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Retrofitting of RC Frames using Steel Braces for Seismic Effect

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Abstract - *In this project, the seismic analysis of 10 story reinforced concrete building with different types of bracing systems is studied. A G+9 building is analyzed for seismic zone III as per IS 1893: 2016 using ETABS 2018 software. Equivalent Static method analysis has been conducted to evaluate the effect of the bracings in different story. The main parameters consider in this seismic analysis of buildings are lateral displacement and story drift. From the analysis it is found that the X type of steel bracing significantly contributes to the stiffness of building and reduces the maximum story drift and lateral displacement of the buildings. From the results it was also found that, the tube section has better performance in comparison to angle section.*

***Key Words*: Retrofitting, Bracings, Equivalent static method, Displacement, Storey drift**

1.INTRODUCTION

Earthquake causes shaking of the ground in all the three directions X, Y and Z, and the ground shakes back and forth along each of these axes. Commonly, structures are designed to withstand vertical loads, so the vertical shaking due to earthquakes is tackled through safety factors used in the design to support vertical loads. However, horizontal shaking along X and Y directions is critical for the performance of the structure since it generates inertia forces and lateral displacement and hence adequate load transfer path shall be provided to prevent its detrimental influences on the structure. Proper inertia force transfer path can be created through retrofitting of structures by steel braces. Steel bracings reduce flexure and shear demands on beams and columns and transfer the lateral loads through axial load mechanism

1.1 TYPES OF BRACING

1.1.1 Single diagonal bracing

In this type of bracing, diagonal structural elements are inserted into the structural frame, and it is called as trussing, or triangulation. This helps in stabilizing the frame. A single brace needs to be resistant to tension and compression.

1.1.2 Inverted V bracing

Inverted bracing also known as chevron bracing is similar to V-bracing, with the difference that bracing elements join at upper member center point

1.1.3 X BRACINGS

When two bracing members cross each other, this is known as cross-bracing, or X-bracing. Such braces need to be tension-resistant, where each brace resists sideways forces. Steel cables can also be used for this kind of bracing. Care must be taken so that external cross-bracing does not clash with the placement and purpose of windows. Cross-tracing also has the potential to bend floor beams in some cases

2. OBJECTIVES

1) To study the seismic behaviour of RC building by performing Equivalent static analysis on a 10 storey RCC braced and unbraced building.

2) To compare the effect of various types of bracings on the structure and adopt the bracing which gives maximum reduction in lateral displacement and story drift

3) To compare the effect of seismic loads on steel section used in bracing of structure and choose the efficient steel section to be used in bracing system.

3. MODELLING OF BUILDING

Table -1: Building data

Type of building	Commercial
No. of bays in x-direction	4
No. of bays in y-direction	4
Length of each bay	5m
Number of stories	10
Height of the floor	3.2m

Table -2: Structural members data

Type of Frame	Ordinary Moment Resisting Frame
Size of Beams	300mm x 450mm
Size of column	300mm x 600mm

Thickness of slab	125 mm
Support condition	Fixed

Table -3: Steel members data

Grade of steel	Fe250
Steel angle section	ISA 200x200x25
Steel tube section	ISB 172x92x5.4

Table -4: Seismic parameters

Seismic zone (Table 2 of IS 1893 – 2016)	III
Zone factor, Z (Table 2 of per IS 1893-2016)	0.16
Importance factor, I (Table 6 of per IS 1893:2016)	1
Response reduction factor, R (Table 7 of per IS 1893:2002)	3
Soil type	II

