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Pushover Analysis of Water Tank Staging

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Abstract - *The present study investigates the behaviour of an elevated circular water tank by Pushover Analysis. It is carried out by considering various parameters like water storage capacity and staging height which are constant, different types of h/d ratio, various types of staging arrangement and variation in number of columns. By inter-combining each of these parameters 54 models of tank was created. All tank models have their locality in earthquake zone III. We have made use of SAP2000 computer program. Pushover analysis is an advanced tool to user-defined nonlinear hinge properties or default-hinge properties, available in some programs based on the FEMA-356 and ATC-40 guidelines. It is used to evaluate nonlinear behavior and gives the sequence and mechanism of plastic hinge formation. Here displacement controlled pushover analysis is used to apply the earthquake forces at C.G. of container. The behavior of each tank with respect to other will be checked for base shear, roof displacement and plastic hinge formation sequence and its pattern within the staging. It describes structure's behaviour with the help of graphs i.e. 'capacity curve' or 'pushover curve'. Due to cantilever action of the structures there is increase in stiffness and there is a change in magnitude of displacement and base shear. There is not much change in base reaction and roof displacement due to arrangement of columns in single layer and double layer. The pushover curve which is a plot of base shear versus roof displacement, gives the actual capacity of the structure in the nonlinear range. The structural behavior remains same for plastic hinge formation, different water storage capacity, staging heights and different number of columns.*

Key Words: Elevated Water Tanks, Tank Staging, Pushover Analysis, Plastic Hinge, ATC, Capacity.

1. INTRODUCTION

1.1 Overview

In public water distribution system, Elevated water tanks are generally used being an important part of a lifeline system. Due to post earthquake functional needs, seismic safety of water tanks is of most important. Elevated water tanks also called as elevated service reservoirs (ESRs) typically consists of a container and a supporting tower. In major cities and also in rural areas elevated water tanks forms an Integral part of water supply system. The elevated water tanks must remain functional even after the earthquakes as water tanks are most essential to provide water for drinking purpose. These structures has large mass concentrated at the top of slender which have Supporting structure and hence these structure are especially vulnerable to horizontal forces due to Earthquakes.

Fig-1: Collapsed Slender and Weak Framed Staging of Water Tanks in Bhuj Earthquake

Fig-2: Bending-Shear Failure in Beam

1.2Pushover Analysis

The well-known practical method i.e. Pushover Analysis is that analysis which is carried out under permanent vertical loads and gradually increasing lateral loads to calculate the deformation as well as damage pattern of a structure. A plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature weakness. This plot is known as 'Capacity Curve'.

For developing modeling parameters, acceptance criteria (performance level) and procedures of pushover analysis, there are requirement of some documents such as The ATC-40(Applied Technology Council) and FEMA-356(Federal Emergency Management Agency) documents. These documents also describe the actions followed to determine the yielding of frame member during the analysis. Two actions are used to govern the inelastic behavior of the member during the pushover analysis that is deformation-controlled (ductile action) or force-controlled (brittle action).

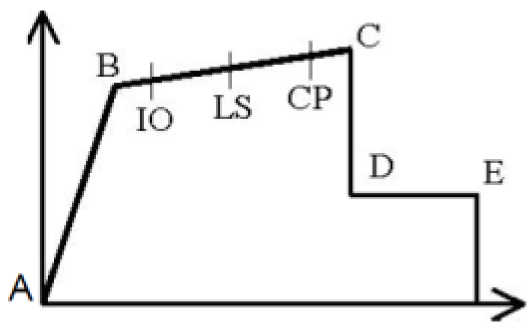


Fig-3: Force-Deformation Criterion for Hinges Used In Pushover Analysis

Acceptance Criteria (Performance Level)

The performance levels (IO, LS, and CP) of a structural element are represented in the load versus deformation curve as shown below,

B - Yield State

IO – immediate Occupancy

LS – Life Safety

CP – Collapse Prevention

C – Ultimate State

1.3 Aim of the Research Work:

The objectives of this investigation are to study the behavior of an elevated circular water tank considering the various structural and geometrical parameters using computer program. Here we shall use SAP, Structural Analysis Program. The final conclusion will be drawn with help of graphs of Base Reaction Versus Displacement (Roof Displacement) and capacity curve for each tank from which we can compare one tank structure with other tank structures and then can predict the behavior of the same.

The main objectives are as given below.
To study the behavior of an elevated water tank by 'Pushover Analysis'
1. Base shear, Bending Moment, Axial Force and Displacement for
(a) Constant Staging height and water storage capacity.
(b) Different h/d Ratio.
(c) Number of periphery columns (Eight, Ten, and Twelve).
(d) Different types of staging arrangement (Normal, Cross, Hexagonal).

