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Comparision of Design Codes ACI 318-11, IS 456:2000 and Eurocode II

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ABSTRACT

National building codes have been formulated in different countries to lay down guidelines for the design and construction of structures. The codes have been evolved from the collective wisdom of expert structural engineers, gained over the years. These codes are periodically revised to bring them in line with current research, and often current trends.

The main function of the design codes is to ensure adequate structural safety, by specifying certain essential minimum reinforcement for design. They render the task of the designer relatively easy and simple, results are often formulated in formulas or charts. The codes ensure a certain degree of consistency among different designers. Finally, they have some legal validity in that they protect the structural designer from any liability due to structural failures that are caused by inadequate supervision and/or faulty material and construction.

The aim of this project is to compare the design codes of IS 456-2007, ACI 318-11code and Eurocode II. The broad design criteria (like stress strain block parameters, L/D ratio, load combinations, formula will be compared along with the area of steel for the major structural members like beams, slab, columns, footing to get an over view how the codes fair in comparison with each other. The emphasis will be to put the results in tabular and graphical representation so as to get a better clarity and comparative analysis.

INTRODUCTION

Structural design is the methodical investigation of the stability, strength and rigidity of structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its intended life.

The shear capacity, compression capacity & moment capacity of a structural member is a fundamental part of the overall analysis required when designing or evaluating an assembly of structural concrete sections.

The aim of the research is to compare broader design criteria of the said three design codes and calculate the area of steel for different structural members using the respective codes for the sake of comparison and subsequent comparative analysis.

A brief about the Design Codes;

- IS 456-2000

This Indian Standard (Fourth Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Cement and Concrete Sectional Committee had been approved by the Civil Engineering Division Council.

This standard was first published in 1953 under the title 'Code of practice for plain and reinforced concrete for general building construction' and subsequently revised in 1957. The code was further revised in 1964 and published under modified title 'Code of practice for plain and reinforced concrete', thus enlarging the scope of use of this code to structures other than general building construction also. The third revision was published in1978, and it included limit state approach to design. This is the fourth revision of the standard. This revision was taken up with a view to keeping abreast with the rapid development in the field of concrete technology and to bring in further modifications/improvements in the light of experience gained while using the earlier version of the standard.

IS 456-2000 Plain and Reinforced Concrete - Code of Practice is an Indian Standard code of practice for general structural use of plain and reinforced concrete. The latest revision of this standard was done in year 2000, reaffirmed 2005. This code uses the limit state design approach. It is written for use in India. It gives extensive information on the various aspects of concrete. IS 456 is considered as the Bible for Civil Engineers in India.

- **ACI 318**

The American Concrete Institute expects to publishes the ACI 318 updating it regularly to keep the code in sync in contemporary design developments, technological achievements and construction requirements. The process to codify design formulas and other design consideration goes back to 1904 in USA when Charles C. Brown with issue of Municipal Engineering discussed the idea of forming an organization to bring order and standard practices to the industry. The newest version of ACI 318 will be launched in 2019.

- **EUROCODE II**

The process of codifying EUROCODE II goes back to 1975 in Treaty Of Rome when European Commission asked CEN (Centre European de Normalisation) to draft structural design standards that could be used across the Common Market. It has been updated several times since then the latest update will be available by 2020.

AIM AND SCOPE OF PROJECT

The crux of this thesis is the comparison of the three prevailing concrete design codes regarding the design and detailing of RCC.

To accomplish this, a series of Excel spreadsheets were created to ensure the accuracy and consistency of all calculations performed; however as programming is not the point of this research several simplifying assumptions were made to reduce the time required to create, vet and utilize these tools.

Both sections focus solely on analytical results; no laboratory experiments were carried out. Comparisons were based on but not limited to maximum predicted allowable load.

The objective of this thesis is to clarify the differences between the two prevailing concrete design codes, ACI 318-05, IS 456, and EUROCODE II and categorize them as 2 major, minor, or insignificant. In cases where other editions are referenced, the edition under discussion shall be noted.

A comprehensive literature review providing coverage of examples illustrating additional differences found between the ACI 318 and IS 456 codes AND EUROCODE II.

