A COMPARATIVE STUDY OF ACI 318-99, BS 8110 AND EUROCODES 2 STANDARDS FOR DESIGN OF A REINFORCED CONCRETE BEAM

by

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Objective:

To compare the beam reinforcement be required by different international design code (American, British and Euro Codes) with the aim of determining which of the three codes provides the most economic design

Design Case:

The structure chosen for the present study is a continuous beam of multiple spans with typical span length 8 m, taken from the floor of a shopping complex.

Design Criteria:

- Characteristic compressive cylinder Strength of concrete at 28 days 28 mPa equivalent cube strength 35 mPa
- Characteristic yield strength of reinforcing steel : 460 mPa
- Design Impose load (Live load) category D : 4.00 kPa (shopping areas)
- Ultimate limit state combination ;
  - I. ACI CODE : 1.4 DL + 1.7 LL
  - II. BS CODE : 1.4 DL + 1.6 LL
  - III. EURO CODE : 1.35 DL +1.5 LL

  DL and LL are dead loads (Superimposed dead load including self-weight) and imposed loads respectively.
- Design Beam section size 600mm width x 500 mm depth
- Design concrete cover 40 mm
- Typical span length 8.00 m maximum, design as continuous beam
- Linear static analysis type
- In this study, uniformly distributed load be apply for all span

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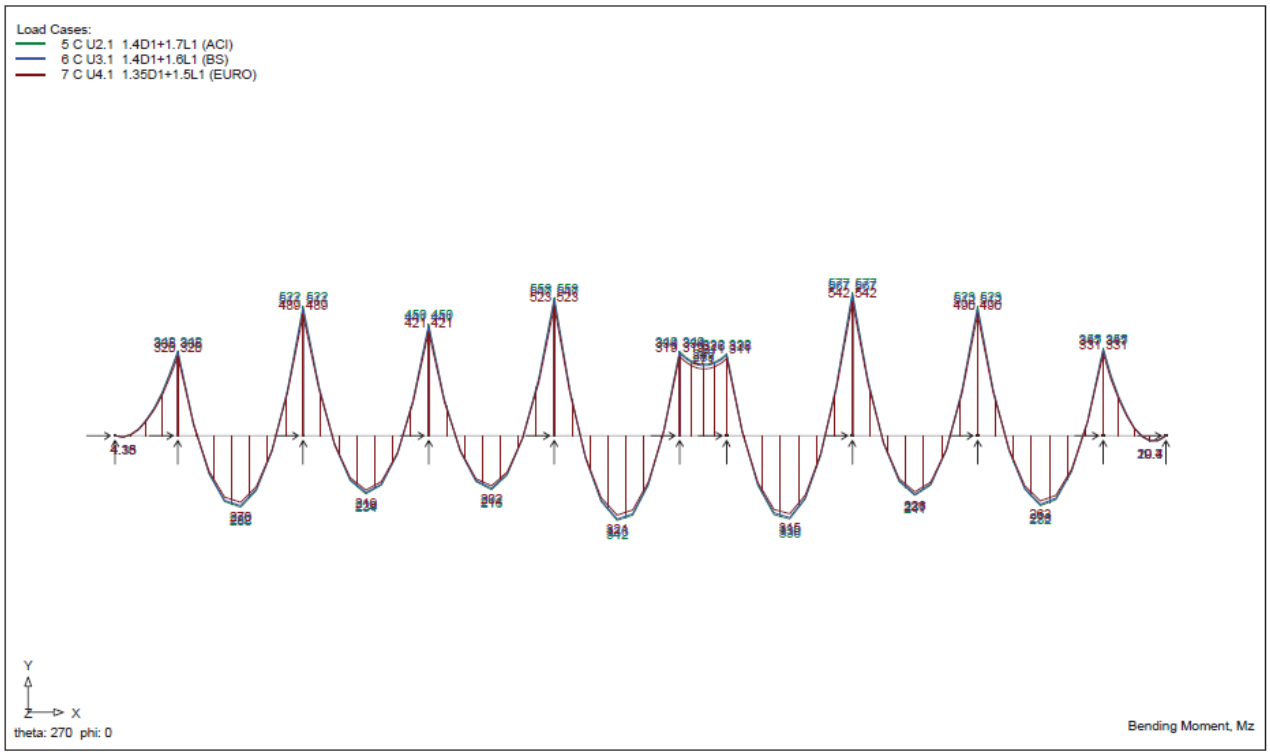
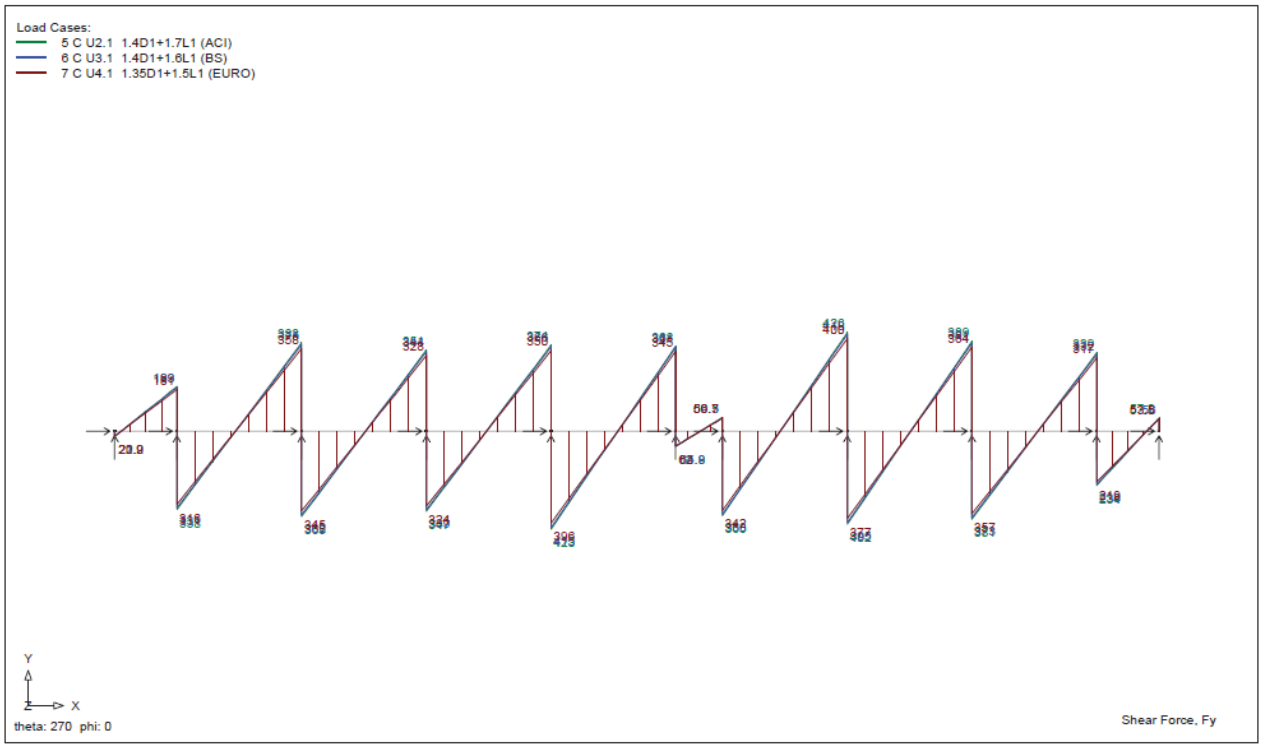
Beam Analysis:

- Bending moment diagram (kNm)



- Shear force diagram (kN)



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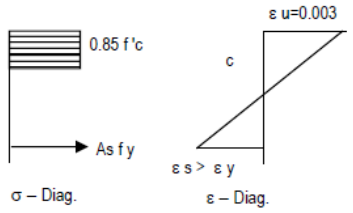
Beam Design:

- American ACI 318M-99

  -calculation shown only at max negative moment

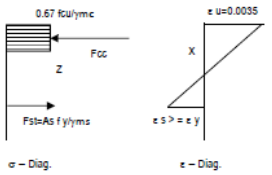
Client :				Rev		Deframing		
Project :				Date				
Subject : Bending of beam				By				
Concrete Design								
ACI 318M-99								
Mu=	577	kN-m						
f ' c=	28	Mpa	Cylinder					
fy=	460	Mpa						
Be=	600	mm	Beam width					
H=	500	mm.	Beam depth					
cover=	40	mm.						
Dia. Bar=	20	mm.						
d=	440.0	mm.						
a=	117.8	mm.	stress box depth					
As req=	**36.6**	cm^2	.....(As=0.85f 'c a b/fy)		As min=	8.0	cm^2	
Use	7	DB	20	mm	As prov.=	22.0	cm^2	
Extra Use	3	DB	25	mm	As prov.=	36.7	cm^3	OK
β1=	0.850							
ρ =	0.0139							
ρ b =	0.0249							
ρ max =	0.0187	ok						



