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Diagrid Structural System: Comparative Study to Reduse the Earthquake Forces on High Rise Building

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Abstract – Generally Lateral load resistance of structure is provided by interior structural system or exterior structural system. Usually shear wall core, braced frame and their combination with frames are interior system, where lateral load is resisted by centrally located elements. While framed tube, braced tube structural system resist lateral loads by elements provided on periphery of structure. Recently diagrid structural system is adopted in tall buildings due to its structural efficiency and flexibility in architectural planning. Diagrid structure consists of inclined columns on the exterior surface of buildings compared to closely space vertical columns in framed tubes.In present work concrete diagrid structure is analysed and compared with convensional concrete building. A regular 4 and 12 storey building with plan size 20m x 20m located in seismic zone III is considered for analysis. All the structural members are design as per IS-800 (2000).STAAD-PRO software is used for the analysis of structural members. All load combinations of seismic forces are considered as per IS-1893:2002. Comparison of analysis results in terms of mode shape, lateral displacement, storey drift.

Keywords: Diagrid Structural System, High-Rise Building, Mode Shape, Storey Drift and Storey Displacement

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1. INTRODUCTION

Construction of multi-storey building is rapidly increasing throughout the world. But when the height of structure increases then the consideration of lateral load is very much important. For that the lateral load resisting system becomes more important than the structural system that resists the gravitational loads. The lateral load resisting systems that are widely used are rigid frame, shear wall, wall frame, braced tube system, outrigger system and tubular system. Recently the diagrid –diagonal grid structural system is widely used for tall buildings due to its structural efficiency and aesthetic potential provided by the unique geometric configuration of the system.

Generally, for tall buildings diagrid structure steel is used. In present work concrete diagrid structure is analysed and compared with convensional concrete building. DIAGRID is combination of words "diagonal" and "grid". It is a system of triangulated beams - straight or curved and horizontal rings that together make up a Diagrid structural system. Therefore the diagonal members in diagrid structures act both as inclined columns and as bracing elements, and carry gravity loads as well as lateral forces due to their triangulated configuration. There are engineering based reasons that would suggest the use of diagrid, Some of them are:

- Increased the stability due to Triangulation.
- Combination of the gravity and lateral load bearing system potentially provide more efficiency.
- Provide alternate load path (redundancy) in the event of structural failure.
- Reduced weight of superstructure can translate into a reduced load on foundation.

Load distribution in diagrid structure is as follows-

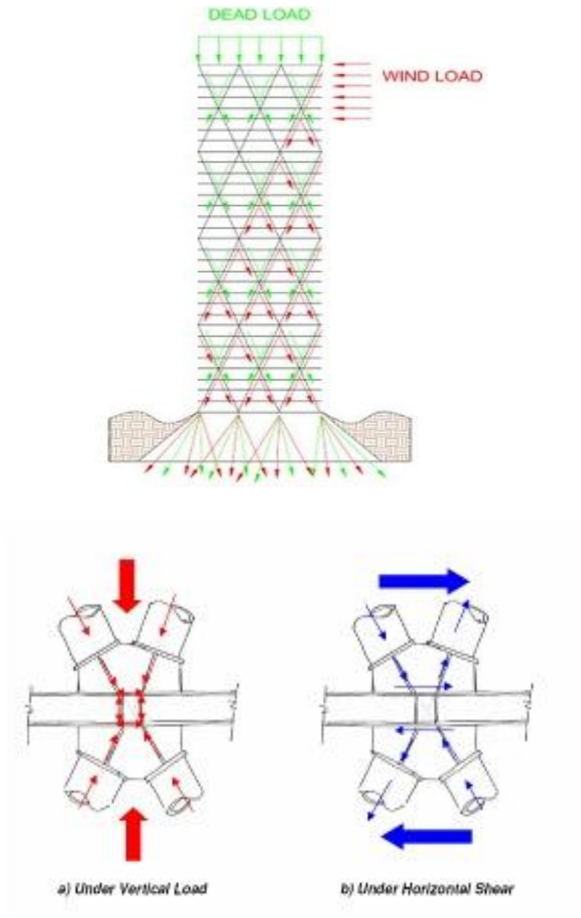


Fig. 01: Load transfer system of Diagrid Structure

The load path can be divided into two main parts, vertical load and horizontal shear as shown in fig. vertical load will be transferred in the form of an axial load from the diagrid members above the node to the gusset plate and stiffners, then to diagrid members below the nodes as shown. The horizontal shear will be in the form of an axial load in the diagrid members above the nodes with one in compression and one in tension to the gusset plate and stiffners. The force will be then transferred as shear force in the gusset plate and then to the other pair of tensile and compressive forces on the diagrid member below the node.

Famous examples of diagrid structure all around the world are the Swiss Re London, Hearst Tower in New York, Capital Gate tower in Abu Dhabi, IBM Building in Pittsburgh, Cyclone Tower in Asan (Korea) and new World Trade Centre in New York.

(i) (ii)

(iii) (iv)

Fig- 2: (i) Swiss Re London, (ii) Hearst Tower, (iii) Capital Gate Tower, (iv) IBM Building

In present work concrete diagrid structure is analysed and compared with conventional concrete building. A regular 4 and 12 storey building with plan size 20m x 20m located in seismic zone III is considered for analysis. All the structural members are design as per IS-800 (2000).STAAD-PRO software is used for the analysis of structural members. All load combinations of seismic forces are considered as per IS-1893:2002. Comparison of analysis results in terms of mode shape, lateral displacement, storey drift.