DESIGN PROCESS AND RESULTS

BROADER DESIG N CRITERIAS

The broad design criteria of AMERICAN CODE (ACI 318), EURO CODE, and IS 456 (2000) are tabulated below to get a contrasted view of differences among the codes.

Sr No	Country Standards	Modulus of Elasticity	Stress block parameter for high grade concrete	Strain Distribution (Deep Beams)
1	American Std.	Ec=w1.50c×0.043√f'cMPa	Changes	Non Linear
2	European Std.	Ec ¼ 22000 (fc'/10)^0.3	Changes	Non Linear
3	Indian Std.	5000 square root of fck	Not considered	Not Considered

ELASTIC MODULUD OF CONCRETE

IS 456 2000 doesn't consider stress block parameters for high grade concrete and strain distribution for deep beams, high grade concrete has become very common now, even in India, so BIS should consider the above given lacunas to stre- ngthen the design code with current situations.

Sr No	Country Standards	Tensile Strength of Concrete (Flexure Design)	Max Concrete strain	Curing Effect on concrete strength	Confined Concrete Stress Strain Curve
1	Americn Std.	Not considered	.003	Not Mentioned	Not Mentioned
2	European Std.	Not considered	.0035	Mentioned	Mentioned
3	Indian Std.	Not considered	.0035	Not Mentioned	Not Mentioned

BASIC STRESS STRAIN PARAMETERS

Load Combination

Code	Combination
IS 456	1.5 (D + L) 1.2 (D + L ± W) 1.5 (D ± W) 0.9 D ± 1.5 W
ACI 318	1.4D 1.2D+1.6L+0.5Lr 1.2D+1.6Lr+(L OR 0.8W) 1.2D+1.6W+1.0L+0.5Lr 0.9D+1.6W
EC 2	1.35D+1.6L 1.0D+1.5W 1.35D+1.5L+0.9W

LOAD COMBINATIONS

The load combinations EUROCODE are more as compared to other two codes, this difference makes its impact in design process that is loads come out to be higher than other two, and hence the area of steel.

Beam Parameters of different country codes

Parameters	Aci 318	Ec2		IS 456
L/d	**8**	**p=1.5%**	**P=.5%**	**7**
Cantilever	**16**	**6**	**8**	**20**
S.S	**18**	**14**	**16**	**26**
Continuous		**18**	**18**	

L/d RATIO

The L/d ratio for ACI 318 is modest as compared to other two codes, while EUROCODE has more strict criteria.

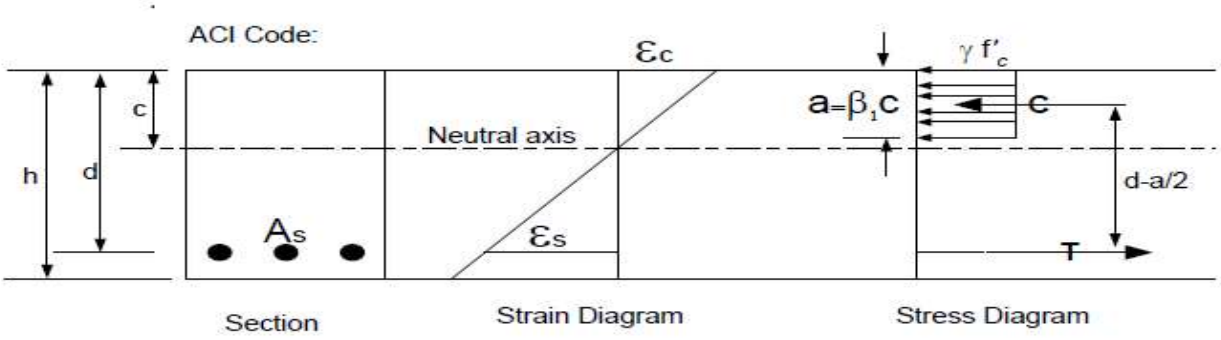
Concrete Design Strength Limits

a. EuroCode II Min=12 Mpa, Max 90Mpa
b. American code Min= 17 Mpa Max no limits
c. Indian std Min 20 Mpa max 80 Mpa

The Indian code has neglected higher grade (higher than 80MPA). Which could be incorporated in future.