- British BS 8110-1997

  -calculation shown only at max negative moment

Client :				Rev		Deframing		
Project :				Date				
Subject :bending of beam				By				
Concrete Design								
BS 8110-1 : 1997								
γ_{mc}	1.50							
γ_{ms}	1.15							
Es=	200,000	mPa						
Mult=	**567.0**	kN-m	<=	Mu	Design as Single reinforced beam			
f cu=	35	Mpa	cube .					
fy=	460	Mpa						
Be=	**600**	mm						
Try THK=	**500**	mm.	no req skin reinf.					
cover =	40	mm.						
link dia=	10	mm						
Dia. Bar=	20	mm.						
effective d=	440.00	mm.						
Mu=0.156 $f_{cu}bd^2$	634.23	kNm						
at Mu , x=d/2=	220.0	mm						
at Mu , a=0.9X=	198.0	mm						
at Mu , Z=d-a/2=	341.0	mm	Z/d= 0.775					
K=M/($f_{cu}bd^2$)	0.139				x= 190.54	mm		
Z_o=Z/d=	0.805				ε_y=fy/γ_{ms}E=	0.0020		
Z=Z_od	354	mm			ε_s=0.0035(d-x)/x=	0.0046	Yield	
Z max = 0.95 d=	418	mm						
$A_{s\,req}$=M/(z fy/γ_{ms})	40.0	cm2						
A_{smax}=	120	cm2	(4%bh)					
A_{smin}=	3.90	cm2	(0.13%bh)					
use	4	DB	20.00	mm	Asprov.=	12.6	cm^2	
Extra use	6	DB	25.00	mm	Asprov.=	42.0	cm^3	ok
Skin Reinf. In case H>750 mm	S=	150	mm	(Smax=250)				
min. bar size along side face =	**12.8**	mm Dia.						



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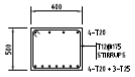
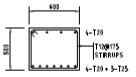
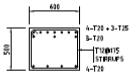
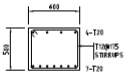
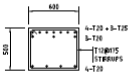
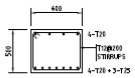
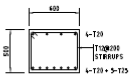
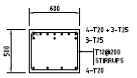
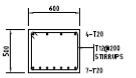
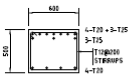
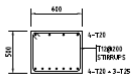
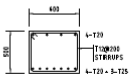
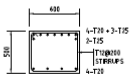
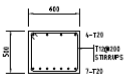
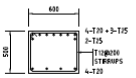
- Euro Code EN1992-EC2

  -calculation shown only at max negative moment

Client :					Rev		Deframing	
Project :					Date			
Subject :Bending of beam					By			
Design of Concrete structures								
EN 1992 : Eurocode 2 :								
γ_c =	1.50							
γ_s =	1.15							
Es=	200,000	mPa						
M_u=M=	542.0	kN-m	<=	M_{Rd}	Design as Single Reinforced Beam			
f_{ck}=	28	Mpa	(Cylinder)		OK			
λ =	0.80							
η =	1.00							
f_{ctm}	2.77	Mpa						
f_{yk} =	460	Mpa						
Be=	600	mm						
Try Beam Depth =	500	mm.						
cover =	40	mm.						
link dia=	10	mm						
Dia. Bar=	20	mm.						
effective d=	440.00	mm.						
M_{Rd} =0.167 f_{ck} bd^2	543	kNm						
at M_{Rd} , X =0.45 d	198.0	mm						
at M_{Rd} , a=λX = 0.8 X=	158.4	mm						
at M_{Rd} , Z=d-a/2=	360.8	mm			Z/d= 0.820			
K=M/(f_{ck} bd^2)	0.167					X =	197.03	mm
Z_o=Z/d=	0.821					ε_y=f_{yk} / γ_s E_s=	0.0020	
Z=Z_od	361	mm				ε_s=0.0035(d-x)/x=	0.0043	Yield
Z max = 0.95 d=	NA							
$A_{s\,req}$=M/(z f_{yk}/γ_s)	37.5	cm^2						
A_{smin}= 0.26 f_{ctm} / f_{yk} bd	4.1	cm^2						
A_{smax}=	120.0	cm^2	(4.00 %bh)					
A_{smin}=	3.4	cm^2	(0.13% bd)					
USE	4	Y	20.00	mm	Asprov.=	12.6	cm^2	
EXTRA USE	5	Y	25.00	mm	Asprov.=	37.1	cm^2	say "OK"