2. DESIGN OF FRAME STRUCTURE MEMBERS-

(A) Slab Design-

Slabmark- S-1,S-2 & S-3

Type- Two way continuous with corners restrained

Spans- Short span (Lx) in metre=5,in mm=5000

Long span (Ly) in metre= 5,in mm=5000

Aspect ratio= $\frac{Ly}{Lx}$,so =1

Live Load (in KN/m^2)= 4

Floor Finish (in KN/m^2) = 2.5

Trial Depth- In case of two-way slab, (L/d) ratio for deflection criteria is related to short span.

In case of two-way slab, the design moments are small compared to those in one-way slabs, percentage of steel required in two way slabs in general is very low (Between 0.20 to 0.30% for M-20 and fe-415) so assumed 0.28% steel.

For, Pt=0.28% …..so Pt= 0.28

corresponding to fs= 240 N/mm^2

α= 1.7…….. As per IS 456:2000,Fig.04, pg. no.38

for continuous slab Basic (L/d) ratio (rb= 26)

…… As per IS 456:2000, clause no. 23.2.1

Required (d) in mm= Lx/(α*rb)= 113.12217 , say (d) in mm ≈ 120

Assuming (d′) in mm= 20

Required (D) in mm= 140,in m0.14

Loads- consider 1 metre width of slab

Wu= 1.5 [(25 x D)+ LL+ FF]

So Wu in KN/m²= 15

Design moments- Boundary condition no.=4

…….. As per IS 456:2000, table 26,pg. no.91

Wu .(Lx)²= 375

Ly / Lx is =1

….. As per IS 456:2000, table 26,pg. no.91

Check for concrete depth-

for slabs (b) in mm= 1000

Mur.max= Rumax.b.(d)²

…..Rumax= 0.138xfck

here fck= 20

for outer bars (KN.m)=39.744……safe

for inner bars (KN.m)=33.396…..safeRequired Ast =

$$A_{st} = 0.5\frac{f_{ck}}{f_y}\left(1-\sqrt{1-\frac{4.6M_u}{f_{ck}Bd^2}}\right)Bd$$

For , M 20 , so fck =20

For , fe 415,so fy= 415

0.5fck/fy=0.02409639

fckxbx(d)² =288000000

b.d =120000

Assume dimeter (in mm)=10

Required Ast (mm²)	Diameter (mm)	Spacing (mm)	Provided Ast (mm²)	**Lx is**
440.56584 **441**	10 ≈	178.00454 **175**	448.571429 **449**	=
320.89298 **321**	10 ≈	244.54829 **240**	327.083333 **328**	
440.56584 **441**	10 ≈	178.00454 **175**	448.571429 **449**	
320.89298 **321**	10 ≈	244.54829 **240**	327.083333 **≈328**	

Distribution Steel –

Assume dimeter (in mm)=**8**

Spacing= 299.047619 ≈290

Check for deflection - Required (Pt) at mid-span of short span=

Ast x100

bx dRequired (Pt) in % = 0.2733333 ……………….Safe

Check for shear - β = Ly/Lx ,so = 1

(a) Long edge – continuous

$$Vumax = 1.2*Wu*Lx\left[\frac{\beta}{(2.\beta+1)}\right]$$

Vumax= 30KN

Ast= Provided Ast of short span of support

(in mm²)=449

Pt = Ast x100 , Pt (in%)=0.374167 bx d

K=1.3…….As per IS 456:2000, clause no. 40.2.1.1

ζuc= ?…….. As per IS 456:2000, table 19,pg. no.73

Check for Development length-

(a) Long edge – continuous

Required (Ld)=ϕ . σs

4. ζbd

…….As per IS 456:2000, clause no.26.2.1

Ϭs =0.87x fy = 361.05

ζbd =1.2*1.6 =1.92

Required (Ld) in mm=470.117188≈471

Available (Ld)=0.3 * Lx

so =1500……………..safe

(b) Long edge - discontinuous

Assuming 50% bars bent up,

M1=Mu, midspan of longspan (Mu) 2

So M1=6.5625 KN.m

Now, K*M1*(1000/Vumax)+Lo

(c) Short edge - continuous

Available (Ld)=0.4 * Ly

so = 2000……………..safe

(d) Short edge - discontinuous

Assuming 50% bars bent up,

M1=Mu, midspan of longspan (Mu) 2

So M1=6.5625 KN.m

Now, K*M1*(1000/Vumax)+Lo

=599.16667……………….safe

So provide slab thickness (D)

in mm= 140 ,0.14 m

(B) BEAM DESIGN

(i) INTERNAL TRANSVERSE BEAM:-(ROOF AND SLAB)

(1) End Condition: Simply Supported

(2) Span L (meter):5

(3) Section : Assumed b (mm)= 300in merer0.3

Depth (mm) =500in meter0.5

d" (mm)=40

d(mm)=460

Slab Thickness (mm)=140in merer0.14

(4) Loads:

Wu=1.5 x(Self weight of Beam+2*RoofSlab'sTriangular Load)

Roof Slab Load =(self-weight + Floor Finish)

Floor finish =2.5

Live load=1.5

Roof Slab Load = 6

i.e. Self-weight of Beam =2.7

Slab's Triangular Load = 20

Wu =34.05Kn/m

Wus =15.3Kn/m

slab=30

Total dead load=32.7

slab=7.5

Total working load=40.2

maximum load Wmax=60.3≈61

minimum load Wmin=32.7≈33

Ratio LL/Total Load=0.19

(5) Design Moment: Mu = $(Wu. L^2)/8$

Mu=106.40625Kn.m

(6) Maximum Ultimate Moment of Resistance of Rectengular Section =

For M 25 ,fck=20

fck 500,fy=415

Mur.max= Ru.max $b.d^2$i.e583.04961

Ru.max =0.36 fck.Kumax (1-0.42 Kumax)