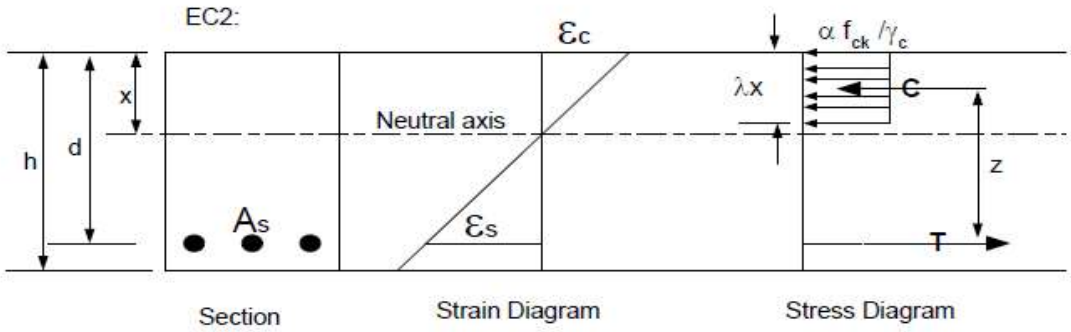
STRESS/STRAIN BLOCK PARAMETERS

a. **ACI 318**



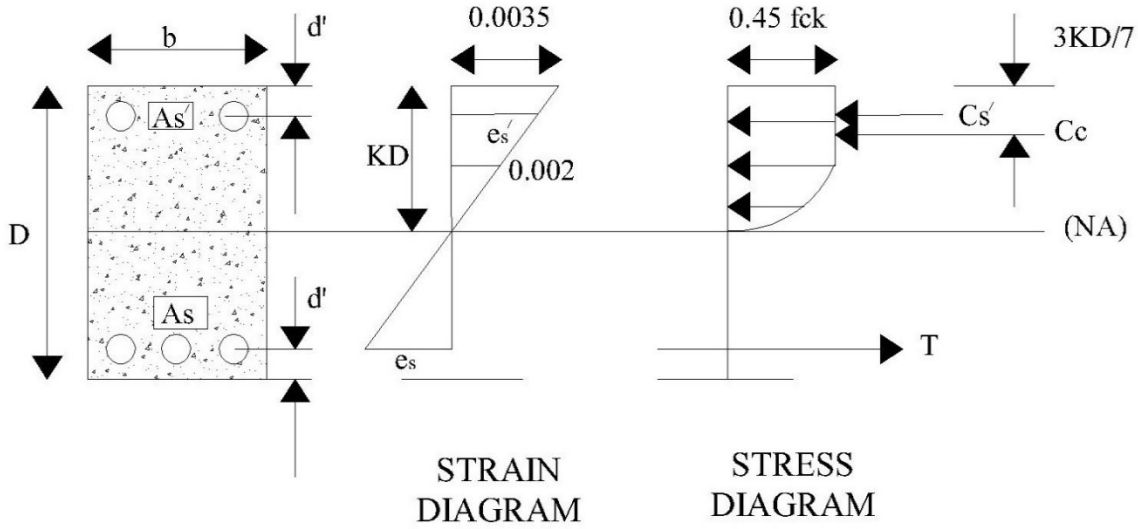
STRESS STRAIN DIAG ACI 318

b. EUROCODE II



STRES/STRAIN DIAG. OF EC II

c. IS 456 2000



IS 456 2000 SRESS/STRAIN

The codes of EC II, ACI 318, don't consider parabolic portion thus this makes the stress block calculation easy also the lever arm calculations. Also the lever arm in EC II, ACI 318 is greater than IS 456, this makes the moment calculation different in all the three codes.