3.1 Model of building without braces

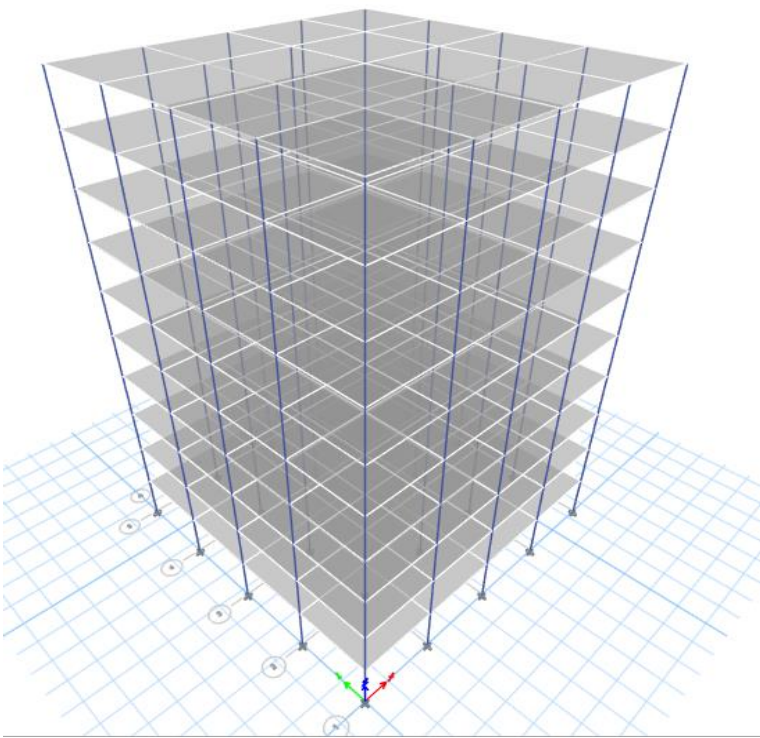

Fig -1: 3D view of the building without braces

3.2 Model of building with braces

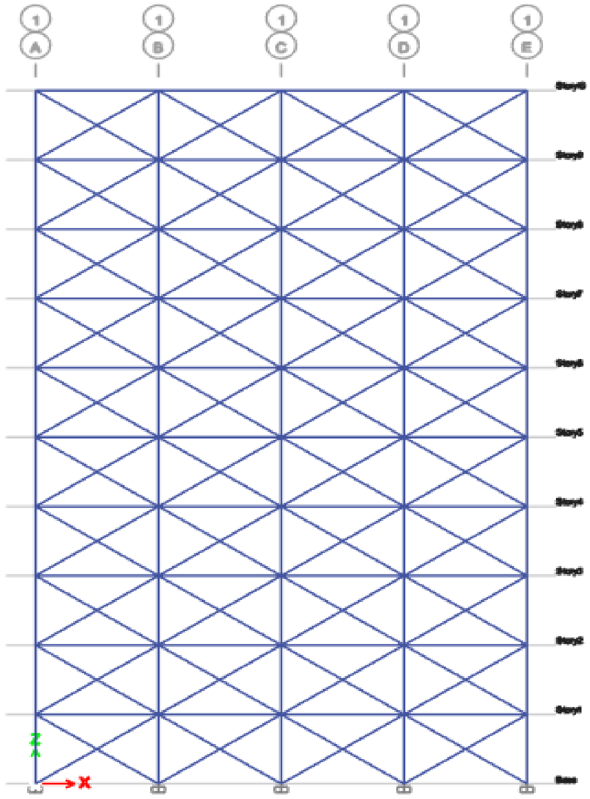

Fig -2: Elevation of the building with X bracings

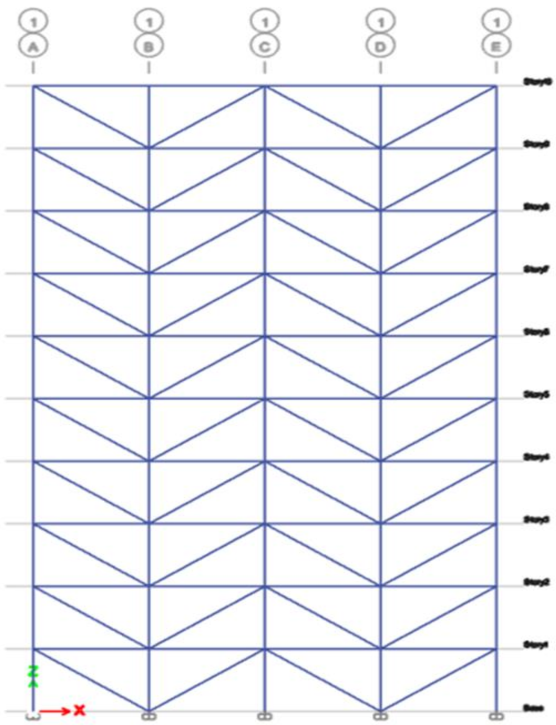

Fig -3: Elevation of the building with Diagonal bracings

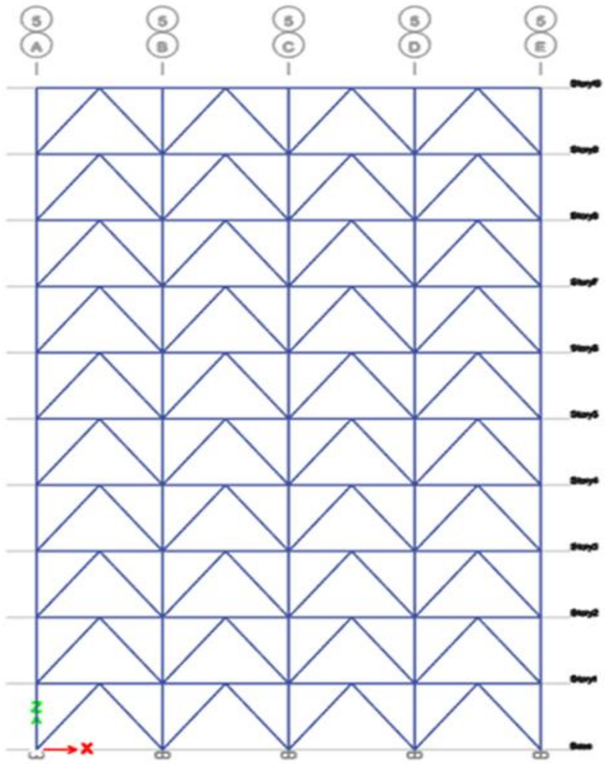

Fig -4: Elevation of the building with Inverted V bracings

4. CALCULATION OF LATERAL LOAD DISTRIBUTION BY EQUIVALENT STATIC METHOD

Total height = 32 m
Floor area = 20*20 = 400 m^2

Only 50% of the live load is lumped at the floors. At the top storey i.e., roof, no live load is to be lumped. Effective weight at each floor except the roof = 6+0.5(4) = 8 kN/m^2

Effective weight at the roof = 4 kN/m^2

COLUMN LOAD CALCULATION

Volume of concrete = 0.3 x 0.6 x 3.2 = 0.576 m^2

Weight of concrete = 0.576 x 2400 = 1382.4 kg

Weight of steel in concrete = 0.576 x 0.01 x7850 = 45.2 kg

Total weight of column = 1382.4 +45.2 = 1430 kg

Weight of column at each floor = 14 x 25 = 350 kN

Weight of column at roof = 0.5 x 350 = 175 kN

BEAM LOAD CALCULATION

Volume of concrete = 0.3 x 0.45 x 1 = 0.135 m^2

Weight of concrete = 0.135 x 2400 = 324 kg

