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Original Research Paper

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STUDY ON SEMI-RIGID CONNECTION IN MULTI-STOREY MULTI-BAY FRAME

ANKIT DESAI	M.Tech (structure) student, B.V.M. Engineering College, Vallabh Vidyanagar (388120), Gujarat, India.
D. R. BHATT	Assoc. Prof., Department of structural engineering, B.V.M. Engineering College, Vallabh Vidyanagar (388120), Gujarat, India
S. V. MEVADA	Asst. Prof., Department of structural engineering, B.V.M. Engineering College, Vallabh Vidyanagar (388120), Gujarat, India.

ABSTRACT This paper deals with the analysis of steel building frame with one, two, & three bays under the effect of dead load, live load, & lateral load(EQ). According to IS 800:2007(appendix-f) Frey-Morris polynomial model is used for determination of secant stiffness (rotational stiffness) of different connection like single web angle connection, double web angle connection, top & seat angle connection with or without stiffener, header plate connection, & t-stub connection which is required for analysis of semi-rigid steel frame. Value of rotational stiffness is incorporated in analysis of steel frame using STAAD. Pro in place of assumption of rigid & ideal pinned condition. Analysis results in terms of parameter like shear force, bending moments, axial force in the member, top storey displacement, weight of frame, time period for rigid & pinned connection have been compared with corresponding results for various semi-rigid connections. Percentage rigidity of various types of connection in multi storey multi bay steel frames has also been determined in the present study.

KEYWORDS : Steel building frame, semi-rigid connection, Frey Morris polynomial model, rotational stiffness, standardization constant, moment-rotation curve.

INTRODUCTION

Analysis of connection is necessary because connection is the integral part of the structural system and behaviour of connection affect the stability of the structure. Connection failure should not happen before the member failure because connection failure is not as ductile as that of steel member. Generally, connection is classified by means of their strength (moment resistant of connection) as well as ductility (rotation capacity), in addition to that, there were three types of beam end connections namely, ideal pinned connection (flexible), semi-rigid connection, rigid or moment connection. In pinned connection, forces are fully transmitting but moment is not transmitting between the connected members so that there may be difference in the rotations of the connected member. As per IS 800-2007, flexible connection is used in frames up to about five storey in height where strength rather than stiffness is important in design. This connection is only used in the non-sway frame. Semi-rigid connection transfers vertical shear and some moment. Frey Morris polynomial model which is given in IS-800(appendix-f) is used for semi-rigid connection. This model is based on polynomial equation $\theta r = C1\ (KM)^{1} + C2\ (KM)^{3} + C3\ (KM)^{5}$, where K is a standardization parameter and is dependent upon connection type and geometry. C1, C2, C3 are curve fitting constants and M is the moment in kN.m. Moment-rotation curve for different connection are as shown in fig. 1-

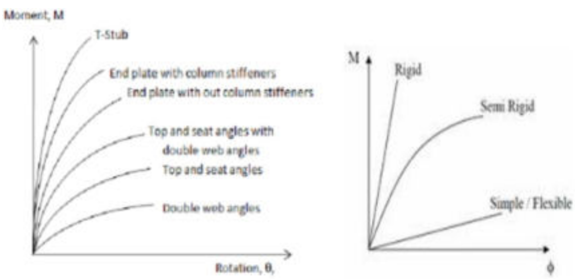

Fig. 1: Moment-Rotation curves for different connection

In rigid or moment connection, forces and moment is fully transmitting between the connected members. In this case, there is no difference between the connected members so that the joint is said to be rotationally stiff means that deformation is negligible and this connection is generally used in sway frame.