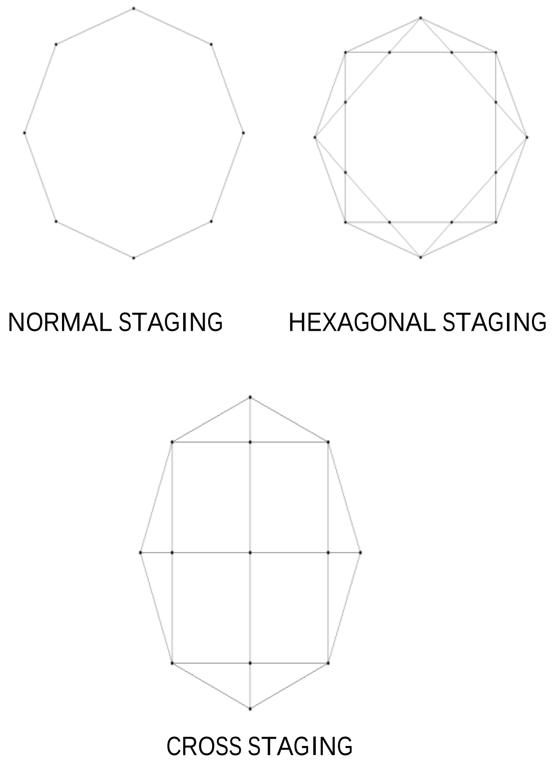


Fig-4: Different Types of Staging Arrangements

2. Plastic hinge pattern and formation sequence within the staging (for earthquake Zone III).

1.4 Methodology

The present study investigates the behaviour of an elevated circular water tank by 'Non – Linear Static Analysis'(Pushover Analysis).It is carried out by considering various parameters like water storage capacity and staging height are constant, different types of h/d ratio, various types of staging arrangement and variation in number of columns. By inter-combining each of these parameters 54 models of tank were created. All tank models have their locality in earthquake zone III. A column foundation is to be fixed. Damping ratio of 5% is assumed for all natural modes. Flexure moment (M3), axial biaxial moment (P-M2-M3) and axial compressive shear force (V) hinges are assigned at the face of beam, column, and bracing by using the static pushover analysis. ATC-40 has described the modeling procedure, acceptance criteria (performance level) and analysis procedures for nonlinear static pushover analysis.

1.4.1 Procedure

- Create three dimensional model of tank.
- Implementation and application of gravity loads, live loads, and water load, etc.
- Define properties and acceptance criteria for the pushover hinges .The program includes several built-in default hinge properties that are based on average values from ATC-40 for concrete members and average values from FEMA-356 for steel members.
- Locate the pushover hinges on the model by selecting one or more frame members and assigning them one or more hinge properties.
- Define the pushover load cases.
- Push the structure using the load patterns of static lateral loads, to displacements larger than those associated with target displacement using static pushover analysis.
- The numbers of hinges are shown in the fig5 and fig6 in each member showing the hinges in columns the immediate occupancy, life safety, collapse prevention to define the force deflection behavior of the hinge.
- The lateral load is applied on the frame, which when deflected forms hinges. The plastic hinge formation at the yielding and significant difference in the hinging patterns at the ultimate state.
- Developing a pushover curve and estimating the force and deformations in each element at the level of displacement corresponding to target displacement.
- The node associated at CG of container is the target point/node selected for comparison with target displacement. The maximum limit for roof displacement is given as 0.004H, where H is the height of the structure. Base shear and roof displacements are recorded at every step, to obtain the pushover curve.

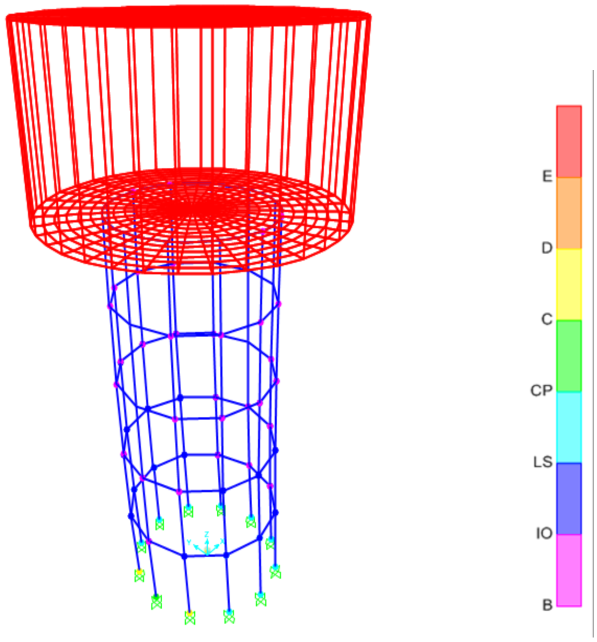


Fig-5: Deformed Shape of the Frame

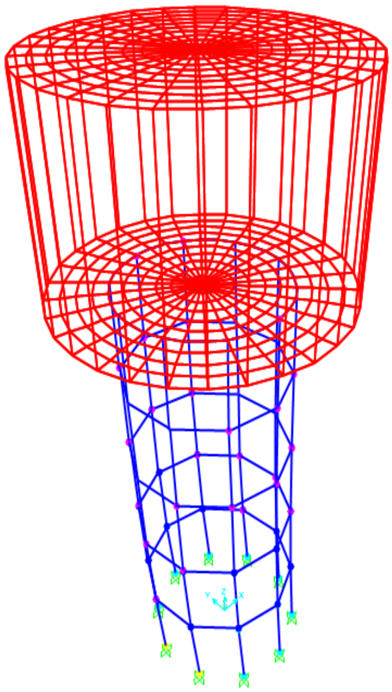


Fig-6: Deformed Shape of the Frame

- The equivalent static methods adopt seismic coefficient, which depends on the natural time period of their vibration of the structure, the time period is required for earthquake resistance design of the structures and to calculate the base shear. Time period of the structure is been taken from the software SAP2000.

