Study of Behavior of Beam Column Joint Under Seismic Loading With Ductile Detailing

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Abstract*-In this paper to study about various on ductility demand and understanding of ductile detailing with Beam, column and Beam-Column joint under seismic force. Putting the concept of importance of ductility in column, strong column and weak beam. Also doing work on Beam-Column joints in building, why they are special? Its classification, behavior and design considerations for Beam- column joint under seismic loading. It included the analysis and design of G+5 building with ETAB with earthquake loading and different load combinations. After this output next process to cost comparison for R.C.C. building with and without ductile detailing of G+5 building of seismic zone III*

Keywords-Ductility, Beam-column-joint, Analysis

I. INTRODUCTION

Earthquake resistant design involves determination of expected seismic forces and designing the structural members to resist these forces. The seismic codes do not intend to ensure that no structure shall suffer damage during a large earthquake. IS 13920:1993 covers that, “The requirements for designing and detailing of monolithic reinforced concrete buildings so as to give them adequate toughness and ductility to resist severe earthquake shocks without collapse”. This is because a structure which can withstand strongest ground shaking without damage will be too expensive to build. Hence, it is obvious that the non-linear behavior of structure, i.e., beyond its yield, will greatly affect its seismic design. It is, therefore, important that structures should be more ductile for better performance during earthquakes [1]. Ductility of a structure means capacity to deform to a large extent without loss of strength before collapse, as compared to its deformation at yield point.[2] Seismic codes around the world ensure adequate ductility of a structure in two ways. Firstly, design seismic forces for a ductile structure are less than for a brittle structure. Secondly, it isrequired that the structures to be built in a highly seismic zone must have a minimum level of ductility [3].

II. OBJECTIVES OF INVESTIGATION

Explaining the term of ductility and beam column jointThe behavior of beam-column joint during severe earthquake using ETABAnalysis and design of G+5 building with ETAB of interior and exterior beam column joints by IS codeFrom this design got the reinforcement details then we will estimate the cost and compare in with ductile detailing and without ductile detailingTo study the effect of ductile detailing in the cost of building for Zone III.

III. LITERATURE REVIEW

Guo-Lin Wang, et.al (2012) this paper presents a new shear strength model for reinforced concrete (RC) beam–column joints subjected to cyclic lateral loading. In the proposed model, the reinforced concrete in the joint panel is idealized as a homogenous material in a plane stress state. The contribution of the joint shear reinforcement (including both the transverse steel reinforcement and the intermediate longitudinal steel reinforcement of the column) is taken into account through the nominal tensile strength of the idealized material.

Chidambaram.K.R et al.(2012)The ductility capacity, energy dissipation capacity and load – deformation behavior of the exterior beam column joints constructed with an external anchorage system by providing a small projection beyond the Column face is evaluated. The evaluation is based on the experimental results of two one fifth scale exterior bam column joint specimens tested as part of an extensive experimental program. The control specimen (CS) constructed and detailed as per IS 13920:1993Codal provisions and externally anchorage specimen (EAS) cast with small projection beyond the column face. A small axial load was applied to the column portion of the subassembly and held constant during the test. The free end of the beam was subjected to cyclic load representing a wide range from elastic to inelastic loading. By providing an external anchorage system, the reinforcement detailing and concrete placement in the joint region become eased and the behavior was better than conventional method of construction.

S. S. Patil, et.al. (2013) The different types of joints are classified as corner joint, exterior joint, interior joint etc.

on beam column joint applying quasi-static loading on cantilever end of the beam. and study of various parameters as to be find out on corner and exterior beam column joint i.e. maximum stress, minimum stress, displacement and variation in stiffness of beam column joint can be analyzed in Ansys software (Non-Linear FEM Software

Rupali R. Bhoir, et.al(2015)Beam-column joint failure is the major cause for such destructions. Therefore major concern is given in refurnishing their behavior. While considering the core behavior, there is need to calculate joint shear demand also. Beam-column joint has no problem in itself until the dead and live loads are concern. As soon as lateral loads, i.e. seismic force, comes into picture it will become a critical problem. This problem has not been solved completely till date. Here through this analytical approach an attempt is made to understand the behavior of joint core and joint shear demand. For this purpose 2d mid to low rise building models with some predefined parameters are considered and modeled in STAAD Pro V8i software. These models were designed by using Limit State Design Method as per IS 456:2000. The joint shear demand is then calculated as per ACI 352-02.