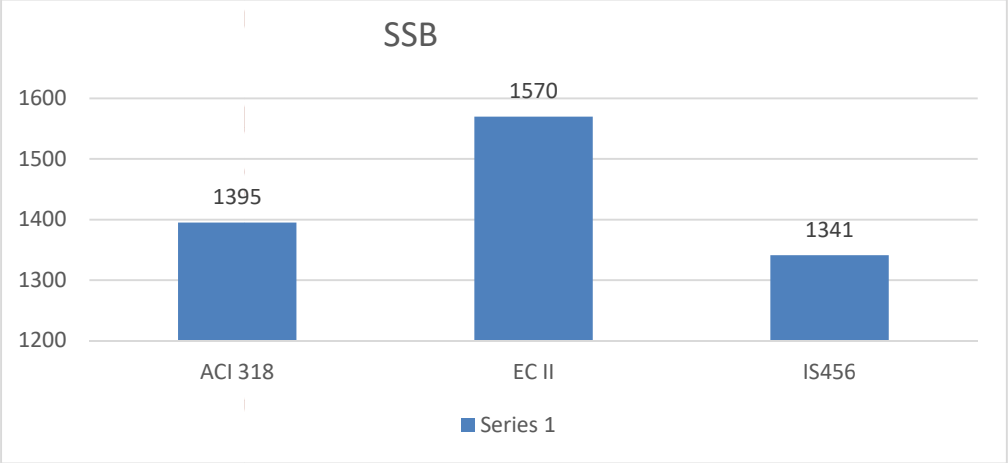
DESIGN OF DIFFERENT STRUCTURAL MEMBERS

DESIGN OF SINGLY REINFORCED BEAM

For the sake of comparison, the parameters required in design process were taken to be same example, Cube compressive strength (fck=30). Fy=500, dimensions of beam were taken to be same.

Example1 length=.6m, Breadth=230mm, Depth=600mm
Live Load of 40kn
BY ACI 318
Area Of Steel (main reinf.) = 1395mm2
By EUROCODE
Area of Steel = 1570.8mm2
By IS456
Area of steel= 1341mm2

DESIGN CODE	ACI 318	EC II	IS456
AREA OF STEEL(mm2)	1395	1570	1341



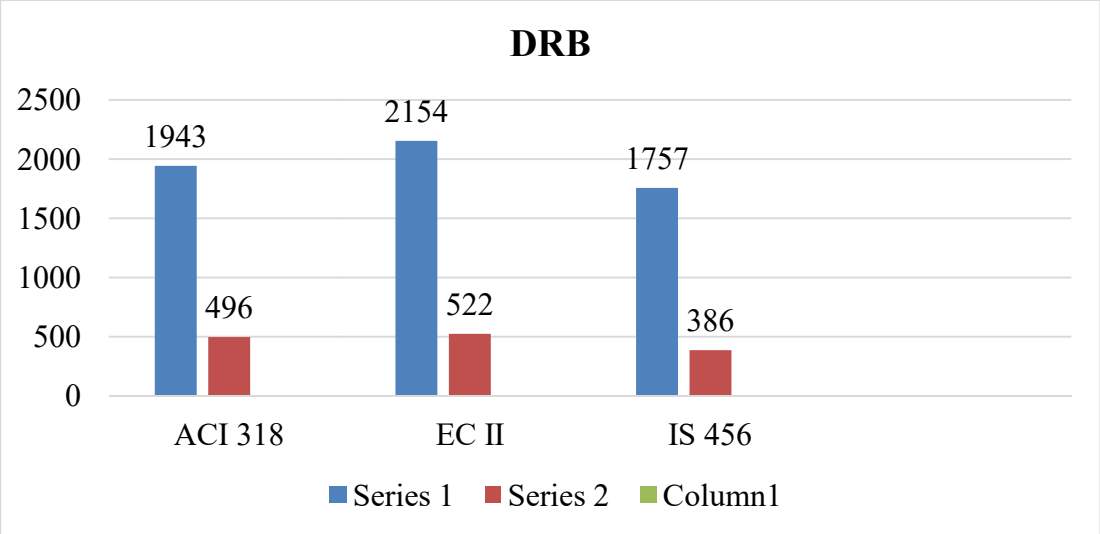
AST FOR SSB

DOUBLY REINFORCED BEAM

LL=80KN/M, B=230 D= 450, fck= 30, fy=500

DESIGN CODE	ACI 18	EC II	IS456
AST	1943	2154	1757
ASC	496	522	386

AST FOR D-R BEAM



AST OF DRB

FLANGE BEAM DESIGN

EXAMPLE

Adjacent slab span = 5m Beam 690*350mm
Fck=30Mpa Fyk= 500Mpa
Cover=45mm
Live Load= 5kn/m2