- Time period can be calculated as

$$T = 2\Pi\sqrt{(\Delta/g)}$$

Where,

Δ = Static horizontal deflection at the top of the tank under static horizontal force equal to Weight W is acting at C.G. of tank.

g = Acceleration due to gravity.

The lateral force shall be taken as

αh x W

αh = design horizontal seismic coefficient as given in 5.2.5

W = the design shall be worked out both when the tank is full and empty condition. When empty, the weight (*W*) used in the design shall consist of the dead load of the tank and 1/3 of staging weight.

- *Seismic Coefficient Method*- the value of horizontal seismic coefficient αh shall be computed as given by the following expression:

$$\alpha h = \beta I \alpha 0$$

β = Co-efficient depending upon soil foundation system

I = Factor depending upon importance of structure

α0 = Basic horizontal seismic co-efficient

1.4.2 SPECIFICATION

SR.NO	PARAMETERS	DIMENSION
1	Capacity	500 M^3
2	h/d Ratio	0.5, 0.6, 0.7
3	Height Of Columns	15 M
4	Staging Level	5
5	Thickness Of Roof Slab	200 Mm
6	Thickness Of Wall	300 Mm
7	Thickness Of Floor Slab	450 Mm
8	Width Of Floor Beam	300 Mm
9	Depth Of Floor Beam	400 Mm
10	Width Of Braces	300 Mm
11	Thickness Of Braces	400 Mm
12	Width Of Top Ring	300 Mm
13	Depth Of Top Ring	600 Mm
14	Diameter Of Column	300 Mm
15	No Of Column	8,10,12
16	Type Of Bracing	Normal, Cross, Hexagonal
17	Unit Weights	Concrete = 25 KN/Cum
18	Material	M25 Grade Concrete & Fe415