LITERATURE REVIEW

M.E.KARTAL; H.B.BASAGA; M.MUVAFIK Studied Effect of semi-rigid connection on structural response. For numerical analysis author developed SEMIFEM finite element programme in FORTRAN language in which semi-rigid connection are define in terms of rotational spring stiffness or by means of connection ratio. In this paper, semi-rigid connection is considering in portal frame, pre-fabricated structure, steel X-braced RC frame, and steel truss system. The variation in moment, shear force, axial force, stress and displacement is investigated. M. N.NADLER; ABOLHASSAN Studied shaking table tests of flexible, semi-rigid, and rigid frames. In this experimental study one-storey, one-bay steel frame was constructed in such a way that connection would be changed from pinned to semi rigid to rigid. Based on the intensities record of past earthquake and with use of shaking table, structure with all these three types of connections were subjected to the base-excitation and studied behaviour of frame in terms of lateral drift and ductility. The main aim of this experiment research was to investigate the potential for using semi-rigid structure in seismically active zone. B.S.DHILLON; O MALLEY [2] Studied interactive design of semi-rigid steel frames. Frey-Morris polynomial is used for design of semi-rigid connection and they used second order non-linear analysis to check the effect of connection flexibility and geometric nonlinearity of the elements. Two-storey, one-bay frame Was analysed with semi-rigid and rigid connection with and without geometric non-linearity and finally, show the effects of connection flexibility and geometric nonlinearity on moments and displacements. S.W.JONES; P.A.KIRBY Studied effect of semi-rigid connection on steel column strength. The main aim of this paper is to determine the effect of connection stiffness on the column behaviour and due to rotational restraint from adjacent beam there would be change in the column effective length. In practice minor-axis buckling is more critical so that for accurate representation of connection behaviour cubic B-spline curve fitting methods are used. A.Y.ELGHAZOULI [3] Studied ductility of frames with semi-rigid connection. The main aim of this experimental study is to analyse the seismic behaviour of frames with semi-rigid partial strength connection. The experiment includes monotonic, cyclic and dynamic test on two-storey steel frames with semi-rigid and rigid beam-column connection and compare the experimental result with analytical results.

ANALYSIS

In the present study, analysis of multi-story multi bay steel frame considering ideally rigid and ideally pinned and semi-rigid conditions in STAAD Pro.2006 using IS-800(2007) has been carried out. To find out percentage rigidity of various types of connection in multi storey steel frames are determined. Analysis results in terms of parameters like bending moments, shear forces, axial forces for members, top storey displacements, time period and weight of frames for ideal pinned and rigid connections have been compared with corresponding results for semi rigid connections. Different types of semi rigid connections incorporated are Single web angle connections, Double web angle connections, Top and seat without web angel connections, End plate with column stiffeners connections, T-Stub connectors and Header plate **connections.**

Flow chart for analysis of semi-rigid connection

EXAMPLE PROBLEM

- Details of loading for steel frame analysis
  - Dead load=1 Kn/m^2
  - Live load=2.5kn/m^2 on typical floring
  - Total dead load per meter width= 4 kn/m
  - Total live per meter length of beam=10 kn/m
  - Typical storey height=3m
  - Zone 3
  - Load case detail-1.5DL+1.5EQX

- **A sample calculation is shown in a sheet as shown in below:**

DESIGN OF BEAM

D.L	4.00	kN/m	Ɣmo	1.10	
L.L	10.00	kN/m	fy	250	N/mm^2
TOTAL	14.00	KN/m			
WIDTH	4.00	m			
max bending moment		42.00	kNm		
section modulus required		184800.00	mm^3		
select suitable section ISMB 200 @0.254KN/M		0.25	kN/m		
D	200.00	mm		R(mm)	11.00
B	100.00	mm		B(mm)	50.00
Tf	10.80	mm			
Tw	5.70	mm			
depth of web(d)		156.40	mm		
moment of inertia about major axis(Izz)		22354000	mm^4		
elastic section modulus(ze)		223500	mm^3		
plastic section modulus(zp)		253860	mm^3		
section classification					
€			1.00		
b/tf			4.63	<	9.40
d/tw			27.44	<	84.00
HENCE SECTION IS PLASTIC					
SELF WT BEAM		0.38	kN/m		
Total load acting on the beam		14.38	kN/m		
max bending moment		42.76	kNm		

PLASTIC SECTION MODULUS REQUIRED		188152	<	253860 mm^3	(safe)
calculation of shear force					
design shear force		43.14	kN		
Vd		181.21	kN		
Also	0.6vd	108.73	kN		
Therefore, the design shear force		V	<	0.6vd	ok
		check for design capacity of the section			
Beta	1.00	(for plastic section)			
		57.70 < 60.93			
design bending moment		KNm			ok

hence, design capacity of member is more than the maximum bending moment

DESIGN OF CONNECTION (3S-1B FRAME)

1)TOP & SEAT ANGLE CONNECTION

BEAM	ISMB 200		Reaction	27.13KN
COLUMN	ISSC 250		tw	5.70 mm
			tf	10.80mm
FLANGE WIDTH OF BEAM		100 mm	r1	10 mm
length of seat angle		100 mm	r2	5.50 mm
			fyw	250N/mm^2
length of bearing required at root line of beam			20.94mm	
end clearance of beam from face of column & tolerance			15.00mm	
required length of outstanding leg			35.94mm	
length of bearing on the cleat		b1	15.14mm	
distance from end of the bearing		b2	12.14mm	
moment at the root of the angle due to load			132.05Nm	
Moment capacity			295.45Nm	

hence connection is safe
provide assume size of seat angle

shear capacity of outstanding leg of cleat	85.39	>27.13KN
shear strength of beam	149.76	>27.13KN