IV. DUCTILITY

Ductile detailing is provided in structures so as to give them adequate toughness and ductility to resist severe earthquake shocks without collapse. The performance criteria in most earthquake code provisions require that a structure be able to

- Resist moderate earthquakes with minor structural and some non-structural damage. With proper design and construction, it is believed that structural damage due to the majority of earthquakes will be limited to repairable damage.

- Resist earthquakes of minor intensity without damage. A structure would be expected to resist such frequent but minor shocks within its elastic range of stresses.

- Resist major catastrophic earthquake without collapse.

V. DATA

Unit weight of concrete- 25 kN/m3
Unit weight of masonry -20 kN/m3
Slab thickness -0.150 m
Height of floor-3 m
Total height of the building from ground level-20 m
Live load for typical slab-2 kN/m2
Live load for terrace slab-2 kN/m2
Concrete grade-M20
Steel grade Fe-415

VI. LOAD COMBINATIONS

TABLE I

As per IS 1893 (Part 1): 2002 Clause no. 6.3.1.2, the following load cases have to be considered for analysis

1.5 (DL + LL)	DL= Dead load
1.5 (DL + EQ X)	LL = Live load
1.5 (DL + EQ Y)	EQY= Earthquake in Y direction
1.5 (DL - EQ X)	EQX= Earthquake in X direction
1.5 (DL - EQ Y)	
(0.9DL + 1.5EQ X)	
(0.9DL + 1.5EQ Y)	
(0.9DL - 1.5EQ X)	
(0.9DL -1.5EQ Y)	
1.2(DL + LL + EQ X)	
1.2 (DL + LL + EQ Y)	
1.2 (DL + LL - EQ X)	
1.2 (DL + LL - EQ Y)	

VII. PLAN

Portion of the building	**Storey no.**
Foundation top – Ground floor	1
Ground beams – First floor	2
First Floor – Second floor	3
Second floor – Third floor	4
Third floor – Fourth floor	5
Fourth floor – Fifth floor	6
Fifth floor - Terrace	7

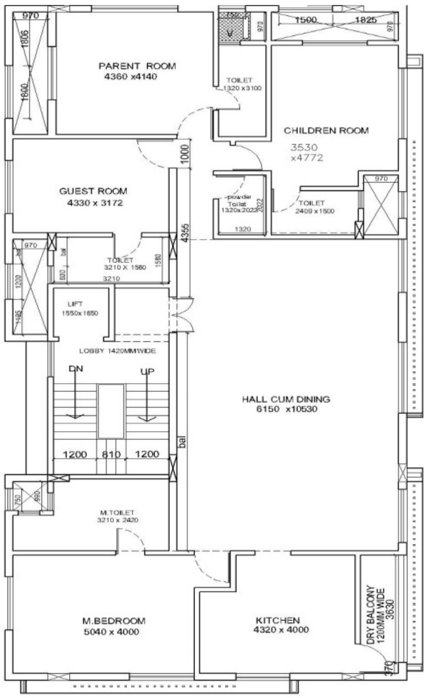

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TABLE II:Distribution of Horizontal Load to Different Floor Levels

Storey	W_i	h_i	$W_ih_i^2$	Qi= $wihi^2$/ $\sum wihi^2$xVi (kN)	V_i
7	3613.385	20	1445.35	182.71	182.71
6	3503.91	17	1012.63	128.0	310.19
5	3503.91	14	686.7	86.82	396.86
4	3503.91	11	423.9	53.59	451.207
3	3503.91	8	224.25	28.35	479.507
2	3004.09	5	75.10	9.5	488.98
1	1154.2	2	4.62	0.58	489.56
Total			3872.69	489.55	

VIII. METHODOLOGY

1. G+5 building selected for analysis and design using ETAB
2. Manual calculation or part calculation for validation of work
3. Comparison involving software and manual reinforcement calculations output
4. This reinforcement includes ductile detailing of beam column and beam column joint
5. From this reinforcement cost comparison can be done with and without ductile detailing