1.4.3 STRUCTURAL MODELING 3D VIEW OF TANKS

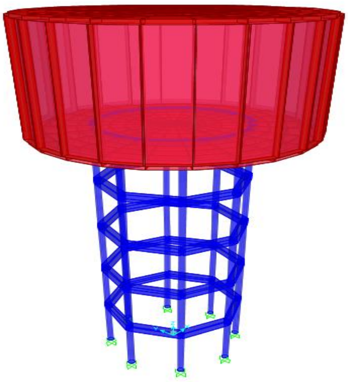


Fig -7: h/d Ratio=0.5, 8 Number of Columns Normal Staging

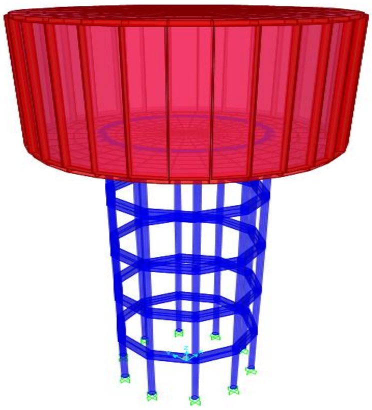


Fig -8: h/d Ratio=0.5, 10 Number of Columns, Normal Staging

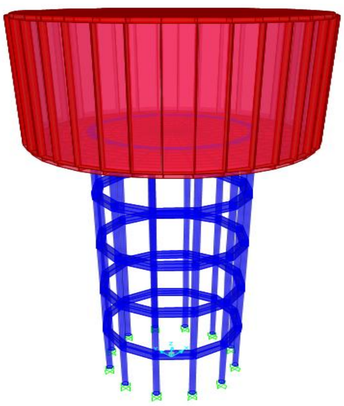


Fig-9: h/d Ratio=0.5, 12 Number of Columns, Normal Staging

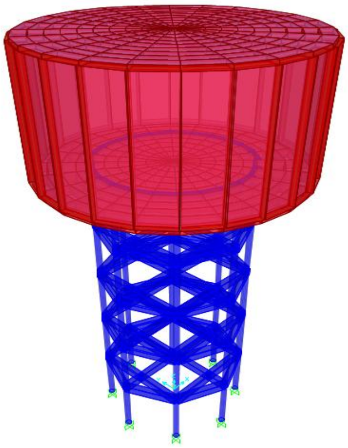


Fig-10: h/d Ratio=0.5, 8 Number of Columns, Cross Staging

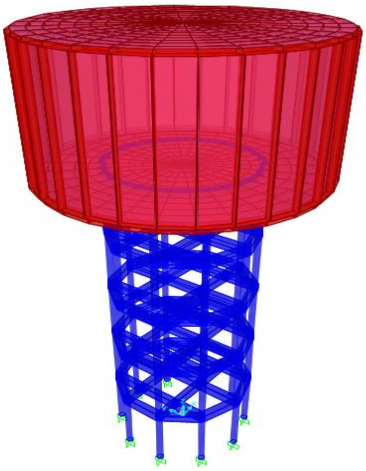


Fig-11: h/d Ratio=0.5, 10 Number of Columns, Cross Staging

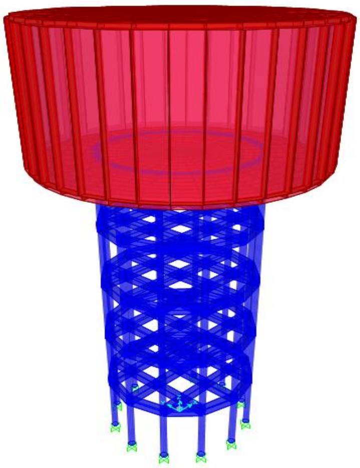


Fig-12: h/d Ratio=0.5, 12 Number of Columns, Cross Staging

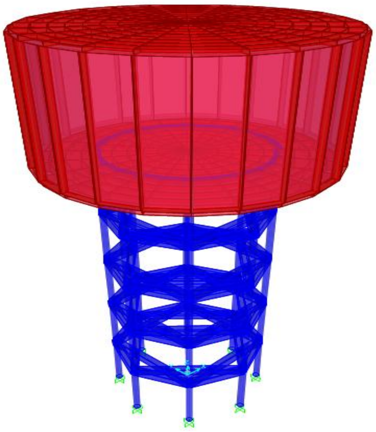


Fig -13: h/d Ratio=0.5, 8 Number of Columns, Hexagonal Staging

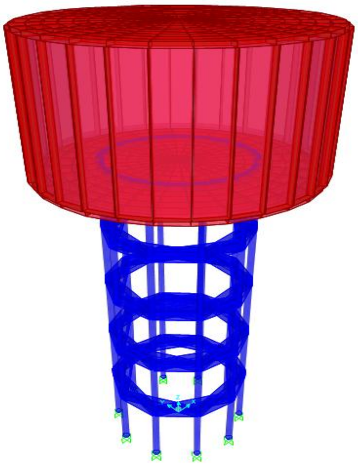


Fig -14: h/d Ratio=0.5, 10 Number of Columns, Hexagonal Staging

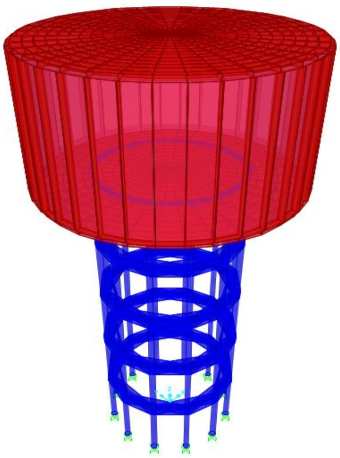


Fig -15: h/d Ratio=0.5, 12 Number of Columns, Hexagonal Staging

2 ANALYSIS AND RESULTS

Table-2.1 Values of Base Shear (Empty Tank)

SR.NO	h/d Ratio	Number Of Columns	Types Of Staging Arrangement	Base Shear (KN)
1	0.5	8	Normal	247.72
2			Cross	299.93
3			Hexagonal	307.88
4				
5		10	Normal	257.053
6			Cross	296.46
7			Hexagonal	308.299
8				
9		12	Normal	265.605
10			Cross	315.512
11			Hexagonal	320.41
12	0.6	8	Normal	243.295
13			Cross	286.68
14			Hexagonal	294.125
15				
16		10	Normal	250.376
17			Cross	290.99
18			Hexagonal	303.192
19				
20		12	Normal	256.06
21			Cross	303.796
22			Hexagonal	308.477
23	0.7	8	Normal	238.25
24			Cross	279.55
25			Hexagonal	277.281
26				
27		10	Normal	245.292
28			Cross	283.955
29			Hexagonal	293.158
30				
31		12	Normal	251.006
32			Cross	290.846
33			Hexagonal	300.902