Weight of steel in concrete = 0.135 x 0.02 x 7850 = 22 kg

Total weight of column = 324 + 22 = 346 kg/m

Weight of beam at floor and roof = 3.5 x 200 = 700 kN Total load at roof level = 4*400 + 700 + 175 = 2475 kN

Total load at floor level = 7.5*400 + 700 + 350 = 4250 kN

Seismic weight of building, W = 2475 + 3250*9 = 40725 kN

FUNDAMENTAL NATURAL PERIOD:

T = 0.075h0.75 = 1.009 sec (Clause 7.6.2. of IS: 1893 Part 1)

The building is located on Type II (medium soil)

From Fig. 2 of IS: 1893, for T=1 sec,

Sa/g = 1.36/T = 1.347

Ah=(ZI)/2R * Sa/g = 0.0359 (Clause 6.4.2 of IS: 1893 Part 1)

DESIGN BASE SHEAR

Vb=Ah*W = 1463.676 kN (Clause 7.5.3 of IS: 1893 Part 1)

Table -5: Lateral force and base shear distribution on each story

Lateral Force (kN)	Shear force (kN)
258.065	258.065
344.145	602.210
270.264	872.475
206.921	1079.397
152.023	1231.421
105.572	1336.993
67.566	1404.559
38.005	1442.565
16.8915	1459.457
4.222	1463.68

5. RESULTS AND DISCUSSIONS
5.1 Maximum Displacement

Storey displacement is the value of maximum lateral displacement of the storey under the action of lateral load. The maximum displacement in the building along X direction is obtained for the seismic load combination 1.2 (DL+LL+EQX).