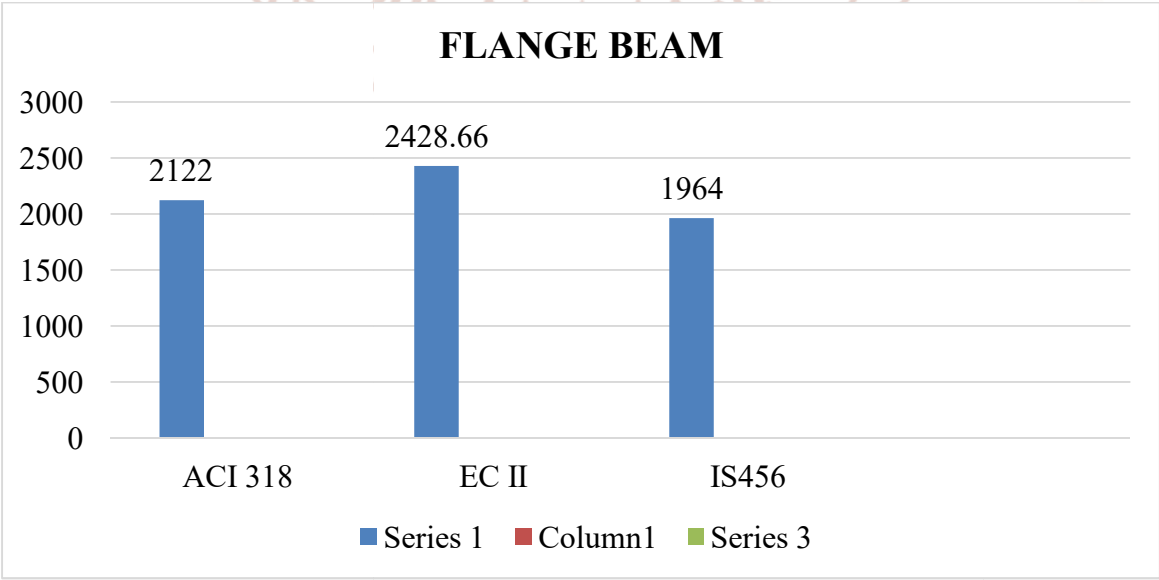
- BY EC-II
  Area of Steel= 2428.86mm2
- BY ACI 318

Area of steel= 2122mm2

- BY IS456
  Area Of Steel=1964mm2

DESIGN CODE	ACI 318	EC-II	IS456
AREA OF STEEL	2122	2428.66	1964

AST OF FLANGE BEAM



AST OF FLANGE BEAM

INTERACTION CURVE ACCORDING TO IS 456:2000 ACI 318:11 AND EC II .