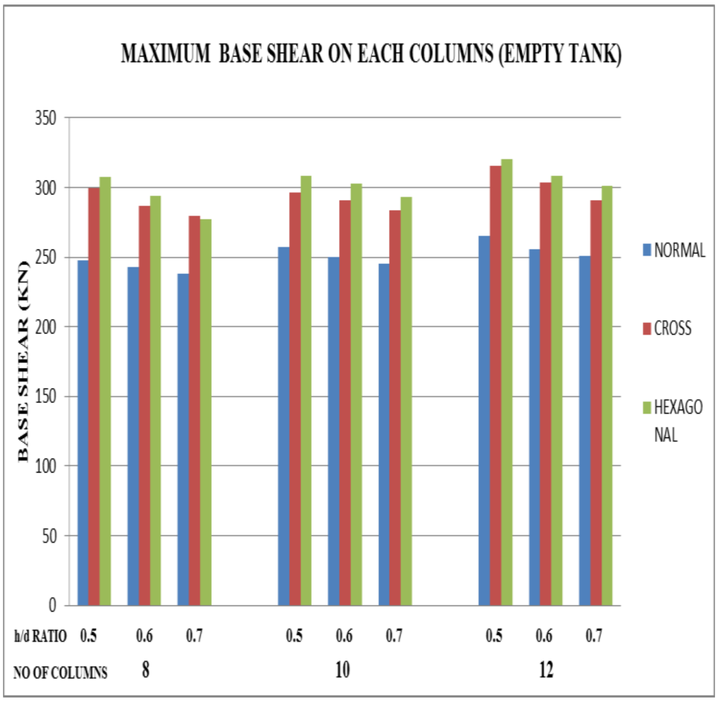


Chart2.1-Maximum Base Shear on Each Column (Empty Tank)

Table-2.2 Values of Base Shear (Full Tank)

SR.NO	h/d Ratio	Number Of Columns	Types Of Staging Arrangement	Base Shear (KN)
1			Normal	571.85
2		8	Cross	629.984
3			Hexagonal	637.93
4				
5			Normal	588.47
6	0.5	10	Cross	627.879
7			Hexagonal	639.72
8				
9			Normal	595.605
10		12	Cross	647.67
11			Hexagonal	652.567
12			Normal	566.792
13		8	Cross	610.178
14			Hexagonal	617.622
15				
16			Normal	575.21
17	0.6	10	Cross	615.828
18			Hexagonal	628.028
19				
20			Normal	581.62
21		12	Cross	623.581
22			Hexagonal	634.041
23			Normal	561.983
24		8	Cross	603.284
25			Hexagonal	601.01
26				
27			Normal	570.363
28	0.7	10	Cross	609.026
29			Hexagonal	618.229
30				
31			Normal	576.806
32		12	Cross	620.607
33			Hexagonal	626.702

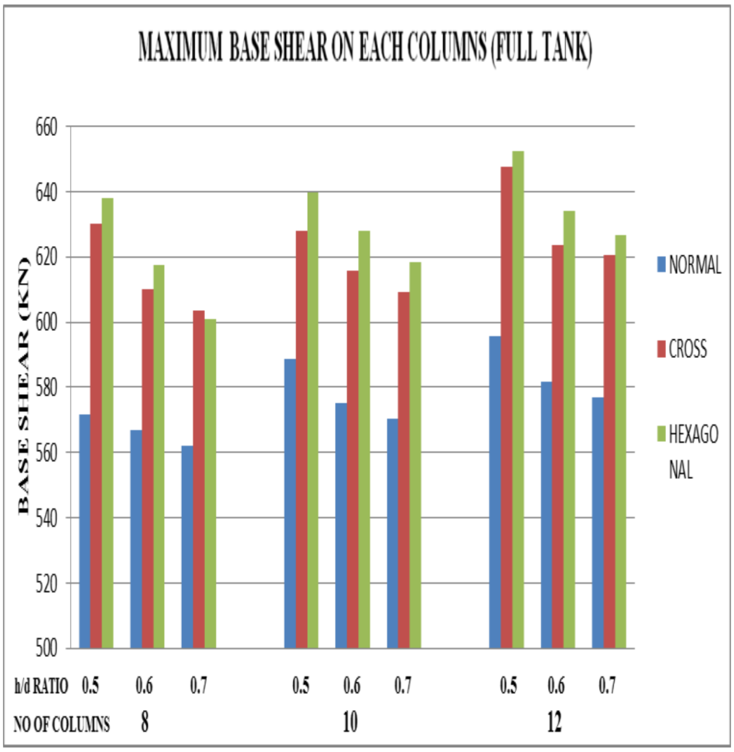


Chart2.2-Maximum Base Shear on Each Column (Full Tank)

Table-2.3 Values of Axial Force (Empty Tank)

SR.NO	h/d Ratio	Number Of Columns	Types Of Staging Arrangement	Axial Force (KN)
1	0.5	8	Normal	789.07
2			Cross	885.492
3			Hexagonal	913.624
4				
5		10	Normal	633.845
6			Cross	711.636
7			Hexagonal	747.706
8				
9		12	Normal	549.469
10			Cross	621.144
11			Hexagonal	638.368
12	0.6	8	Normal	773.89
13			Cross	870.549
14			Hexagonal	897.639
15				
16		10	Normal	614.102
17			Cross	709.926
18			Hexagonal	715.996
19				
20		12	Normal	541.311
21			Cross	605.378
22			Hexagonal	627.218
23	0.7	8	Normal	777.453
24			Cross	870.854
25			Hexagonal	872.847
26				
27		10	Normal	630.5
28			Cross	693.089
29			Hexagonal	715.339
30				
31		12	Normal	544.128
32			Cross	607.871
33			Hexagonal	626.761