5.1.1 X Bracings

Table -6: Maximum displacement of building with X bracings for the load combination 1.2 (DL+LL+EQX)

Story	Elevation	Without braces	Steel tubes	Steel angles
	(m)	(mm)	(mm)	(mm)
10	32	54.566	16.926	18.579
9	28.2	52.418	15.954	17.568
8	25.6	48.937	14.691	16.221
7	22.4	44.204	13.181	14.584
6	19.2	38.475	11.474	12.722
5	16	32.016	9.638	10.707
4	12.8	25.068	7.735	8.608
3	9.6	17.845	5.821	6.487
2	6.4	10.599	3.948	4.398
1	3.2	3.907	2.152	2.38
Base	0	0	0	0

5.1.2 Diagonal Bracings

Table -7: Maximum displacement of building with diagonal bracings for the load combination 1.2 (DL+LL+EQX)

Story	Elevation	Without braces	Steel tubes	Steel angles
	(m)	(mm)	(mm)	(mm)
10	32	54.566	25.963	28.145
9	28.2	52.418	24.713	26.843
8	25.6	48.937	22.994	25.011
7	22.4	44.204	20.801	22.652
6	19.2	38.475	18.246	19.891
5	16	32.016	15.436	16.844
4	12.8	25.068	12.469	13.616
3	9.6	17.845	9.428	10.299
2	6.4	10.599	6.383	6.967
1	3.2	3.907	3.371	3.662
Base	0	0	0	0

5.1.3 Inverted V Bracings

Table -8: Maximum displacement of building with Inverted V bracings for the load combination 1.2 (DL+LL+EQX).

Story	Elevation	Without braces	Steel tubes	Steel angles
	(m)	(mm)	(mm)	(mm)
10	32	54.566	19.507	21.433
9	28.2	52.418	18.53	20.406
8	25.6	48.937	17.203	18.979
7	22.4	44.204	15.539	17.172
6	19.2	38.475	13.625	15.08
5	16	32.016	11.541	12.792
4	12.8	25.068	9.362	10.389
3	9.6	17.845	7.152	7.943
2	6.4	10.599	4.976	5.521
1	3.2	3.907	2.791	3.077
Base	0	0	0	0

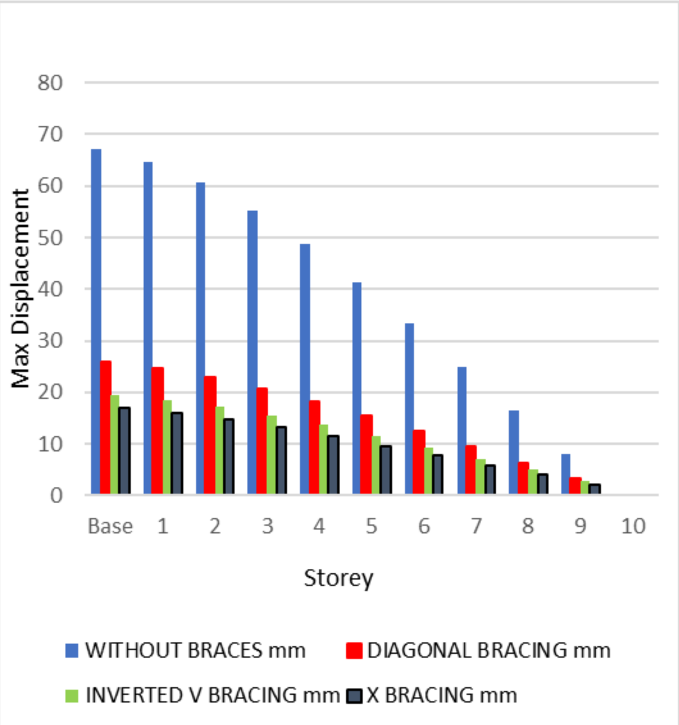

Chart -1: Graph of Maximum Lateral Displacements (mm)for different types of bracings

Table -9: Percentage reduction in top story displacement

Model	Steel tubes	Steel angles
X Bracings	68.98 %	65.95%
Inverted V Bracings	64.25%	60.72%
Diagonal Bracings	52.41%	46.92%

The displacements are reduced drastically for bracing types X, diagonal, and Inverted V. It is observed that the displacement is reduced to largest extent for X type of bracings, while the displacement is maximum for the system without bracing. Top floor displacement for the system with X bracing is reduced by 68.98% with tube sections and 65.95% for angle sections in X direction as compared to that of without braces.