=2.75543292

Kumax=700/1100+0.87fy =0.4791075

If Murmax > Mu……………….Singly Reinforced

(7) Main steel :

0.5* fck/fy=0.024096386

b.d=138000

{1-(4.6*Mu.10^6/fck*b*d²)}^1/2 =

Required Ast=3325.301205mm²

assumed Diameter of stirrups ϕ (mm)=6

assumed Diameter of Bar ϕ (mm)=25

Number of Bars=6.777683984≈ 7

(8) check for Width=

Required b=n.ϕ+(n+1)x25+2.ϕst

Required b (mm)=287……………….ok

(9) Check for Effective cover d :

For Moderate Environment (M 25)

nominal cover in mm=20

d'=Nominal cover + Diameter of stirrups

+ (ϕ/2)

d'=38.5…………..ok

(10) Design for Shear :

Vu.max = Wu*L/2so,85.125

Ast1=3434.375

Pt =100.Ast1/b.d = 2.488677536….in %

ζuc= ?…….. As per IS 456:2000,

table 19,pg. no.73

2.625	Pt (in%)= 2.5 2.75	2.625 0.81 0.82
	0.25 0.125	0.01 x= ?
	x=	0.005

ζuc (N/mm²)= 0.815

ζuc=0.815

Vuc= ζuc.bd , so, Vuc=112.47Kn

Vusv.min=0.4 bd, so, Vusv.min=55.2

Vur.min=167.67

……………..min. stirrups are sufficient

(11) Check for Development Length :

Required Ld= 47 ϕ = 1175in mm

1.3 M1/V+L0

275.8408984 Kn.m………. M1

L0=Ld/3-bs/2 = 276.6666667

1.3 M1/V+L0 =4489.214894

Required Ld=1175 mm

(12) Check for Deflection :

Actual L/d = 10.86956522

Basic L/d = 20 …………………. safe

(13) Load on column : Vu.max = Wu*L/2

Load on column = so, in KN = 85.13 ……………… safe

(ii)INTERNAL&EXTERNAL LONGITUDINAL ROOF BEAM & INTERNAL LONGITUDINAL FLOOR BEAM:-

(1) End Condition: Simply Supported

(2) Span L (meter): 5

(3) Section : Assumed b (mm)= 300 in merer 0.3

Depth (mm) = 300 in meter 0.3

d" (mm)= 40

d(mm)= 260

Slab Thickness (mm)= 140 in merer 0.14

(4) Loads:

Wu =1.5x(Selfweight of Beam +

2*Roof Slab's TriangularLoad)

Roof Slab Load =(self weight + Floor Finish)

Floor finish =2.5

Roof Slab Load =6

i.e. Self weight of Beam =1.2

Slab's Triangular Load =20

Wu =31.8Kn/m

Wus =13.05Kn/m

(5) Design Moment :Mu = (Wu. L^2)/8

Mu=99.375 Kn.m

(6) Maximum Ultimate Moment of Resistance of Rectengular Section =

For M 25 , fck= 20

fck 500, fy= 415

Mur.max= Ru.max b.d^2 i.e 186.26727

Ru.max = 0.36 fck.Kumax (1-0.42 Kumax)

=2.75543292

Kumax= 700/1100+0.87fy = 0.4791075

If Murmax > Mu……….Singly Reinforced

(7) Main steel :

0.5* fck/fy= 0.024096386

b.d= 78000

{1-(4.6*Mu.10^6/fck*b*d^2)}^1/2 =

Required Ast= 1879.518072 mm^2

assumed Diameter of stirrups ϕ (mm)= 6

assumed Diameter of Bar ϕ (mm)= 25

Number of Bars=3.830864861≈ 4

(8) Check for Width=

Required b=n.ϕ+(n+1)x25+2.ϕst

Required b (mm)=212……………….ok

(9) Check for Effective cover d :

For Moderate Environment (M 25)

nominal cover in mm= 20

d'=Nominal cover + Diameter of stirrups+ (ϕ/2)

d'= 38.5………….ok

(10) Design for Shear :

Vu.max = Wu*L/2 so,79.5

Ast1= 1962.5

Pt = 100.Ast1/b.d = 2.52 ….in %

ζuc= ? …….. As per IS 456:2000, table 19,pg. no.73

	Pt (in%)=	2.52
2.625	2.5	0.81
	2.75	0.82
	0.25	0.01
	0.125	x= ?
	x=	0.0092

ζuc (N/mm^2)= 0.8108

ζuc= 0.8108

Vuc= ζuc.bd , so, Vuc=63.2424Kn

Vusv.min=0.4 bd, so, Vusv.min=31.2

Vur.min= 94.4424…..min. stirrups are sufficient

(11) Check for Development Length :

Required Ld= 47 ϕ = 574 in mm

61.82785102 Kn.m………. M1

L0=Ld/3-bs/2 = 73

1.3 M1/V+L0= 1701.903485 MM

Required Ld=564 mm…………………. safe

(12) Check for Deflection :

Actual L/d =12.19512

Basic L/d =20……………….safe

(13) Load on column :