2)HEADER PLATE CONNECTION

ASSUME THICKNESS OF END PLATE	6	mm
length of plate	150	mm
width of plate	120	mm
gauge distance	50	mm
length of fillet weld connecting end plate	138	mm
size of the weld	2.29	mm
provide fillet weld	6.00	mm
shear stress on web of the beam	31.73	<131.37 N/mm^2

3)T-STUB CONNECTION

split beam to beam top flange connection	MOMENT 14.55KN.m	
flange force	72.73	kN
thickness of T-web	3.20	< 5.70 mm
hence, thickness is adequate		
split beam to column flange connection		
minimum edge distance	24.00	mm
distance fillet line to bolt	11.15	mm
moment in T-stub	405.49	KNm
MOMENT CAPACITY OF T-STUB FLANGE	530.18	kNm

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4)DOUBLE WEB ANGLE CONNECTION

shear capacity of M16 bolt in single shear	29.13KN	dia of bolt 16mm
		e 40mm
bearing capacity on web of beam	43.62KN	P 45mm
strength of the bolt	29.13KN	da 130mm
		tc 10mm
gauge distance(g)	105.70mm	kb 0.58mm
use four M16 bolt with vertical pitch	45 mm	
horizontal shear force on bolt due to moment	7.23 KN	
vertical shear force per bolt	6.78KN	
Resultant shear force	9.92KN < 29.30 KN	

hence, connection is safe
connection to the column flange

slip resistance per bolt	62.63 KN
bearing resistance on 8 mm cleat per bolt	61.23KN
hence, bolt strength	61.23KN
horizontal shear force on bolt	24.11KN
vertical shear force	6.78 KN
resultant shear force	25.05KN

hence, connection is safe

Cleat angle :

provide two angle of 130*130*8 of length	175.00 mm
bending moment	830.48 Nm
moment capacity	12250 Nm

hence, the chosen cleat angle size is as required

According to Frey-morris polynomial model calculate secant-stiffness(kNm/rad)

θ=c1(km)^1+c2(km)^3+c3(km)^5

1 top & seat angle connection MOMENT 7.61KNm

c1	1630	equation of k
c2	7.25E+14	k=(d^-1.5)*(ta^-0.5)*(la^-0.7)*(db^-1.1)
c3	3.31E+23	Ta 10mm
		D 200mm
		La 100mm
		Db 20mm

K 1.64938E-07

θ 0.00348 rad

secant stiffness (m/θ) 2186.36 kNm/rad

2 header plate connection

c1	3.87
c2	271000
c3	6.06E+11

K=(tp^-1.6)*(g^1.6)*(dp^-2.3)*(tw^-0.5)

tp	6mm
g	50mm
Dp	150mm
Tw	5.7mm

K	0.00012313
?	0.00428694

SECANT STIFFNESS(M/θ)
1775.16KNm/rad

3. T-STUB CONNECTION

C1	405	K=(d^-1.5)*(tf^-0.5)*(lt^-0.7)*(db^-1.1)
		d 200mm
C2	4.45E+13	tf 10.8mm
C3	-2.03E+23	lt 100mm
		Db 16mm

K 2.02867E-07

? 0.0007872

SECANT STIFFNESS (M/θ) 9667.14KNm/rad

4 DOUBLE WEB ANGLE CONNECTION

C1	1640	K=(da^-2.4)*(tc^-1.81)*(g^0.15)
C2	1.03E+14	da=130 mm
C3	8.18E+25	tc=10mm
		g=105.7mm

k=2.63E-07

θ=0.006743

SECANT STIFFNESS (M/θ) 1128.51KNm/rad

• RESULT AND DISCUSSION

SIZE PARAMETER & SECANT STIFFNESS FOR 3S-1B FRAME

NO	TYPE OF THE CONNECTION	DIMENSION(mm)	ROTATIONAL STIFFNESS (KNm/rad)
1	Top & seat angle connection	La=100,ta=10,db=20,r1=8, Width=65	2186
2	Double web angle	da=130,tc=10,g=105.7	1128.50
3	Header plate connection	Tp=6,dp=150,tw=5.7,g=50	1775
4	T-stub connection	d=200,tf=10.8,lt=100,db=16	9667