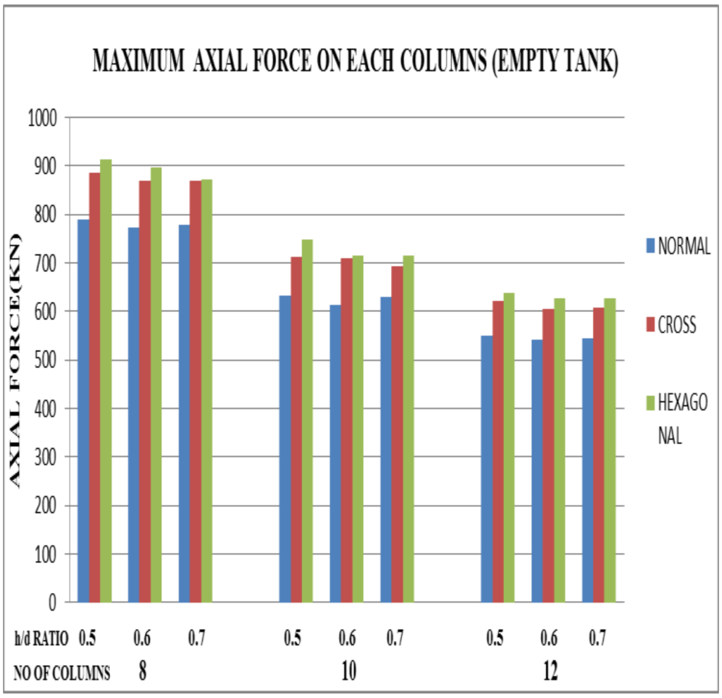
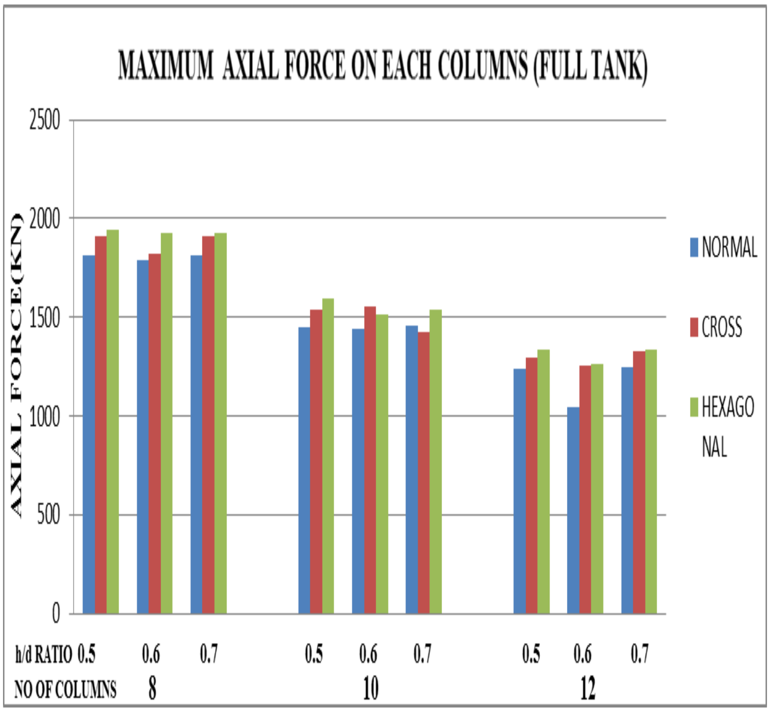


Chart2.3-Maximum Axial Force on Each Column (Empty Tank)

Table-2.4 Values of Axial Force (Full Tank)

SR.NO.	h/d Ratio	Number Of Columns	Types Of Staging Arrangement	Axial Force (KN)
1	0.5	8	Normal	1816.658
2			Cross	1907.213
3			Hexagonal	1941.144
4				
5		10	Normal	1452.464
6			Cross	1538.17
7			Hexagonal	1593.945
8				
9		12	Normal	1241.9
10			Cross	1295.123
11			Hexagonal	1339.733
12	0.6	8	Normal	1790.467
13			Cross	1821.661
14			Hexagonal	1925.192
15				
16		10	Normal	1439.282
17			Cross	1554.798
18			Hexagonal	1516.628
19				
20		12	Normal	1046.561
21			Cross	1254.306
22			Hexagonal	1260.51
23	0.7	8	Normal	1811.362
24			Cross	1908.164
25			Hexagonal	1927.466
26				
27		10	Normal	1454.683
28			Cross	1428.566
29			Hexagonal	1536.145
30				
31		12	Normal	1245.027
32			Cross	1328.436
33			Hexagonal	1334.746



Char2.4-Maximum Axial Force on Each Column (Full Tank)

Table-2.5 Values for Displacement (Empty Tank)

SR.NO	h/d Ratio	Number Of Columns	Types Of Staging Arrangement	Displacement (mm)
1			Normal	52.18845
2		8	Cross	47.53424
3			Hexagonal	47.23258
4				
5			Normal	43.86804
6	0.5	10	Cross	39.50485
7			Hexagonal	38.857
8				
9			Normal	37.96874
10		12	Cross	35.68548
11			Hexagonal	33.993
12			Normal	51.465
13		8	Cross	45.847
14			Hexagonal	45.678
15				
16			Normal	42.805
17	0.6	10	Cross	38.737
18			Hexagonal	38.177
19				
20			Normal	36.763
21		12	Cross	32.667
22			Hexagonal	33.005
23			Normal	50.646
24		8	Cross	45.322
25			Hexagonal	43.455
26				
27			Normal	42.143
28	0.7	10	Cross	38.203
29			Hexagonal	37.566
30				
31			Normal	36.29
32		12	Cross	31.339
33			Hexagonal	32.605