Vu.max = Wu*L/2 so, in KN49.34

Load on column =98.69

(C) COLUMN DESIGN:-

Column Height=3

assume,column width=300 =0.3 METER

assume,column depth=500 = 0.5 METER

Shear from longitudinal beam=171.5

Maximum Shear from transverse beam=182.75

self weight of beam=16.875

Load= 3340.125

Shear from longitudinal beam=98.69

Maximum Shear from

transverse beam=91.38

self weight of beam=16.875

Load=2483.34

Shear from longitudinal beam=98.69

self weight of beam=16.875

Load=462.26

Total load on column=251.429≈252

Pu (Kn)=987

Assume Asc=1%Ag

Asc=0.01Ag

Ac=0.9999Ag

Assumed Column is short column

Slenderness Ratio=Leff / Least lateral dimension

12 =2700/Least lateral dimension

Least lateral dimension (b) =225≈300

Calculation of Ag

Pu= 0.4 fck.Ac + 0.67 fy.Asc

fck= 20

fy=415

7.9992 Ag

2.7805 Ag

987000 10.7797 Ag

Ag =91560.98964

Column is Rectangular

Other Dimension =Ag /b

Other Dimension =305.2033≈500

So provide 300 X 500 mm column

3.PROBLEM STATEMENT

Type- G+3 Storeyed R.C. Framed Structure

Floor to Floor Height- 3 meter

Loads- Live Load-Roof-1.5 KN/m2

-Floors-4KN/m2

Dead Load-Floor Finish-Roof-2.5 KN/m2

Floor-1KN/m2

Slab Thickness-140 mm

Beam Section (a)Roof level-

Longitudinal External and Internal-300 x 300 mm

Transverse-300 x 500 mm

Beam Section (b) Floor level-

Longitudinal External-300 x 450 mm

Longitudinal Internal-300 x 300 mm

Transverse-300 x 500 mm

Column Section-300 x 500 mm

4. G+3 STAAD_Pro Model

DETERMINATION OF BASE SHEAR

MANUALLY

- FRAME STRUCTURE

Step 1- calculation of lumped masses at various floor level

(1) Mass of column- [(0.300x0.500x25)x25]x4 = 375 KN

(2) Mass of Beam-

[(0.300x0.300x25)x(20x14)]=630 KN

[0.300x0.450x25)x(20x6)]= 405 KN

[0.300x0.500x25)x(20x20)]=1500 KN

So total mass of beam = 2535 KN

(3) Mass of Slab-

Roof Slab- [(20x20)x(0.140x25+2.5)]

=2400 KN

Floor slab- [(20x20)x(0.140x25+1+2)]x3

= 7800 KN

Seismic weight of building-

= 375+2535+2400+7800

=13110 KN

Step 2- Determination of Fundamental

Natural Period

Ta = 0.075 x h ^ 0.75

= 0.075x 12 ^0.75

= 0.48 seconds

Step 3- Determination of Design Base

Shesr

Vb= Ah x W

Ah= (Z/2)x(I/R)x(Sa/g)

Z= Zone Factor= III=0.16

I= Importance Factor = 1

R= Response Reduction Factor

= SMRF= 1

Sa/g = Average response acceleration coefficient for medium soil

= 2.5

SO, Ah= (0.16/2)x(1/5)x2.5 = 0.04

Vb = 0.04 x 13110 KN

= 524.40 KN

DESIGN SEISMIC BASE SHEAR OF FRAME = 524.40 KN

- DIAGRID STRUCTURE

Step 1- calculation of lumped masses at

various floor level

(1) Mass of column-

[(0.300x0.500x25)x4]x4 = 60 KN

[(0.300x0.500x25x3.91)/2]x85 = 620 KN

So total mass of column = 680 KN

(2) Mass of Beam-

[(0.300x0.300x25)x(20x16)]=720 KN

[0.300x0.450x25)x(20x6)]= 405 KN

[0.300x0.500x25)x(20x20)]=1500 KN

Deduct releases= (0.300x0.450x25x15x12)

+(0.300x0.500x25x2.5x12) = 720

So total mass of beam = 1905 KN

(3) Mass of Slab-

Roof Slab- [(20x20)x(0.140x25+2.5)]

=2400 KN

Floor slab- [(20x20)x(0.140x25+1+2)]x3

= 7800 KN

Seismic weight of building-

= 680+1905+2400+7800

=12785 KN

Step 2- Determination of Fundamental

Natural Period

Ta = 0.075 x h ^ 0.75

= 0.075x 12 ^0.75

= 0.48 seconds

Step 3- Determination of Design Base Shear

Vb= Ah x W

Ah= (Z/2)x(I/R)x(Sa/g)

Z= Zone Factor= III=0.16

I= Importance Factor = 1

R= Response Reduction Factor = SMRF= 1

Sa/g = Average response acceleration coefficient for medium soil = 2.5

SO, Ah= (0.16/2)x(1/5)x2.5 = 0.04

Vb = 0.04 x 12785 KN

= 511.40 KN

Design Seismic Base Shear Of Diagrid= 511.40 Kn

5. DETERMINATION OF BASE SHEAR BY STAAD-PRO

Design Seismic Base Shear Of Frame = 0.0400x 13110 Kn

=524.40 Kn

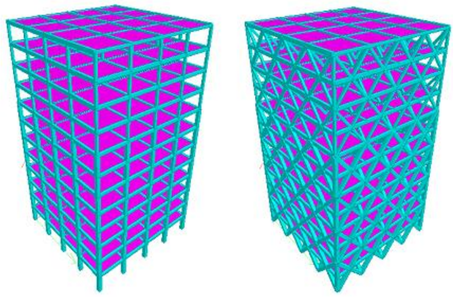
Design Seismic Base Shear Of Diagrid = 0.0400x 12785 Kn