ETAB ANLYSIS AND DESIGN

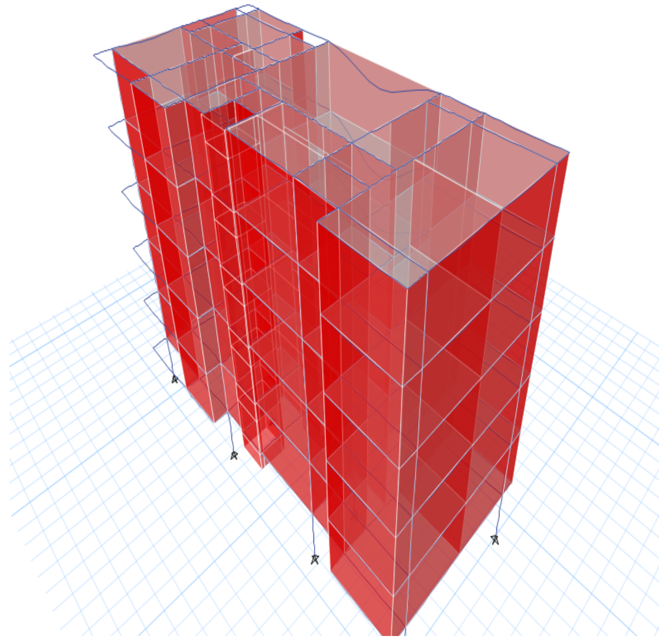

Fig.1: ETAB analysis shows deformation

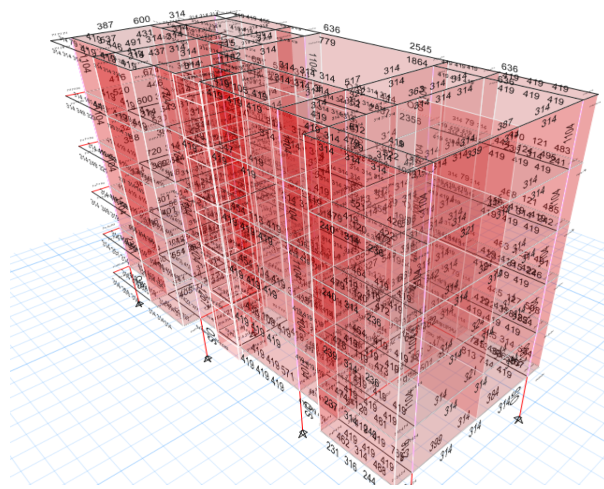

Fig.2: ETAB analysis shows moment on sections

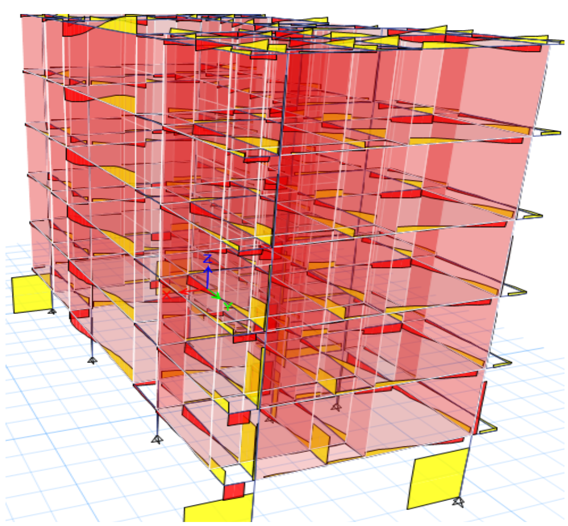

Fig.3: ETAB analysis shows shear force on sections

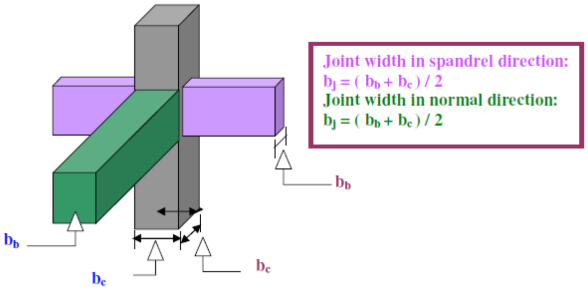

Fig.4: Joint width for exterior beam column joint

TABLE III: Design formulas by IS and ACI method which used to analysis

IS formule	ACI formule
Column longitudinal R/F Arrangement of bar acceptable	Column longitudinal R/F Arrangement of bar acceptable
Column transverse R/F $Ash = 0.18.S.h.\frac{fck}{fy}[\frac{Ag}{Ak} - 1.0]$	Column transverse R/F $Ash = 0.3Sh.h'.\frac{fc'}{fyh}[\frac{Ag}{Ak} - 1.0]$ $Ash = 0.09Sh.h'.\frac{fc'}{fyh}$
Shear(Normal direction) $xu = \frac{(0.87.fy.Ast)}{0.36\ fck.b}$ $Mu = 0.87.fy.Ast(d - 0.42xu)$ $Vcol = \frac{Mu}{Lc}$	Shear (Normal direction) $a = \frac{As.\alpha.fy}{0.85.fc.b}$ $Mu = As.\alpha.fy\left(d - \frac{a}{2}\right)$ $Vcol = \frac{Mu}{Lc}$
Joint Shear (Normal direction) $Tu = Ast.\alpha.fy$ $Vu = Tu - Vcol$	Joint Shear (Normal direction)$Tu=As_t.\alpha.fy$ $Vu = Tu - Vcol$
