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Analysis of Steel Structures for Various knee bracings using different loading conditions

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ABSTRACT

Steel has become the predominate material for the development of bridges, buildings, towers and other structures. Its great strength, uniformity light weight and lots of other desirable properties makes steel the fabric of choice for varied structures like steel bridges, high rise buildings, towers and other structures. The benefits normally credited to steel as a structural design material are high strength/weight ratio, ductility, predictable material properties, speed of erection structures, and quality of construction easy repair, prefabrication adaptive, use of repetition, expanding existing structures and fatigue strength. Steel structures have the capacity for stiff enough to limit the drift have enough ductility to stop collapse .This steel bracing provides an efficient and economical solution for resisting lateral loads in a framed structure. Knee braced steel frame has a good ductility and lateral stiffness. Since the knee element is correctly fused, yielding occurs only to the knee element and no damage to major elements. In this study, the effect of various styles of bracing are compared with knee braced steel frame are studied and analysed using SAP 2000 software.

***Keywords*: Strength, Ductility, steel bracing, pushover analysis, inter storey drift, Equivalent static analysis, lateral force, base shear.**

1. INTRODUCTION

Structures designed to resist moderate and often occurring earthquakes must have sufficient stiffness and strength to manage deflection and forestall damage. However, it's inappropriate to style a structure to stay elastic under severe earthquake on account of economic constraints. The inherent damping and yielding of structural elements are advantageously utilized to lower the strength requirements, resulting in a more economical design. This yielding provides ductility or toughness of structure against sudden brittle type structural failure. In steel structures, the instant resisting and concentrically braced frames are widely accustomed to resist earthquake loadings. The instant resisting frame possesses good ductility through flexural yielding of beam element because of its limited stiffness it is necessary to style a structure to perform well under seismic loads. Shear capacity of the structure can be increased by introducing steel bracings within the structural systems. Bracing has been used as retrofit yet. There are n number of possibilities are there to rearrange steel bracings. Such as X, V, inverted V and knee type bracings in comparison with bare frames. The current study develops a pushover analysis and equivalent static analysis for different configurations bracing steel frames designed in step with IS 800 – 2007 and ductility behavior of every frame. Knee bracing is a new bracing technique employed in the framed system in which the diagonal brace is anchored to a short member instead of the beam-column joint. This short member is called as the "knee element" which is designed to yield in flexure whereby buckling of the brace is prevented. Knee Braced Frames are the frames in which a non buckling diagonal member provides more lateral stiffness. The knee element provides an excellent ductility during flexural or shear yielding. In this way, the damage is concentrated in a secondary member, which can be easily repaired or replaced at minimum cost. In knee bracing, the damage is mainly concentrated in a secondary member placed on the knee elements so that it can be easily repaired or replaced at minimum cost.

1.1. OBJECTIVE OF THE STUDY

a) To compare different bracing arrangement such as X bracing, V bracing, inverted V bracing , knee bracing , in comparison with bare frames using SAP 2000 software.
b) Using SAP 2000 software, the results of pushover analysis and equivalent static analysis can be evaluated.
c) Various analysis such as base shear, story drift, displacement in steel structure with a different combination of bracing are involved.
d) The effective bracing of G +5 storey was evaluated from the bracing analysis.

2. METHOD OF ANALYSIS

2.1 PUSHOVER ANALYSIS

Pushover analysis is defined as an analysis where a mathematical model directly inculcating the nonlinear load deformation characteristics of individual components and elements of the building is subjected to step by step increasing lateral loads which represents inertia forces in an earthquake until a target displacement is exceeded. The structural Pushover analysis uses a nonlinear static analysis algorithm to assess performance by estimating the force and deformation capacity and seismic demand. The seismic demand parameters are storey drifts, global displacement (at roof or the other reference point), storey forces, and component deformation and component forces. The analysis accounts for material inelasticity, geometrical nonlinearity and also the redistribution of internal forces.

2.2 EQUIVALENT STATIC ANALYSIS

The Equivalent static analysis (ESA) is the easiest method for accounting the dynamics nature of the building by identifying the load carry capacity for the frame structure .This concept involves the design of seismic loads by using IS 1893:2002 (PART 1). The design base shear and lateral forces are computed for the whole building and distributed by means of mass seismic weights of the structure. Zones may be vary for each individual depending on the conditions and logistics of importance factor, response reduction factor and zone factor. Base shear or total lateral shear can be determined by the Criteria for the Earthquake Resistant Design of structures.

