.91	86.11	85.40
8	285.71	424.30	275.36	428.62	10.094	40	10.39	32	68.92	69.15	98.96	99.01

For steel grade of fyk=500mpa

L(m)	do	duo	dn	dun	Δcal,o	Δall,o	Δcal,n	Δall,n	Vcr,o	Vcr,n	Mmax,o	Mmax,n
3	123.21	215.73	112.94	219.54	2.82	15.00	3.10	12.00	23.75	23.91	12.94	12.93
3.5	143.75	238.26	131.77	262.03	3.31	17.50	3.71	14.00	27.90	27.88	17.73	17.71
4	164.29	259.43	150.59	265.25	3.75	20.00	4.28	16.00	32.12	32.30	23.33	23.29
4.5	184.82	279.55	169.41	286.28	4.15	22.50	4.81	18.00	36.44	36.61	29.77	29.70
5	205.36	298.83	188.24	306.40	4.52	25.00	5.31	20.00	40.85	41.01	37.09	36.96
5.5	225.89	317.44	207.06	325.78	4.87	27.50	5.77	22.00	45.37	45.51	45.31	45.12
6	246.43	335.51	225.88	344.58	5.19	30.00	6.21	24.00	50.01	50.12	54.48	54.20
6.5	266.96	353.15	244.71	362.88	5.50	32.50	6.62	26.00	54.77	54.83	64.65	64.24
7	287.50	370.45	263.53	380.79	5.80	35.00	7.02	28.00	59.67	59.67	75.85	75.29
7.5	308.04	387.48	302.52	389.15	6.08	37.50	5.91	30.00	64.72	65.07	88.14	88.47
8	328.57	404.29	344.20	397.81	6.36	40.00	5.02	32.00	69.92	70.91	101.57	103.44

For steel grade of fyk=600mpa

L(m)	do	duo	dn	dun	Δcal,o	Δall,o	Δcal,n	Δall,n	Vcr,o	Vcr,n	Mmax,o	Mmax,n
3	139.29	206.55	135.53	206.36	1.96	15.00	1.85	12.00	23.59	23.70	13.00	13.03
3.5	162.50	227.91	158.12	228.15	2.27	17.50	2.17	14.00	27.76	27.88	17.85	17.88
4	185.71	248.05	180.71	248.70	2.55	20.00	2.47	16.00	32.02	32.17	23.53	23.58
4.5	208.93	267.25	203.30	268.30	2.81	22.50	2.74	18.00	36.40	36.57	30.09	30.15
5	232.14	285.72	225.88	287.15	3.04	25.00	2.99	20.00	40.89	41.08	37.56	37.64
5.5	255.36	303.62	248.47	305.41	3.26	27.50	3.23	22.00	45.52	45.74	46.00	46.09
6	278.57	321.08	271.06	323.22	3.47	30.00	3.46	24.00	50.29	50.53	55.44	55.55
6.5	301.79	338.20	293.65	340.67	3.67	32.50	3.67	26.00	55.23	55.49	65.95	66.09
7	325.00	355.07	316.24	357.86	3.86	35.00	3.88	28.00	60.33	60.61	77.59	77.74
7.5	348.21	371.74	363.03	366.70	4.05	37.50	3.26	30.00	65.61	66.56	90.41	92.11
8	371.43	388.28	413.05	376.17	4.23	40.00	2.77	32.00	71.09	73.13	104.49	108.73

The deflection and depth of a beam are represented on the y-axis in mm while the span of a beam is represented on the x-axis in m. The variation of depth and deflection under different steel grades is presented below.