Joint Shear strength (Normal direction) $Vn = 0.063.\gamma.\sqrt{fck}.bj.hcol$ $bj = \frac{bb + bc}{2}$	Joint Shear strength (Normal direction) $Vn = 0.083\ .\gamma\ \sqrt{fck}\ .bj\ .hcol$ $bj = \frac{bb + bc}{2}$
Shear (spandrel direction) Ast=top R/F Asb=bottom R/F $xu1 = \frac{(0.87.fy.Ast)}{0.36\ fck.b}$ $Mu1 = 0.87.fy.Ast(d - 0.42xu)$ $xu2 = \frac{(0.87.fy.Asb)}{0.36\ fck.b}$ $Mu2 = 0.87.fy.Asb(d - 0.42xu)$ $Vcol = \frac{Mu1 + Mu2}{Lc}$	Shear (spandrel direction) Ast=top R/F Asb=bottom R/F $a1 = \frac{Ast.\alpha.fy}{0.85.fc.b}$ $Mu1 = As.\alpha.fy\left(d - \frac{a}{2}\right)$ $a2 = \frac{Asb.\alpha.fy}{0.85.fc.b}$ $Mu2 = As.\alpha.fy\left(d - \frac{a}{2}\right)$ $Vcol = \frac{Mu}{Lc}$
Joint shear (Spandrel Direction) $Cu_1=Ast.\alpha.fy$ $Cu_2=Tu_2$ $Vu = Cu1 + Cu2 - Vcol$	Joint shear (Spandrel Direction) $Cu_1=Ast.\alpha.fy$ $Cu_2=Tu_2$ $Vu = Cu1 + Cu2 - Vcol$
Joint shear strength (Spandrel Direction) $Vn = 0.063.\gamma.\sqrt{fck}.bj.hcol$ $bj = \frac{bb + bc}{2}$	Joint shear strength (Spandrel Direction) $Vn = 0.083.\gamma.\sqrt{fck}.bj.hcol$ $bj = \frac{bb + bc}{2}$