SIZE PARAMETER & SECANT STIFFNESS FOR 3S-2B FRAME

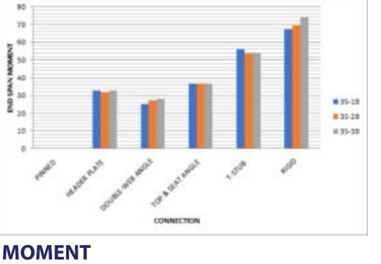
NO	TYPE OF THE CONNECTION	DIMENSION(mm)	ROTATIONAL STIFFNESS (KNm/rad)
1	Top & seat angle connection	La=100,ta=10,db =20,r1=8,b=75	2322
2	Double web angle	da=130,tc=10,g= 105.7	1282.72
3	Header plate connection	Tp=6,dp=150,tw= 5.7,g=50	1838.15
4	T-stub connection	d=200,tf=10.8,lt= 100,db=16	9954.73

SIZE PARAMETER & SECANT STIFFNESS FOR 3S-3B FRAME

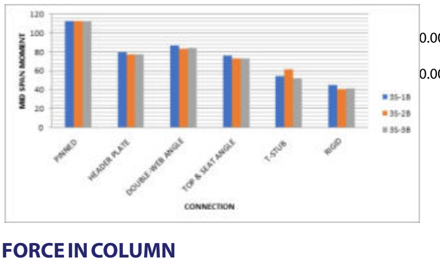
NO	TYPE OF THE CONNECTION	DIMENSION(mm)	ROTATIONAL STIFFNESS(KNm/rad)
1	Top & seat angle connection	La=100,ta=12,db=20,r 1=8,b=75	2700
2	Double web angle	da=130,tc=10,g=105.7	1268.67
3	Header plate connection	Tp=6,dp=150,tw=5.7,g =50	1832
4	T-stub connection	d=200,tf=10.8,lt=100, db=16	9929.23

RESULT

1)END SPAN MOMENT



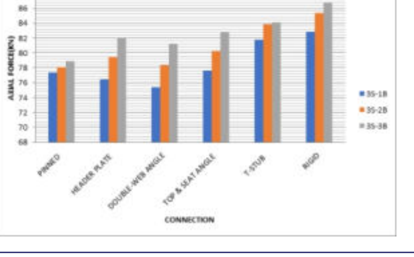
2)MID SPAN MOMENT



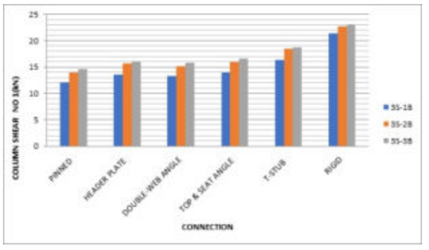
0.000123
13
0.004286
94

31.14 kNm/degr

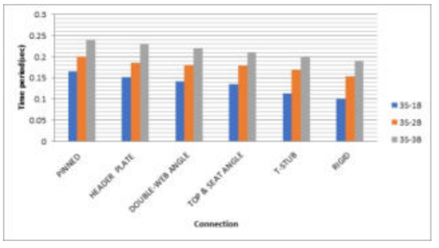
3) AXIAL FORCE IN COLUMN



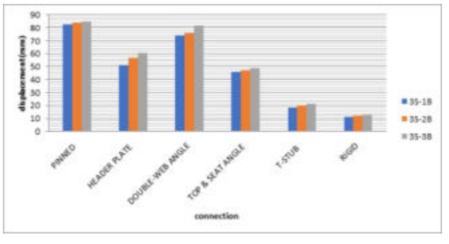
4)SHEAR FORCE IN COLUMN



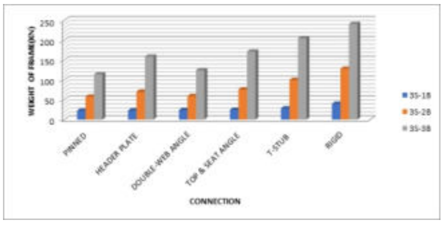
5) TIME PERIOD IN FRAME



6)TOP STROEY DISPLACEMENT



7) WEIGHT OF FRAME



CONCLUSION

- It has been observed that increase in end span moment in the beam enhances with increase in rigidity of end conditions for the beam.
- It has been observed that axial force and shear force in the column is also increase with increasing the rigidity of the end condition and also with increasing the bay.
- Time period and top storey displacement of frame is increased with increasing the flexibility of the connection and it is increased with increase the number of bay.

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