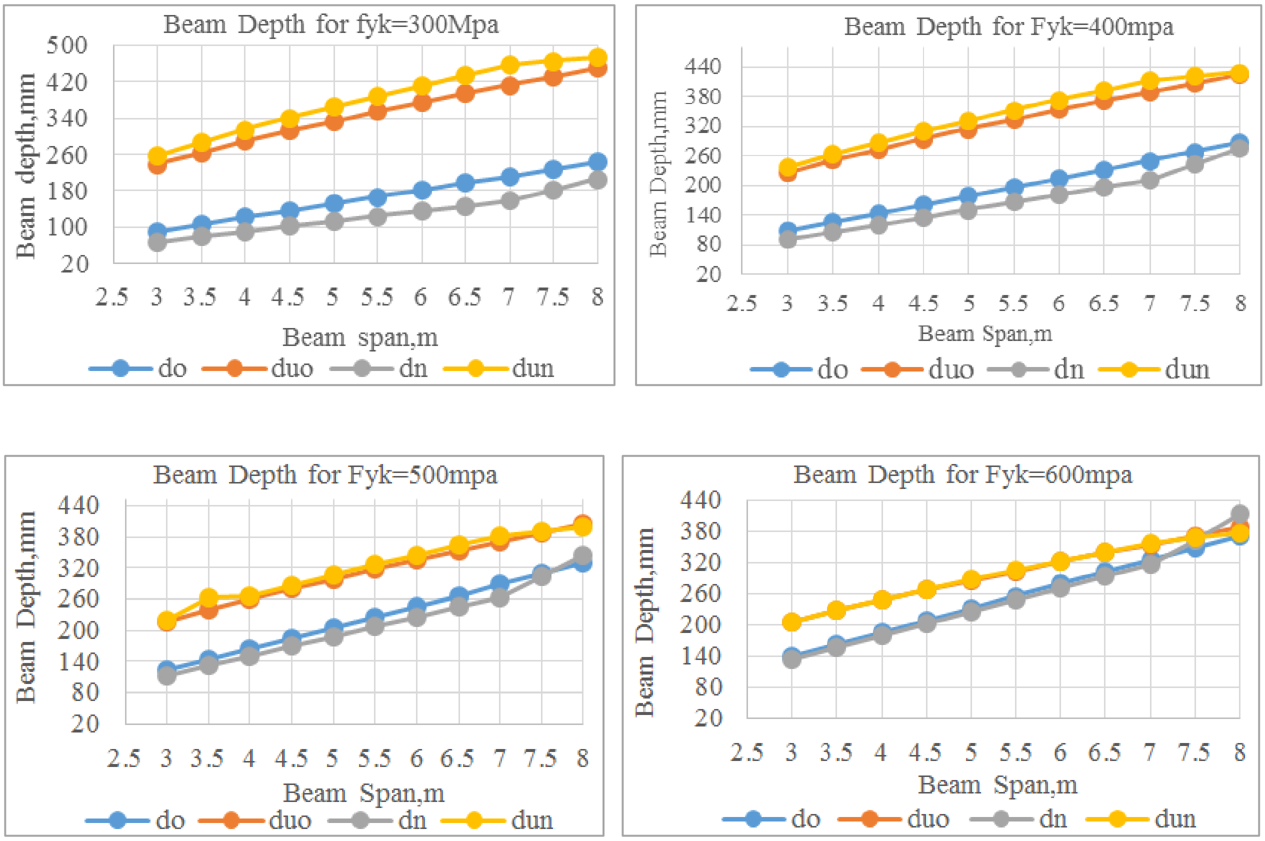

Figure 3. Variation of serviceability and ultimate beam depth.

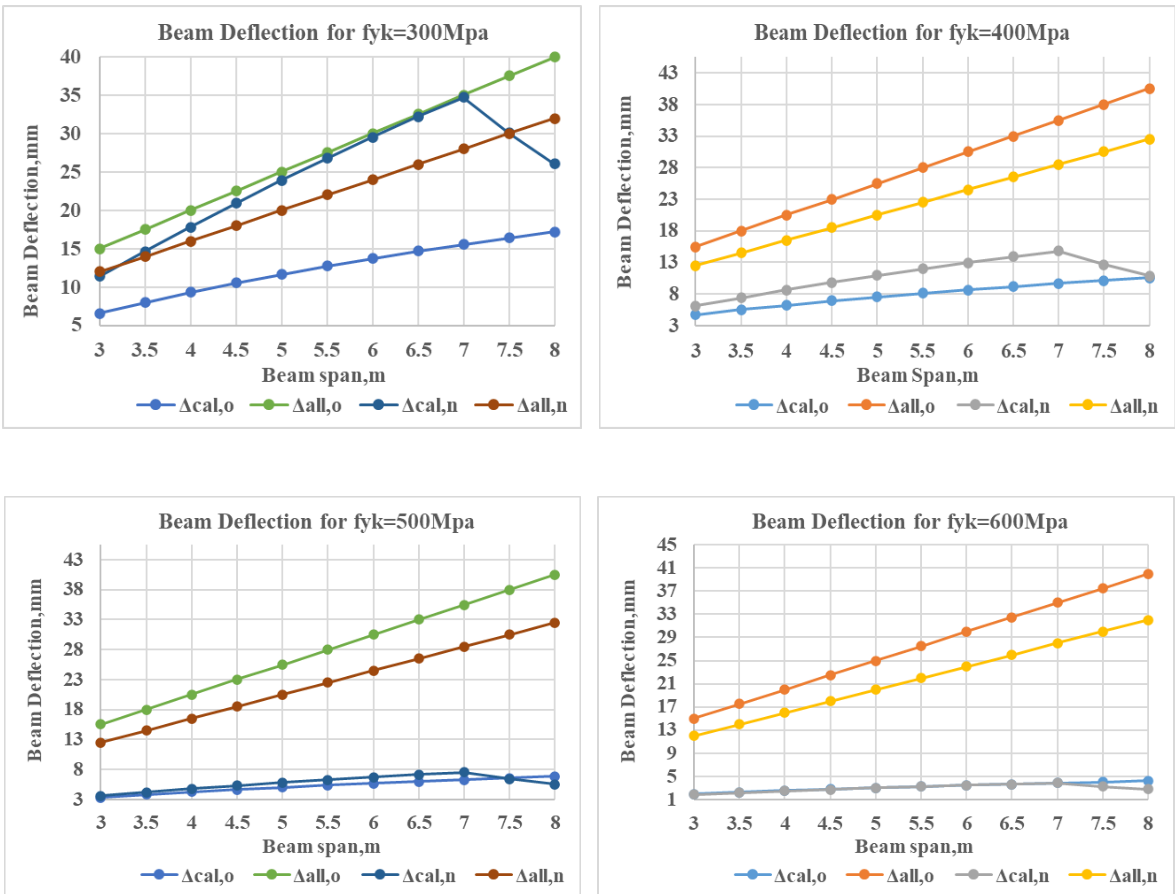

Figure 4. Variation of maximum and allowable beam deflection.