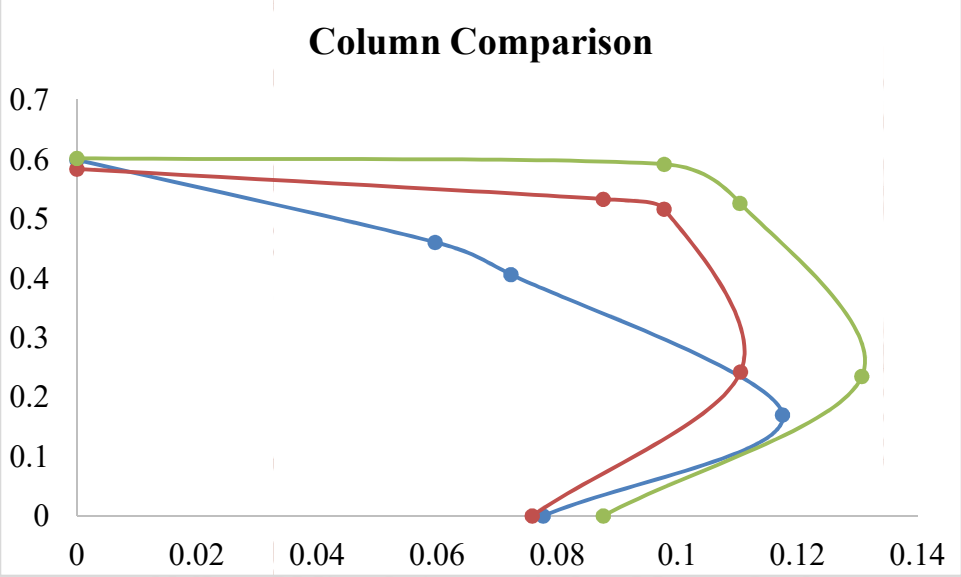
- For pt. = 1%

b = 230mm D = 525mm d'/D = 0.1 f_{ck} = 25 N/mm^2

F_y = 500 N/mm^2

IS		ACI		EC II	
M_U/f_{ck} .b.D^2	P_U/f_{ck}. b. D	M_U/f_{ck} .b.D^2	P_U/f_{ck}. b. D	M_U/f_{ck} .b.D^2	P_U/f_{ck}. b. D
0	.5983	0	.5832	0	0.6012
.05965	.4599	.09854	.5832	0.1071	0.5912
.07227	.4058	.09778	.5158	0.1104	0.5256
.1175	.1697	.1105	.2421	0.1307	0.2346
.07765	0	.07582	0	.08766	0