5.2 Story Drift

Story drift is the drift of one level of a multi-story building relative to the level below. It is the difference between the two floor displacements of any given story as the building sways during the earthquake. The analysis results of story drift of the building with and without braces in X directions for load combination 1.2(DL+LL+EQX) is obtained.

5.2.1 X Bracings

Table -10: Story drift of building with X bracings for the load combination 1.2 (DL+LL+EQX)

Story	Elevation	Without braces	Steel tubes	Steel angles
	(m)			
10	32	0.000779	0.000321	0.000333
9	28.2	0.001237	0.000395	0.000421
8	25.6	0.001679	0.000478	0.000516
7	22.4	0.002034	0.00054	0.000588
6	19.2	0.002299	0.00058	0.000635
5	16	0.002482	0.000601	0.000662
4	12.8	0.002594	0.000605	0.000669
3	9.6	0.002639	0.000592	0.000658
2	6.4	0.002602	0.000583	0.000652
1	3.2	0.001925	0.000512	0.000567
Base	0	0	0	0

5.2.2 Diagonal Bracings

Table -11: Story drift of building with diagonal bracings for the load combination 1.2 (DL+LL+EQX)

Story	Elevation	Without braces	Steel tubes	Steel angles
	(m)			
10	32	0.000779	0.000395	0.000413
9	28.2	0.001237	0.000544	0.000579
8	25.6	0.001679	0.000694	0.000745
7	22.4	0.002034	0.000806	0.00087
6	19.2	0.002299	0.000884	0.000958
5	16	0.002482	0.000933	0.001014
4	12.8	0.002594	0.000956	0.001042
3	9.6	0.002639	0.000957	0.001046
2	6.4	0.002602	0.00096	0.00105
1	3.2	0.001925	0.000803	0.000872
Base	0	0	0	0

5.2.3 Inverted V Bracings

Table -12: Story drift of building with Inverted V bracings for the load combination 1.2 (DL+LL+EQX).

Story	Elevation	Without braces	Steel tubes	Steel angles
	(m)			
10	32	0.000779	0.000322	0.000337
9	28.2	0.001237	0.000424	0.000454
8	25.6	0.001679	0.000528	0.000572
7	22.4	0.002034	0.000604	0.000659
6	19.2	0.002299	0.000655	0.000718
5	16	0.002482	0.000684	0.000753
4	12.8	0.002594	0.000693	0.000767
3	9.6	0.002639	0.000684	0.000761
2	6.4	0.002602	0.000694	0.000776
1	3.2	0.001925	0.000664	0.000733
Base	0	0	0	0

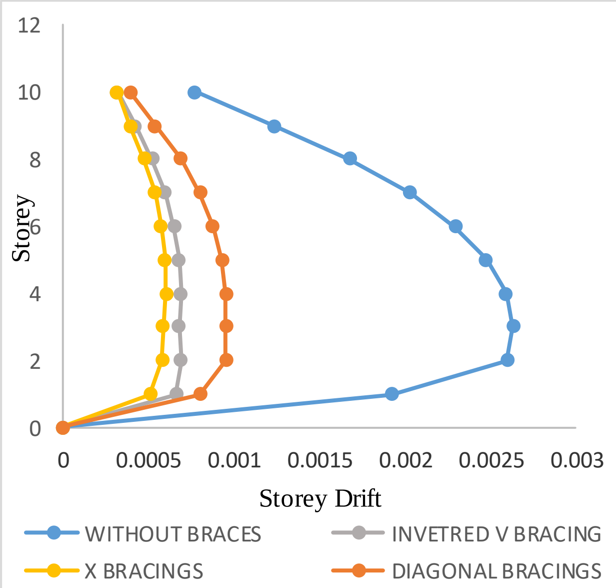

Chart -2: Graph of Storey drift for different types of bracings

The addition of steel bracings reduces maximum inter story drift and distributed more uniformly along the height of structure. The X type of bracings reduces the story drifts in the building and provides safety against collapse by reducing the lateral displacements.