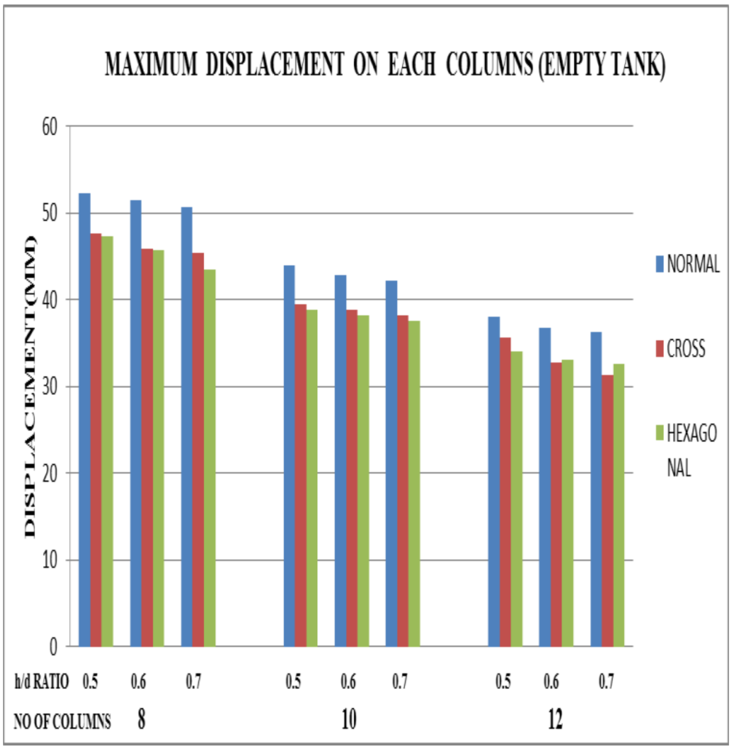


Chart2.5-Maximum Displacement on Each Column (Empty Tank)

Table-2.6 Values for Displacement (Full Tank)

SR.NO	h/d Ratio	Number Of Columns	Types Of Staging Arrangement	Displacement (mm)
1	0.5	8	Normal	130.0213
2			Cross	116.4416
3			Hexagonal	124.944
4				
5		10	Normal	121.8135
6			Cross	97.34312
7			Hexagonal	94.79996
8				
9		12	Normal	105.7719
10			Cross	85.35779
11			Hexagonal	82.08006
12	0.6	8	Normal	141.88
13			Cross	123.0294
14			Hexagonal	111.6943
15				
16		10	Normal	109.2108
17			Cross	106.8127
18			Hexagonal	102.6148
19				
20		12	Normal	93.43906
21			Cross	79.79761
22			Hexagonal	79.79
23	0.7	8	Normal	130.6254
24			Cross	112.0661
25			Hexagonal	109.2998
26				
27		10	Normal	118.0973
28			Cross	100.3313
29			Hexagonal	98.92294
30				
31		12	Normal	92.62803
32			Cross	88.72641
33			Hexagonal	79.30758

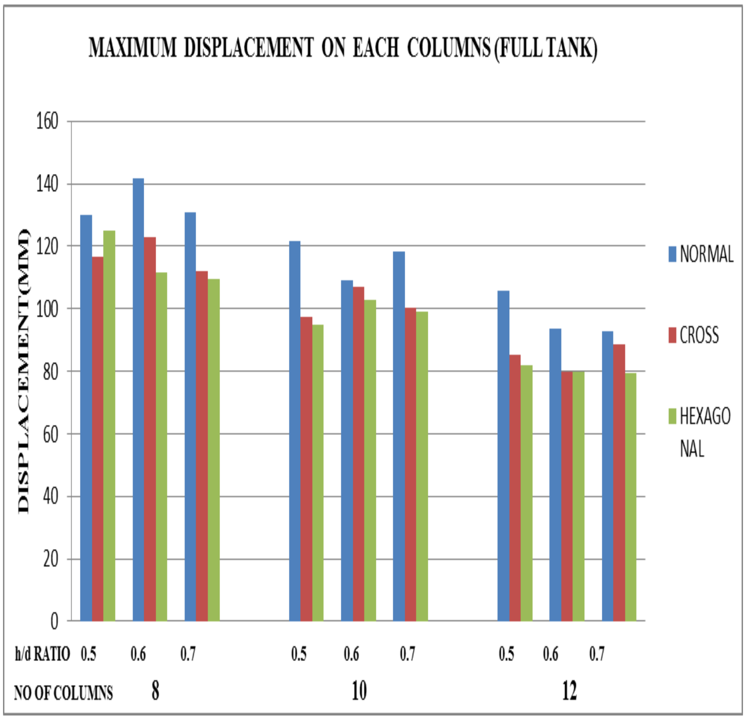


Chart2.6-Maximum Axial Force on Each Column (Full Tank)