Beam Details:

- Section 1 -shown at exterior column, section 2- shown at midspan of exterior span, section 3-shown at first interior column, section 4-shown at midspan of interior span, section 5-shown at interior column
- Beam details of each design approach (ACI,BS,EURO) shown respectively below ;

SECTION 1	SECTION 2	SECTION 3	SECTION 4	SECTION 5	REMARKS
					ACI CODE
					BS CODE
					EURO CODE

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Beam reinforcement quantities:

The beam reinforcement both of longitudinal rebar and vertical stirrup be breakdown as shown below:

Client :		Rev :	
Project :		Date :	
Subject :	TAKEOFF MATERIAL	By :	

Steel Reinforced in RC Beam

Beam	Reinforcement (section)	gross section (mm)		Span Length	Number of span	Reinforced		curtailment %	Total Rebar (m)	unit weight(kg/m)	Total Weight of Rebar (kg)	Stirrup			unit weight(kg/m)	Loop Length (mm)	span (m)	Weight of Stirrup (kg)	volume of concrete (m³)	Steel / Concrete (kg/m³)
		b	h	m		No.	rebar					Loop	rebar	@spacing						
B2	main top	600	500	8.00	9	4	T20	1.0	288.0	2.47	710.3	1	T12	175	0.89	2080	68	721.8	21.6	
ACI CODE	main bottom			8.00	9	4	T20	1.0	288.0	2.47	710.3									
	Extra top (3&5)			8.00	8	3	T25	0.65	124.8	3.85	480.9									
	Extra top (3&5)			8.00	8	3	T20	0.65	124.8	2.47	307.8									
	Extra bottom (2)			8.00	2	3	T25	1.00	48.0	3.85	185.0									
	Extra bottom (4)			8.00	7	3	T20	1.00	168.0	2.47	414.3									
	SUM										2808.5							721.8	21.6	163
B2	main top	600	500	8.00	9	4	T20	1.0	288.0	2.47	710.3	1	T12	200	0.89	2080	68	631.6	21.6	
BS CODE	main bottom			8.00	9	4	T20	1.0	288.0	2.47	710.3									
	Extra top (3&5)			8.00	8	6	T25	0.55	211.2	3.85	813.8									
	Extra bottom (2)			8.00	2	3	T25	1.00	48.0	3.85	185.0									
	Extra bottom (4)			8.00	7	3	T20	1.00	168.0	2.47	414.3									
	SUM										2833.6							631.6	21.6	160
B2	main top	600	500	8.00	9	4	T20	1.0	288.0	2.47	710.3	1	T12	200	0.89	2080	68	631.6	21.6	
EURO CODE	main bottom			8.00	9	4	T20	1.0	288.0	2.47	710.3									
	Extra top (3&5)			8.00	8	5	T25	0.70	224.0	3.85	863.2									
	Extra bottom (2)			8.00	2	3	T25	1.00	48.0	3.85	185.0									
	Extra bottom (4)			8.00	7	3	T20	1.00	168.0	2.47	414.3									
	SUM										2882.9							631.6	21.6	163

Summary &Conclusion:

From analysis, design, details and quantities breakdown be summarized as below:

	ACI318M-1999	BS8110-1997	EURO EC2
1.Bending & Shear force			
1.1) Ultimate Max negative moment -Mu (kNm)	577	567	542
1.2) Ultimate Max Shear -Vu (kN)	406	400	382
2.Required Reinforcement			
2.1) A_S (cm^2) at max negative Moment	36.6	40.0	37.5
2.2) A_V /S (cm.) at max Shear	0.121	0.105	0.096
3.Rebar Contents (kg/m^3)	**163**	**160**	**163**

The results of the comparative study led to the following conclusion:

- The Eurocode 2 given the lowest ultimate design loads due to partial factor of actions are lowest cause to the lowest of moment and shear force in beam(refer 1.1&1.2)
- The ACI requires area of tension reinforcements lowest (refer 2.1)
- The Eurocode2 requires shear reinforcements lowest (refer 2.2)
- The BS8110 require curtailment of extra reinforcement shortest (refer table of take off material) although BS8110 requires area of tension reinforcement highest(refer 2.1)
- Due to the theoretical of three codes require shear&tension reinforcement not significant different and the available on bar size, practical stirrup spacing be considered when detailing the beam cause to the rebar content of the three codes given similar (refer 3)

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