From IS 1893:2002 (PART 1), Clause 7.5.3.

VB = Ah * W

Where,

A = Seismic coefficient for a structural building.

W = Seismic weight of structural building.

The design horizontal seismic coefficient for a structure A is given by from 1893:2002, Clause 6.4.2

$A = (Z*I*S_a) /(2*R*g)$.

Z = The zone factor from the Table 2 of IS 1893:2002 (part 1).

I = The importance factor.

R = The response reduction factor.

Sa / g = The coefficient of response acceleration for rock and soil sites as given in fig 2 of IS 1893:2002 (part 1). The values show 5% damping of the structure are given.

T = the fundamental natural period for buildings calculated as per clause 7.6 of IS 1893:2002 (part1).

$Ta = 0.075h^{0.75}$ for resisting structures RC frame building.

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Ta = $0.085h^{0.75}$ for resisting steel frame building.

Ta = 0.09 h/ $\sqrt{d}$ for the other building of moment resisting frames and structures.

h = Height of the building from the base foundation to top roof in m.

2.2.1 Lateral distribution of base shear

The lateral force magnitude at floor node is determined by:

1) Mass of that floor.

2) Distribution of stiffness over the height of the structure.

3) Nodal displacement in given mode.

IS 1893:2002 (part 1) uses a lateral force along the parabolic distribution of the height of the building. The base shear was distributed with the vertical direction of the building.

As per IS 1893:2002 (part 1), Clause 7.7.1.

$Q_i = V_B W_i h_i^2 / \Sigma j_{n=1} W_i h_i^2$

Where,

Q_i = design lateral force at floor i.

W_i = seismic weight at floor i.

h_i = height of storey from foundation and to the top roof.

n = number of stories in a structure.

3. STRUCTURAL MODELLING AND DESIGN

Five bay frame 3D four storied moment resisting frame is selected for analysis. The length and width of building is 9m. Height of typical storey is 3m. Building is symmetrical to X and Y axis. The non-structural element and components that do not significantly influence the building behavior were not modelled. The joints between Beams and Columns are rigid. At the foundation the moment rotation and displacement of columns are assumed to be fixed at the ground level. The following represents the building description as in table 3.1

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SI .no	BUILDING DESCRIPTION	
1	Bay width	3m
2	Floor to floor height	3.3m
3	Total height of the building	16.50m
4	Assume thickness of the slab	150mm
5	Grade of the concrete	M 20
6	Grade of the steel	Fe550
7	Live load	3.0 kN/m^2
8	Zone	III
9	Zone factor	0.3
10	Response reduction factor	5
11	Importance factor	1.0
12	Soil type	Hard Strata
13	Column details	ISHB 300
14	Beam details	ISLB 225
15	Bracing details	ISMB 225

3.1 Descriptions of the building

3.1 Different type of bracing pattern

Same identical rolled steel sections are used for bare frame and other bracing patterns. Different type of bracing patterns such as X, V type, Inverted V type and Knee bracing frame are shown in fig.3.1.