= 511.40 Kn

6. COMPARATIVE RESULTS OF DESIGN BASE SHEAR

………………..Validation Satisfied

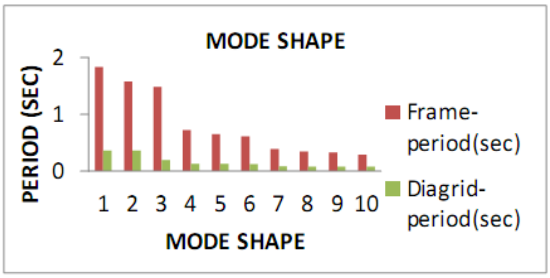
7. G+11 STAAD_Pro Model



8. RESULTS

(1) MODE SHAPE-

mode shape	Frame-period(sec)	Diagrid-period(sec)
1	1.83758	0.36088
2	1.58242	0.36001
3	1.48678	0.19585
4	0.72467	0.12678
5	0.65194	0.12395
6	0.61032	0.1219
7	0.39177	0.08568
8	0.3473	0.0796
9	0.32802	0.0787
10	0.2903	0.07857



(2) DISPLACEMENT IN (MM)-

(a) COLUMN "A"

FRAME Column A-Node	storey	(L/C)-8	(L/C)-10
61	12	1718.66	1703.29
56	11	1667.32	1652.51
51	10	1563.07	1549.12
46	9	1408.65	1395.93
41	8	1206.31	1195.12
36	7	1099.25	1089.46
31	6	974.01	965.71
26	5	828.79	822.07
21	4	663.78	658.71
16	3	480.05	476.65
11	2	282.66	280.84
6	1	104.93	104.39

diagrid Column A-Node	storey	(L/C)-8	(L/C)-10
61	12	84.414	84.417
56	11	78.844	78.816
51	10	71.72	71.717
46	9	63.958	63.937
41	8	55.947	55.943
36	7	49.209	49.2
31	6	43.489	43.486
26	5	35.764	35.757
21	4	30.198	30.195
16	3	21.397	21.392
11	2	15.912	15.911
6	1	6.747	6.746

(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
2148.37	2129.16	1307.69	1288.48
2084.20	2065.69	1268.27	1249.77
1953.88	1936.46	1188.51	1171.09
1760.86	1744.97	1070.54	1054.65
1507.92	1493.94	916.18	902.20
1374.12	1361.87	834.50	822.25
1217.56	1207.18	739.07	728.69
1036.04	1027.64	628.57	620.17
829.76	823.42	503.16	496.82
600.09	595.84	363.70	359.45
353.34	351.08	214.03	211.77
131.18	130.51	79.40	78.74

(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
106.491	106.495	64.54	64.544
99.592	99.558	60.357	60.323
90.797	90.793	55.007	55.003
81.016	80.99	49.071	49.045
71.032	71.027	43.006	43.001
62.55	62.538	37.86	37.849
55.475	55.471	33.57	33.565
45.661	45.652	27.623	27.614
38.705	38.701	23.409	23.405
27.447	27.44	16.595	16.588
20.489	20.487	12.384	12.383
8.706	8.704	5.261	5.259

COLUMN “B”

FRAME Column B-Node	storey	(L/C)-8	(L/C)-10
65	12	1718.05	1702.68
60	11	1666.57	1651.75
55	10	1562.35	1548.40
50	9	1407.85	1395.13
45	8	1205.88	1194.70
40	7	1098.45	1088.64
35	6	973.32	965.02
30	5	828.12	821.39
25	4	663.14	658.07
20	3	479.42	476.02
15	2	282.20	280.39
10	1	104.12	103.58

DIAGRID Column B-Node	storey	(L/C)-8	(L/C)-10
65	12	78.287	78.333
60	11	71.817	71.836
55	10	64.026	64.075
50	9	56.03	56.058
45	8	47.165	47.214
40	7	40.33	40.369
35	6	33.08	33.133
30	5	26.229	26.269
25	4	19.042	19.095
20	3	12.737	12.77
15	2	6.557	6.604
10	1	2.569	2.588

(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
2147.57	2128.35	1307.20	1287.99
2083.21	2064.69	1267.67	1249.16
1952.94	1935.51	1187.93	1170.51
1759.82	1743.92	1069.91	1054.02
1507.35	1493.38	915.83	901.85
1373.06	1360.80	833.85	821.60
1216.65	1206.27	738.52	728.13
1035.14	1026.74	628.03	619.62
828.93	822.58	502.66	496.32
599.28	595.02	363.21	358.95
352.75	350.49	213.68	211.41
130.15	129.47	78.78	78.11

(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
98.011	98.097	59.392	59.478
89.922	89.979	54.486	54.542
80.182	80.28	48.562	48.659
70.18	70.249	42.493	42.561
59.087	59.184	35.753	35.849
50.545	50.628	30.574	30.657
41.472	41.577	25.07	25.174
32.907	32.991	19.884	19.967
23.908	24.012	14.432	14.535
16.018	16.088	9.662	9.732
8.285	8.376	4.984	5.075
3.266	3.306	1.961	2.001

COLUMN “C”

FRAME Column C-Node	storey	(L/C)-8	(L/C)-10
321	12	1718.06	1702.68
316	11	1666.58	1651.76
311	10	1562.36	1548.41
306	9	1407.87	1395.14
301	8	1205.89	1194.70
296	7	1098.46	1088.65
291	6	973.33	965.02
286	5	828.13	821.40
281	4	663.15	658.07
276	3	479.43	476.02
271	2	282.21	280.39
266	1	104.12	103.58

DIAGRID Column C-Node	storey	(L/C)-8	(L/C)-10
321	12	78.298	78.254
316	11	71.845	71.769
311	10	64.076	64.018
306	9	56.077	56.004
301	8	47.224	47.168
296	7	40.381	40.318
291	6	33.168	33.106
286	5	26.289	26.226
281	4	19.146	19.083
276	3	12.796	12.74
271	2	6.649	6.592
266	1	2.607	2.574