6. COMPARISON OF STEEL SECTIONS IN TERMS OF DISPLACEMENT & STOREY DRIFT

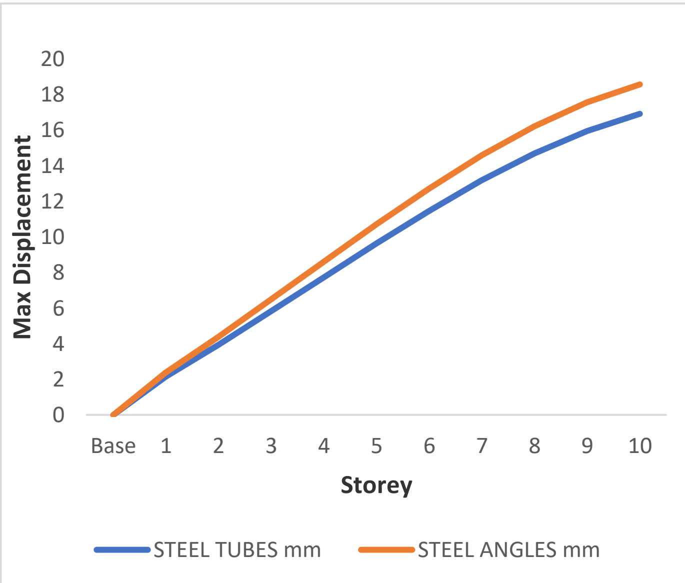

Chart -3: Graph of comparison between steel tubes and steel angles in terms of maximum displacement

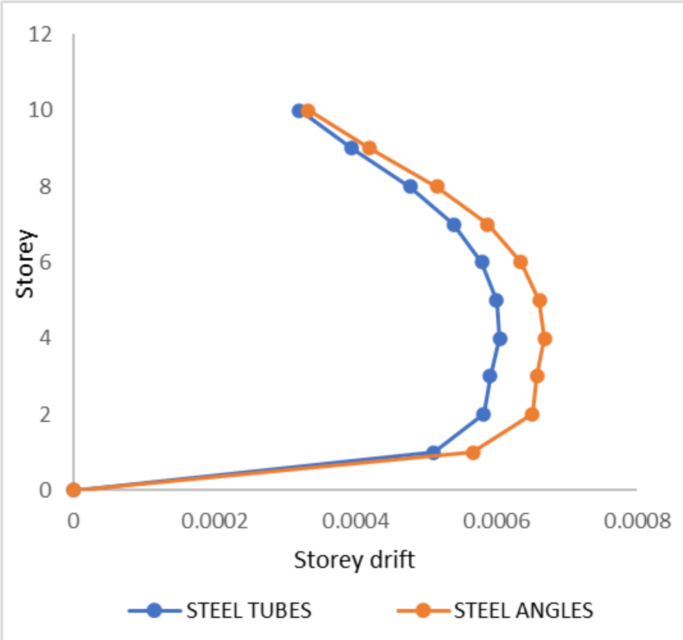

Chart -4: Graph of comparison between steel tubes and steel angles in terms of storey drift

7. CONCLUSIONS

- The maximum story displacement and story drift of the building is reduced by the use of bracing system.
- By using Steel Bracing the total weight on the existing building did not change significantly i.e., only 0.3% to 0.36% increase in weight.
- X type of bracing is found to be more effective than other bracings. The reduction in the displacement along X direction is about 68.98% by use of steel tube section and 65.95% by the use of steel angle section.
- The performance of steel tube section braced frame is better than steel angle section frame.
- Thus, by retrofitting the RCC structures with steel braces, the effect of lateral loads can be reduced.

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BIOGRAPHIES

Prof. R. B. Kulkarni received his Bachelor's degree in Civil Engineering from Karnataka University, Dharwad, India in the year 1984. In the year 1988 received Post graduate diploma in Construction management from NICMAR, Mumbai, India. Completed Master's degree in Structural Engineering from Karnataka University, Dharwad, India in the year 1991. Worked as Structural Engineer at M/s Gammon India Ltd, Mumbai, Technical Manager at NABARD & Society Engineer in KLS for the Maintenance, Design and execution of the Society Buildings. Presently serving as an Assistant Professor at KLS Gogte Institute of Technology, Belgaum.

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