INTERACTION CHART



INTERACTION CHART

SLAB DESIGN

For the sake of comparison design parameters are taken same which are as

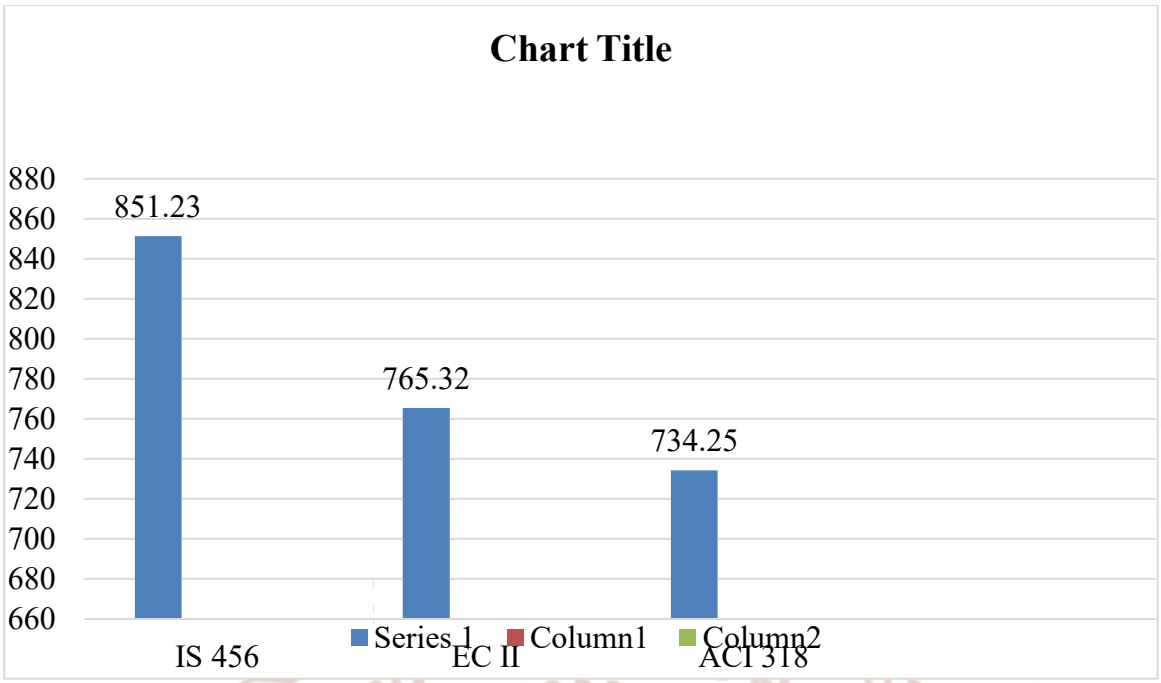
fck = 30, fy 500,

Effective length of slab from center to center of support = 5m

Live load = 10kn/m2, assuming 1m stretch for design purposes so b= 1000mm

CODE	IS 456	EC II	ACI 318
AREA OF STEEL	851.23	765.32	734.25

AST OF SLAB



AST OF SLAB

DESIGN OF FOOTING

EXAMPLE OF A SINGLE SQUARE FOOTING

fck = 30, fy = 500,

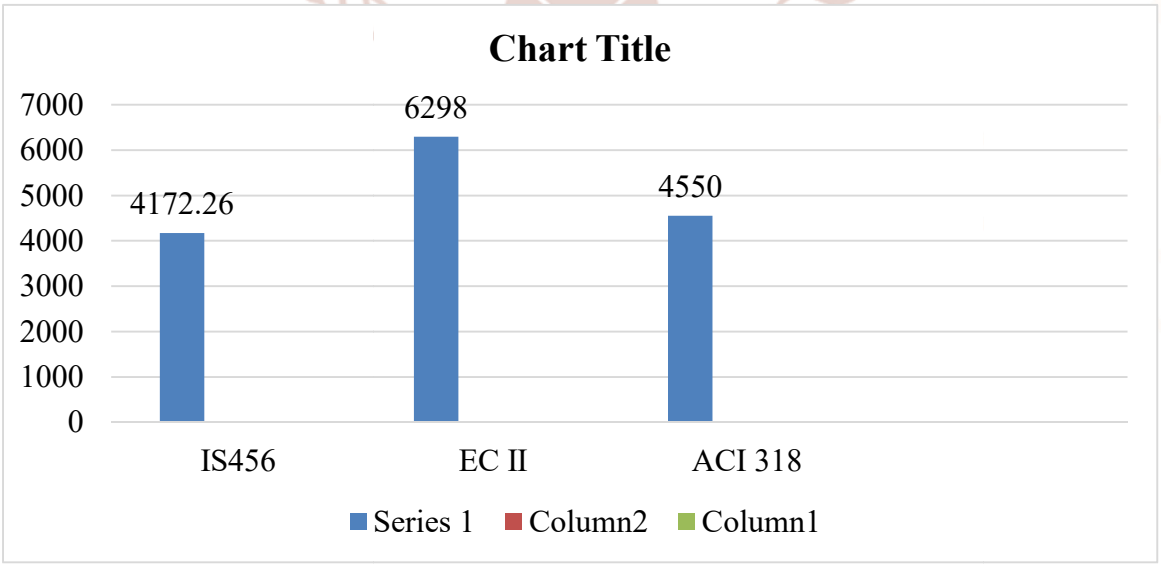
load coming through column Service live load= 1000KN, Service dead load= 1500KN

Allowable bearing capacity or safe bearing capacity = 250KN/m2,

Size of column 400mm*400mm

CODE	IS 456	EC II	ACI 318
AREA OF STEEL (mm2)	4172	6298	4550

AST OF FOOTING



AST OF FOOTING

1. FUTURE SCOPE OF WORK

The Bearou OF Indian Standards which has developed IS456 2000 has not considered the strain distribution in deep beams which is a major lacuna when it comes in comparison with EUROCODE II or ACI 318, One can develop the strain distribution for IS 456 in line with the other major codes.

In the current times the civil engineering is touching new heights and conquering milestones one after other, the innovation has brought to light new materials which have a great effect on strength, durability, setting time, exothermic heat generation etc of concrete, materials such as add mixtures like plasticizers, water reducing agents retarders etc. Light Weight materials, Geo-Synthetic materials. Their effects are not codified in IS 456, there is a vast field of research in this area. One can test these materials vis a vis concrete and codify the behavior of the same in guided circumstances which will in-turn put into our design code.

IS456 doesn't recognize concrete characteristic strength beyond M80, and this is an area of research one can formulate design criteria for is 456 for concrete strength beyond M80.

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