(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
2147.58	2128.35	1307.21	1287.99
2083.23	2064.70	1267.68	1249.17
1952.96	1935.52	1187.95	1170.52
1759.84	1743.93	1069.92	1054.02
1507.37	1493.38	915.84	901.86
1373.08	1360.82	833.87	821.61
1216.67	1206.28	738.53	728.14
1035.16	1026.75	628.04	619.63
828.94	822.60	502.67	496.32
599.29	595.03	363.22	358.96
352.76	350.49	213.68	211.41
130.15	129.48	78.79	78.11

(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
98.032	97.948	59.438	59.355
89.977	89.85	54.555	54.429
80.281	80.173	48.662	48.554
70.272	70.147	42.586	42.462
59.201	59.095	35.862	35.756
50.643	50.53	30.672	30.56
41.644	41.528	25.217	25.101
33.024	32.912	19.992	19.881
24.109	23.992	14.595	14.48
16.132	16.033	9.764	9.666
8.461	8.358	5.127	5.025
3.337	3.28	2.023	1.966

OLUMN “D”

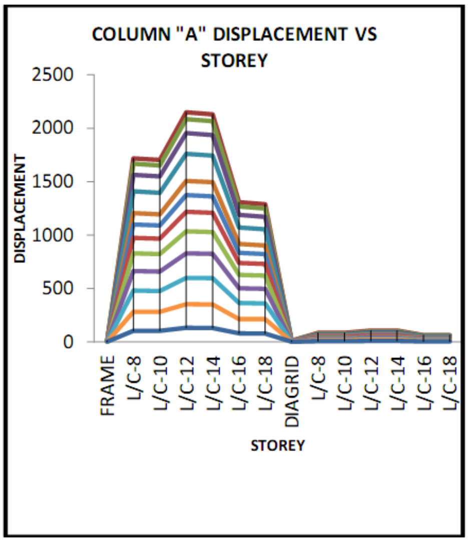
FRAME Column D-Node	storey	(L/C)-8	(L/C)-10
325	12	1718.56	1703.19
320	11	1667.20	1652.39
315	10	1562.95	1549.01
310	9	1408.53	1395.81
305	8	1206.22	1195.03
300	7	1099.14	1089.34
295	6	973.91	965.61
290	5	828.70	821.98
285	4	663.69	658.62
280	3	479.97	476.57
275	2	282.60	280.79
270	1	104.88	104.34

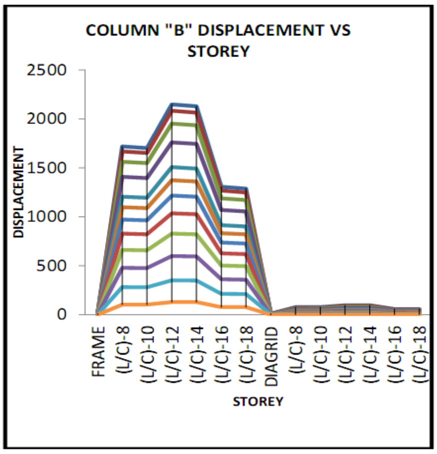
(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
2148.16	2128.95	1307.56	1288.36
2083.95	2065.44	1268.12	1249.62
1953.64	1936.21	1188.36	1170.94
1760.61	1744.72	1070.39	1054.50
1507.74	1493.76	916.07	902.09
1373.88	1361.63	834.35	822.11
1217.35	1206.97	738.94	728.56
1035.84	1027.44	628.45	620.05
829.58	823.24	503.05	496.72
599.94	595.69	363.61	359.36
353.23	350.97	213.97	211.70
131.08	130.41	79.34	78.68

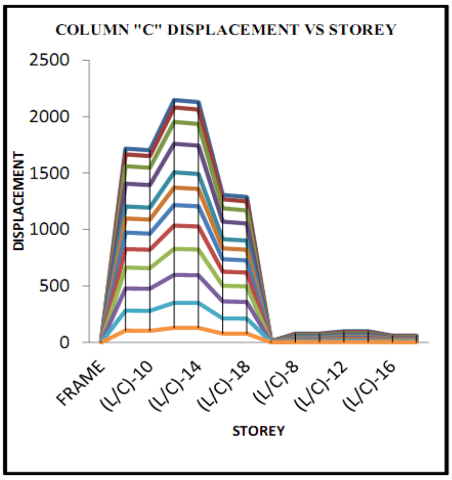
DIAGRID Column D-Node	storey	(L/C)-8	(L/C)-10
325	12	81.908	81.91
320	11	76.175	76.145
315	10	68.73	68.726
310	9	61.159	61.137
305	8	52.998	52.994
300	7	46.387	46.378
295	6	40.394	40.391
290	5	33.077	33.07
285	4	27.427	27.424
280	3	19.349	19.343
275	2	14.105	14.104
270	1	5.92	5.918

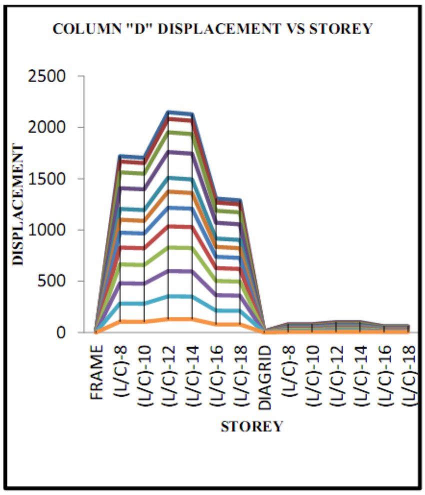
(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
101.673	101.676	61.647	61.65
94.441	94.403	57.264	57.227
85.017	85.013	51.537	51.532
75.611	75.584	45.825	45.798
65.341	65.336	39.588	39.583
57.128	57.115	34.604	34.591
49.523	49.519	29.995	29.991
40.52	40.511	24.535	24.525
33.403	33.399	20.225	20.222
23.548	23.541	14.253	14.246
17.048	17.048	10.319	10.318
7.139	7.137	4.32	4.318