The effective depth to span ratio at different steel grades is calculated. The result shows that the depth calculated from EBCS 1995 is independent of steel grade while the depth calculated from ES EN 2015 depends on the grade of steel.

Table 7. Span-to-depth Ratio for EBCS 1995, l/d(o) and ES EN 2015,l/d(n).

	fyk=300mpa		fyk=400mpa		fyk=500mpa		fyk=600mpa	
L(m)	l/d(o)	l/d(n)	l/d(o)	l/d(n)	l/d(o)	l/d(n)	l/d(o)	l/d(n)
3	32.94	44.27	28.00	33.20	24.35	26.56	21.54	22.14
3.5	32.94	44.27	28.00	33.20	24.35	26.56	21.54	22.14
4	32.94	44.27	28.00	33.20	24.35	26.56	21.54	22.14
4.5	32.94	44.27	28.00	33.20	24.35	26.56	21.54	22.14
5	32.94	44.27	28.00	33.20	24.35	26.56	21.54	22.14
5.5	32.94	44.27	28.00	33.20	24.35	26.56	21.54	22.14
6	32.94	44.27	28.00	33.20	24.35	26.56	21.54	22.14
6.5	32.94	44.27	28.00	33.20	24.35	26.56	21.54	22.14
7	32.94	44.27	28.00	33.20	24.35	26.56	21.54	22.14
7.5	32.94	41.32	28.00	30.99	24.35	24.79	21.54	20.66
8	32.94	38.74	28.00	29.05	24.35	23.24	21.54	19.37

5. Conclusions

1) EBCS 1995 is independent of concrete grade in beam depth determination while ES EN 2015 is highly dependent on the grade of concrete and level of stressing the concrete for use.
2) At a higher grade of steel EBCS 1995 gives a little higher serviceable depth for lower spans than ES EN 2015 which makes uneconomical design in steel and concrete proportioning.
3) Under a given concrete grade and variable steel grade EBCS-1995 quickly satisfies both serviceability and flexural requirements than ES EN 2015.
4) Under a given service load EBCS 1995 gives relatively lesser deflection than ES EN 2015.
5) Allowable deflection as per ES EN 2015 is restricted to less than 20% allowed as per EBCS 1995 to higher spans.
6) EBCS 1995 gives higher section depth, for lesser critical design shear, and lesser ultimate moment than ES EN 2015 for different steel and concrete grades which results in uneconomical design.
7) EBCS 1995 better satisfies serviceability depth for a given span and concrete grad than ES EN 2015, while ES EN 2015 better satisfies ultimate depth requirement than EBCS 1995.
8) Under a given span up to 7m, shows the smaller value of under l/d EBCS-1995 than ES EN 2015 and for a beam span greater than 7m, l/d ratios are reduced from ES EN-2015 consideration.
9) ES EN-2015 gives an economical and effective beam width under a given l/D ratio than EBCS 1995.
10) When the grade of steel increase l/d ratio in both codes decreases while for ES EN 2015 l/d ratio decreases for a beam span greater than 7m.
11) Both design codes have no mechanism for the calculation to reduce the cross-section of the beam in the subsequent uppermost story to minimize cost and self-weight effects.
12) Generally, EBCS 1995 is uneconomical for shear and moment design which needs more section depth, especially for longer spans, and also the code is independent of concrete grade to determine the depth of the section while ES EN 2015 provides smaller but effective serviceable depth by limiting smaller deflection values.

6. Recommendations

1) Due to self-weight and the live load reduction in the subsequent top stories, the depth of the beam should be decreased as compared to lower story beam depths, but most code formulas don’t consider the effect of story in-depth determination. This should be studied.
2) A study should be done on how to select the grade of steel and the grade of concrete to have a better combination of steel-concrete grades to achieve a strong and

economical RC structure.

Highlights of the Research

1) Design codes and standards
2) Interior beam
3) Ultimate depth
4) Serviceability depth

Abbreviations

EBCS: Ethiopian Building Code of Standard
ESCP: Ethiopian Standard Code of Practice
ES EN: Ethiopian Standard Euro Norm
DL: Ddead Load
KN: Kilo Newton
LL: Live Load
MPa: Mega Pascal
RC: Reinforced Concrete
UDL: Uniformly Distributed Load
UVL: uniformly Varying Load

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Data Availability Statement

The data will be made available upon the request

Conflicts of Interest

The author declares no conflicts of interest.

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