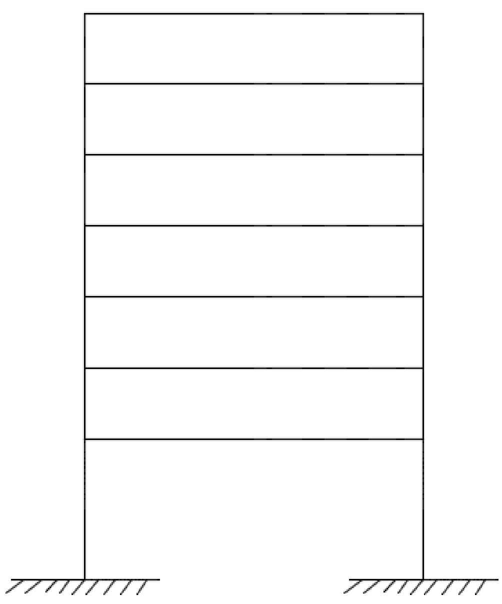

Fig (a) Bare frame

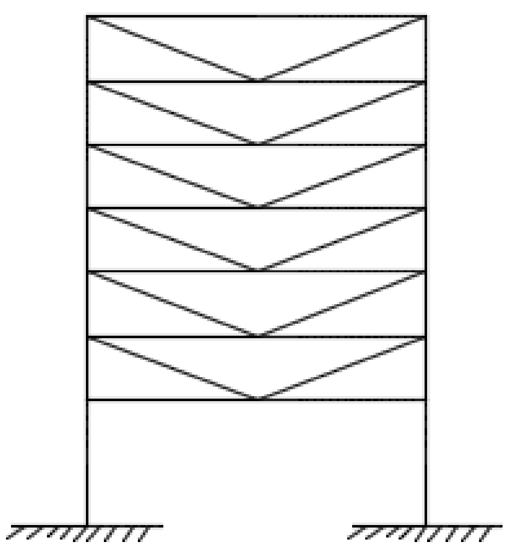

Fig (b) V shaped braced frame

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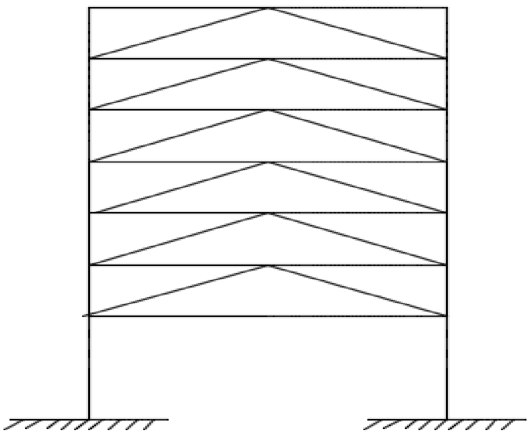

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Fig (c) Inverted V shaped braced frame

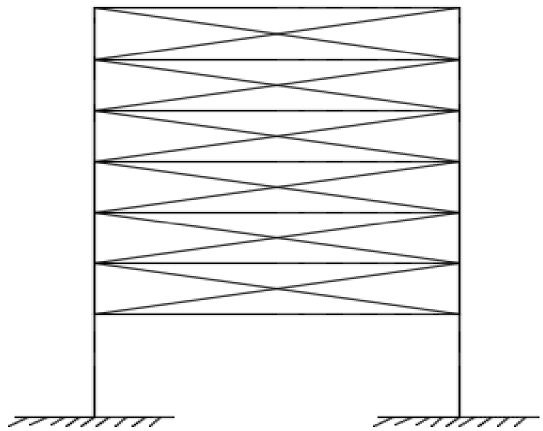

Fig (d) X cross shaped braced frame

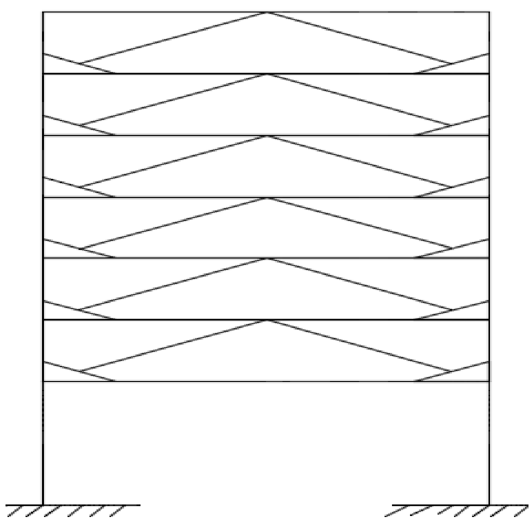

Fig (e) Knee braced frame

Fig 3.1 Different types of braced configurations

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3.2 Load and Load Combinations

Earthquake loads shall be calculated as per IS 1893 (Part I), expect that the reduction factors are recommended in IS 1893 may be used. In the limit state design of frames resisting earthquake loads, the load combination shall conform to table no. 4 from IS 800: 2007.

3.3 Structural Configuration

Following two types of structural configurations has been studied.

1. G + 5 steel moment resisting bare framed structure.
2. G + 5 moment resisting steel bare frame with different bracing patterns such as X, V type, Inverted V type and Knee bracing frame.

Following identical rolled steel sections are used for beams, columns and bracings.

Beam: ISLB 225

Column: ISHB 300

Bracing: ISMB 225

3.4 Preliminary Design of Building

The Equivalent lateral force analysis procedure involves the magnitude and distribution of the lateral forces in the direction of the ground motion components over the height of the structure .This method is mainly suitable for the preliminary design of the structure .Equivalent lateral force analysis can be carried out by using SAP 2000.