GRAPH OF DISPLACEMENT –









DRIFT IN (MM)-

(a) COLUMN "A"

FRAME Column A-Node	storey	(L/C)-8	(L/C)-10
61	12	17.12	16.93
56	11	34.75	34.46
51	10	51.47	51.06
46	9	67.45	66.94
41	8	35.69	35.22
36	7	41.75	41.25
31	6	48.41	47.88
26	5	55.01	54.45
21	4	61.24	60.69
16	3	65.80	65.27
11	2	59.24	58.82
6	1	34.98	34.80

(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
21.39	21.16	13.14	12.90
43.44	43.08	26.59	26.23
64.34	63.83	39.32	38.81
84.31	251.03	51.45	50.82
44.60	44.02	27.23	26.65
52.19	51.56	31.81	31.19
60.51	59.85	36.83	36.17
68.76	68.07	41.80	41.12
76.56	75.86	46.49	45.79
82.25	81.59	49.89	49.23
74.05	73.52	44.88	44.34
43.73	43.50	26.47	26.25

(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
21.45	21.22	13.18	12.94
43.42	43.06	26.58	26.22
64.37	63.86	39.34	38.83
84.16	83.51	51.36	50.72
44.76	44.19	27.33	26.75
52.14	51.51	31.78	31.16
60.50	59.84	36.83	36.17
68.74	68.05	41.79	41.10
76.55	75.85	46.48	45.79
82.18	81.51	49.84	49.18
74.20	73.67	44.97	44.43
43.38	43.16	26.26	26.04

DIAGRID Column A-Node	storey	(L/C)-8	(L/C)-10
61	12	1.86	1.87
56	11	2.37	2.37
51	10	2.59	2.59
46	9	2.67	2.67
41	8	2.25	2.25
36	7	1.91	1.90
31	6	2.58	2.58
26	5	1.85	1.85
21	4	2.93	2.94
16	3	1.83	1.83
11	2	3.05	3.05
6	1	2.25	2.25

DIAGRID Column B-Node	storey	(L/C)-8	(L/C)-10
65	12	2.16	2.16
60	11	2.60	2.59
55	10	2.67	2.67
50	9	2.95	2.95
45	8	2.28	2.28
40	7	2.42	2.41
35	6	2.28	2.29
30	5	2.40	2.39
25	4	2.10	2.11
20	3	2.06	2.06
15	2	1.33	1.34
10	1	0.86	0.86

(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
2.30	2.31	1.39	1.41
2.93	2.92	1.78	1.77
3.26	3.27	1.98	1.98
3.33	3.32	2.02	2.02
2.83	2.83	1.72	1.72
2.36	2.36	1.43	1.43
3.27	3.27	1.98	1.99
2.32	2.32	1.40	1.40
3.75	3.75	2.27	2.27
2.32	2.32	1.41	1.40
3.93	3.93	2.37	2.37
2.90	2.90	1.75	1.75

(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
2.70	2.71	1.63	1.65
3.25	3.23	1.98	1.96
3.33	3.34	2.02	2.03
3.70	3.69	2.25	2.24
2.85	2.85	1.73	1.73
3.03	3.02	1.83	1.83
2.85	2.86	1.73	1.73
3.00	2.99	1.82	1.81
2.63	2.64	1.59	1.60
2.58	2.57	1.56	1.55
1.67	1.69	1.01	1.03
1.09	1.10	0.65	0.67

COLUMN “B”

(c) COLUMN “C”

FRAME Column B-Node	storey	(L/C)-8	(L/C)-10
65	12	17.16	16.98
60	11	34.74	34.45
55	10	51.50	51.09
50	9	67.32	66.81
45	8	35.81	35.35
40	7	41.71	41.21
35	6	48.40	47.88
30	5	54.99	54.44
25	4	61.24	60.68
20	3	65.74	65.21
15	2	59.36	58.94
10	1	34.71	34.53

FRAME Column C-Node	storey	(L/C)-8	(L/C)-10
321	12	17.16	16.97
316	11	34.74	34.45
311	10	51.50	51.09
306	9	67.33	66.81
301	8	35.81	35.35
296	7	41.71	41.21
291	6	48.40	47.87
286	5	54.99	54.44
281	4	61.24	60.68
276	3	65.74	65.21
271	2	59.36	58.94
266	1	34.71	34.53

(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
21.45	21.22	13.18	12.94
43.42	43.06	26.58	26.22
64.37	63.86	39.34	38.83
84.16	83.52	51.36	50.72
44.76	44.19	27.32	26.75
52.14	51.51	31.78	31.16
60.50	59.84	36.83	36.17
68.74	68.05	41.79	41.10
76.55	75.86	46.48	45.79
82.18	81.51	49.85	49.18
74.20	73.67	44.96	44.43
43.38	43.16	26.26	26.04

DIAGRID Column C-Node	storey	(L/C)-8	(L/C)-10
321	12	2.15	2.16
316	11	2.59	2.58
311	10	2.67	2.67
306	9	2.95	2.94
301	8	2.28	2.28
296	7	2.40	2.40
291	6	2.29	2.29
286	5	2.38	2.38
281	4	2.12	2.11
276	3	2.05	2.05
271	2	1.35	1.34
266	1	0.87	0.86