IX. DESIGN OF EXTERIOR BEAM COLUMN JOINT

TABLE IV:Design of Exterior beam column joint by IS and ACI method

IS VALUE	ACI VALUE
Column transverse R/F $75mm^2$,8mmdia,cover40mm, spacing 75 mm	Column transverse R/F $75mm^2$,8mmdia,cover40mm, spacing 100 mm
Shear(Normal direction) 2-16mm+1-10 = $481mm^2$, d=450mm,α=81mm,Mu=92kN-m,V=31kN	Shear (Normal direction) 2-16mm+1-10 = $481mm^2$ d=450mm,α=49mm,Mu=134kN-m,V=45kN
Joint Shear(Normal direction) Tu=209kN, V=416kN	JointShear(Normal direction) Tu=250kN, V=214kN
Joint Shear strength(Normal direction) b_j=230mm,h_{col}=600mm,Vn=773 kN	JointShear strength (Normal direction)b_j=230mm, h_{col}=600mm,Vn=1019 kN
Shear(spandrel direction) D=450,α=86mm,Mu_1=98Knm, α=68mm,Mu_2=78kNm,V_{col}=59kN	Shear(spandrel direction) D=450,α=53mm,Mu_1=143Kn-m, α=41mm, Mu_2=113kNm, V_{col}=86kN
Joint shear(Spandral Direction) Cu_1=268kN,Cu_2=Tu_2=209kN, Vu=418kN	Joint shear(Spandral Direction) Cu_1=268kN,Cu_2=Tu_2=209kN, Vu=391kN
Joint shear strength(Spandral Direction) b_j=230mm, h_{col}=230mm Vn=577 kN	Joint shear strength(Spandral Direction) b_j=230mm, h_{col}=230mm Vn=760 kN

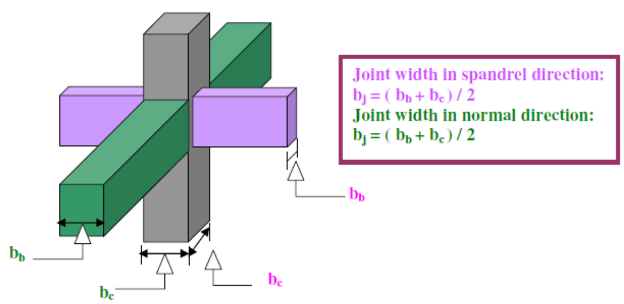

Fig.5: Joint width for interior beam column joint

X. DESIGN OF INTERIOR BEAM COLUMN JOINT

TABLE V: Design of Interior beam column joint by IS and ACI method

IS VALUE	ACI VALUE
Column transverse R/F $75mm^2$,8mmdia,cover40mm , spacing 75 mm	Column transverse R/F $75mm^2$,8mmdia,cover40mm, spacing 100 mm
Shear(Spandrel direction) Top r/f = 3-16mm+2-20 =$1231mm^2$bottom r/f=3-16=$603mm^2$, d=450mm,xu_1=206mm,Mu_1 =210 kN-m,xu_2=101mm, Mu_2=113kN-m, Vcol=108kN	Shear (Spandrel direction) Top r/f = 3-16mm+2-20 =$1231mm^2$ bottom r/f=3-16=$603mm^2$, d=450mm,a=125mm,Mu_1=318 kN-m,a_2=62mm, Mu_2=165kN-m, Vcol=161kN
Joint shear (Spandral Direction) Cu_1=639kN,Cu_2=Tu_2=313kN,Vu=844kN	Joint shear (Spandral Direction) Cu_1=639kN,Cu_2=Tu_2=313kN ,Vu=791kN
Jointshearstrength(Spandral Direction) b_j=230mm, h_{col}=230mm Vn=1031kN	Jointshearstrength(Spandral Direction) b_j=230mm, h_{col}=230mm Vn=1358kN

XI. ACKNOWLEDGMENT

Anlytical work was carried out using the ETAB software in Civil Engineering Department computer lab of D.V.V.P.COE, Ahmednagar. I wish to thank Prof. U.R. Kawade, my guide, Prof. P.B.Autade, ME Co-ordinatorfor their valuable Suggestionsandauthorities for their kind support. I also wish to thank the laboratory staff for their help and support during this work

XII. DISCUSSION

As the concept of ductile detailing is not so old various researches have been made in other parts of world. It has become compulsory for all the country to ductile detailing for high seismic area where earthquake are more frequent. Ductility increased more by using composite material in building. Experimental work can be done for beam column joint taking moment frame with lateral forces.

XIII. CONCLUSION

1. Above table is comparison of IS and ACI with manual calculations done by IS and ACI code it seems percentage differences maximum difference is occurred in reinforcement details and ductile detailing
2. Manual calculations done by IS and ACI code it seems nearly same difference is occurred in moment and shear force.
3. Also analyzed with ETAB software and we get output which put with picture
4. By ETAB analysis and design we get idea of failure beam, column and joint also which help to improve section
5. With selected section and size we checked design in ETABagain andanalyzed to check its safety it provides safe detailing.

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