4. RESULTS & DISCUSSIONS

4.1 Inter Storey drifts in X- direction Following table shows the storey level, storey displacement and inter storey drift for steel bare frame and different types of bracing patterns such as bare frames ,X bracing,V bracing, Inverted V type bracing, knee bracing in X- direction by RSA as shown in Table4.1.

Level of the storey	Bare frame	V bracing	Inverted V bracing	X bracing	Knee brace	IS 1893 :2002
5	0.0021	0.0015	0.0002	0.0002	0.0002	0.004
4	0.003	0.0018	0.00017	0.0003	0.00019	0.004
3	0.0037	0.00014	0.00019	0.000068	0.00019	0.004
2	0.0025	0.003	0.0018	0.0003	0.00017	0.004
1	0.0003	0.00027	0.00025	0.00025	0.00015	0.004
0	0	0	0	0	0	0.004

Table 4.1 Tabulation of interstorey drift in X direction

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4.2 Inter Storey drifts in Y- direction Following table shows the storey level, storey displacement and inter storey drift for steel bare frame and different types of bracing patterns such as X, V bracing, Inverted V type bracing, knee bracing in Y- direction by RSA as shown in Table 4.2.

Level of the storey	Bare frame	V bracing	Inverted V bracing	X bracing	Knee bracing	IS 1893:2002
5	0.00298	0.00015	0.00014	0.0002	0.00061	0.004
4	0.00426	0.00018	0.00012	0.000067	0.00015	0.004
3	0.00514	0.00017	0.00011	0.0002	0.00018	0.004
2	0.0049	0.00014	0.00011	0.0001	0.00045	0.004
1	0.0081	0.0062	0.00064	0.00065	0.0008	0.004
0	0	0	0	0	0	0.004

Table 4.2 Tabulation of interstorey drift in Y direction

4.3The Performance Point are the values which represents the state of maximum inelastic capacity of the structure, was found through the cross point of the Capacity Spectrum and Demand Spectrum for a given damping ratio .Performance point Following table shows the values of performance point for steel bare frame with different types of bracing patterns such as X, V bracing, Inverted V type bracing, knee bracing as shown in table 4.3.

Frame model	V	D	Sa	Sd
Bare frame	524.64 5	0.013	0.297	0.103
V bracing	1831.0 2	0.021	0.75	0.026
Inverted V bracing	1701.0 5	0.026	0.665	0.029
X bracing	2137.4 9	0.019	0.81	0.014
Knee brace	2031.3 1	0.028	0.831	0.024

Table 4.3 Performance point for steel bare frame with different bracing patterns

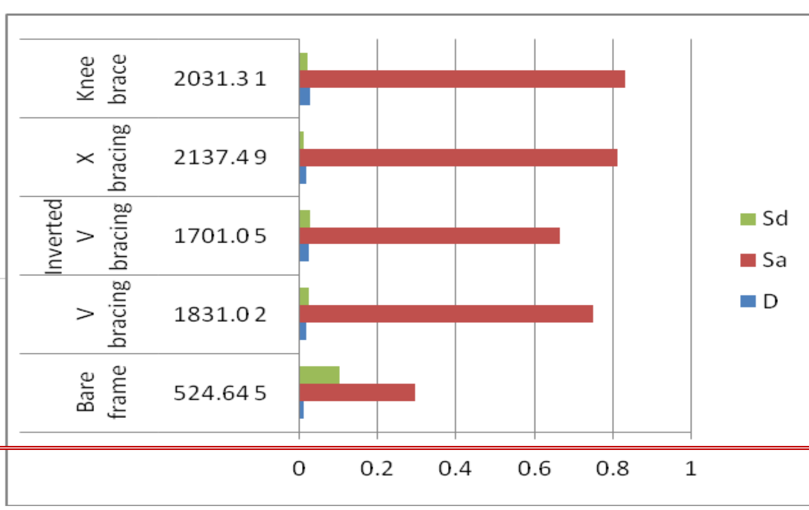

Fig 4.3 represents the performance point graph.

5. CONCLUSIONS

From the above experimental study, the following conclusions were made that the seismic behavior on G+5 structural model with different bracing arrangements are included for investigation. The internal storey drift in X-direction is far compared to permissible drift ratio as per IS 1893:2002 (part 1).Hence the knee braced frame system is significant to reduce the effect on lateral displacement by spectral acceleration (Sa).The internal storey drift in Y-direction is far compared to permissible drift ratio as per IS 1893:2002 (part-1). Therefore, the knee bracing frame structural internal storey drift is acceptable by IS 1893:2002 (part 1).

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