(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
2.68	2.70	1.63	1.64
3.23	3.23	1.97	1.96
3.34	3.34	2.02	2.03
3.69	3.68	2.24	2.23
2.85	2.86	1.73	1.73
3.00	3.00	1.82	1.82
2.87	2.87	1.74	1.74
2.97	2.97	1.80	1.80
2.66	2.65	1.61	1.60
2.56	2.56	1.54	1.55
1.71	1.69	1.04	1.02
1.11	1.09	0.67	0.66

(d)COLUMN “D”

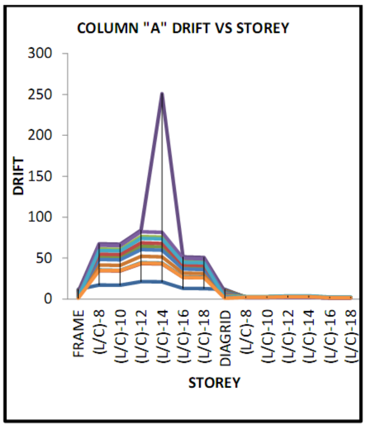
FRAME Column D-Node	storey	(L/C)-8	(L/C)-10
325	12	17.12	16.93
320	11	34.75	34.46
315	10	51.47	51.07
310	9	67.44	66.93
305	8	35.69	35.23
300	7	41.74	41.24
295	6	48.40	47.88
290	5	55.00	54.45
285	4	61.24	60.68
280	3	65.79	65.26
275	2	59.24	58.82
270	1	34.96	34.78

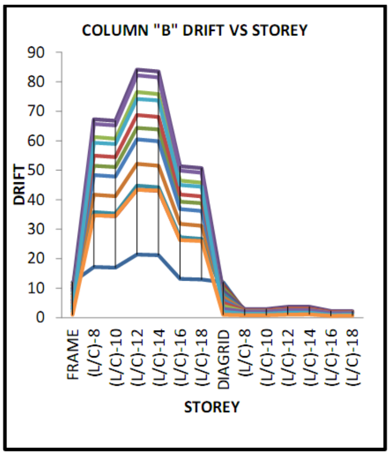
(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
21.40	21.17	13.15	12.91
43.44	34.08	26.59	26.23
64.34	63.83	39.32	38.81
84.29	83.65	51.44	50.80
44.62	44.04	27.24	26.66
52.18	51.55	31.80	31.18
60.50	59.84	36.83	36.17
68.75	68.07	41.80	41.11
76.55	75.85	46.48	45.79
82.24	81.57	49.88	49.22
74.05	73.52	44.88	44.34
43.69	43.47	26.45	26.23

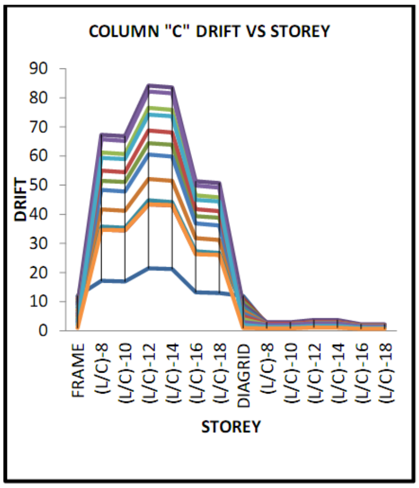
DIAGRID Column D-Node	storey	(L/C)-8	(L/C)-10
325	12	1.91	1.92
320	11	2.48	2.47
315	10	2.52	2.53
310	9	2.72	2.72
305	8	2.20	2.20
300	7	2.00	2.00
295	6	2.44	2.44
290	5	1.88	1.88
285	4	2.69	2.69
280	3	1.75	1.75
275	2	2.73	2.73
270	1	1.97	1.97

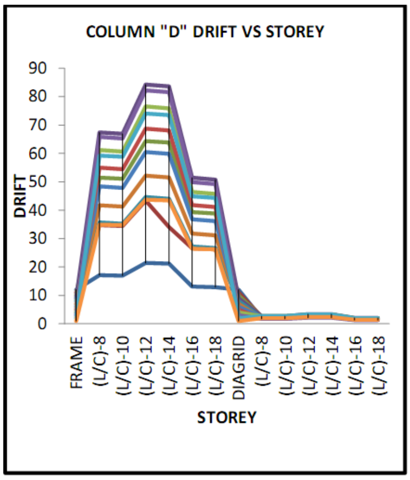
(L/C)-12	(L/C)-14	(L/C)-16	(L/C)-18
2.41	2.43	1.46	1.47
3.14	3.13	1.91	1.90
3.14	3.14	1.90	1.91
3.42	3.41	2.08	2.07
2.74	2.74	1.66	1.66
2.54	2.53	1.53	1.53
3.00	3.00	1.82	1.82
2.37	2.37	1.44	1.44
3.28	3.29	1.99	1.99
2.17	2.16	1.31	1.31
3.30	3.30	2.00	2.00
2.38	2.38	1.44	1.44

GRAPH OF DRIFT –









CONCLUSIONS

In this paper, comparative analysis & design of 4-storey & 20-storey diagrid structural system building and simple frame building is presented here. A regular floor plan of 20m x 20m size is considered. STAAD-PRO software is used for modelling and analysis of structure. Analysis results like mode shape, displacement, storey drift are presented here. Also design of both structures is done and optimum member sizes are decided to satisfy the code criteria.

We conclude from the study that,

- The mode shape is very much less for diagrid structural system.
- As the lateral loads are resisted by diagonal columns, the storey displacement is very much less in diagrid structure as compared to the simple frame building.
- The storey drift is very much less for diagrid structural system.
- Diagrid provide more resistance in the building which makes system more effective.
- The design of both structures is done by using same member size. The higher sizes of members are selected to prevent the failure criteria.

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