Table-2.7 Values of Moment in Y-Direction (Empty Tank)

SR.NO	h/d Ratio	Number Of Columns	Types Of Staging Arrangement	Moment (KN-M)
1	0.5	8	Normal	19.56697
2			Cross	14.8008
3			Hexagonal	15.4493
4				
5		10	Normal	20.9001
6			Cross	18.0462
7			Hexagonal	18.5027
8				
9		12	Normal	19.5132
10			Cross	16.8857
11			Hexagonal	17.8988
13	0.6	8	Normal	19.4335
14			Cross	14.4025
15			Hexagonal	15.0102
16				
17		10	Normal	18.5438
18			Cross	15.5872
19			Hexagonal	16.0851
20				
21		12	Normal	18.6488
22			Cross	15.6447
23			Hexagonal	16.7927
24	0.7	8	Normal	18.636
25			Cross	14.3791
26			Hexagonal	15.1734
27				
28		10	Normal	18.2297
29			Cross	15.4687
30			Hexagonal	16.4457
31				
32		12	Normal	18.3105
33			Cross	16.0585
34			Hexagonal	16.5315

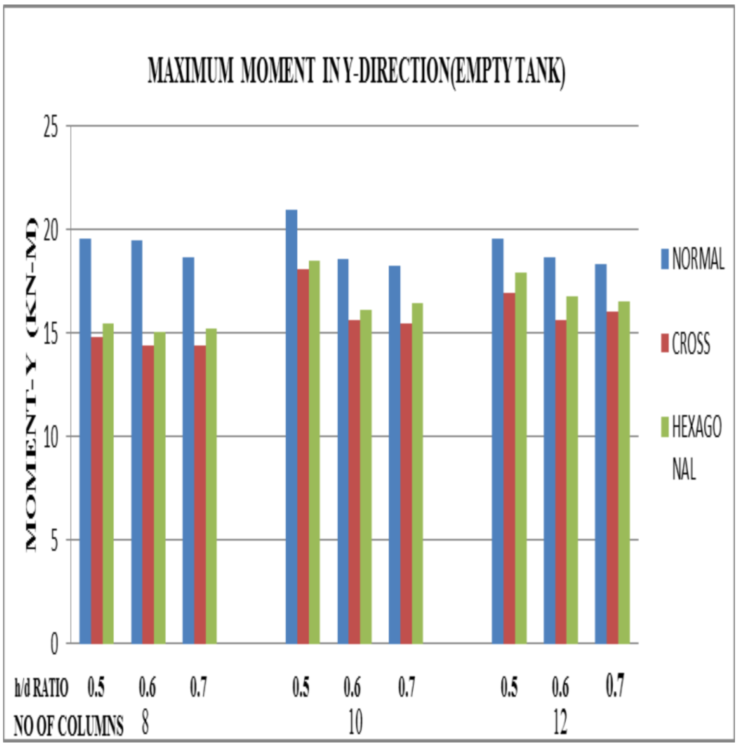
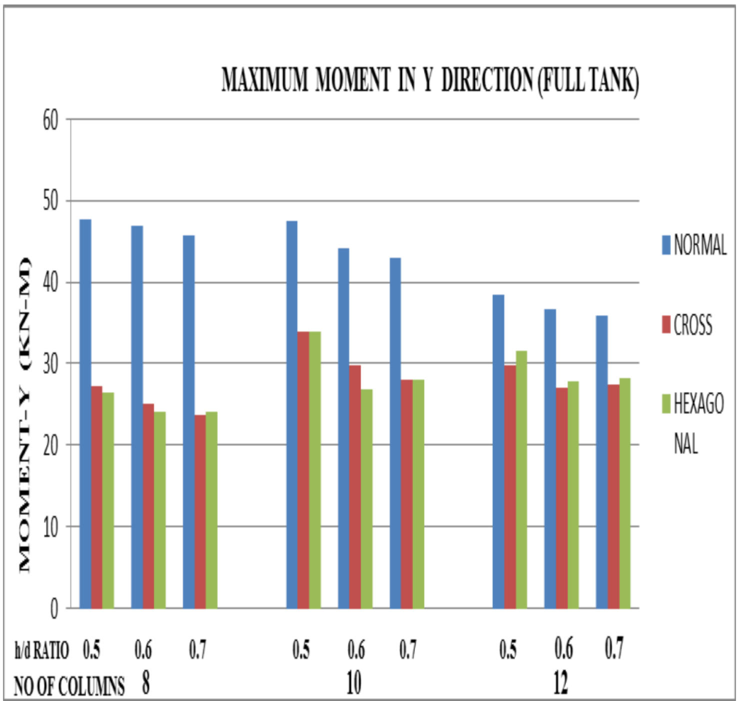


Chart2.7-Maximum moment-y on each column (empty tank)

Table-2.8 Values of Moment in Y-Direction (Full Tank)

SR.NO	h/d Ratio	Number Of Columns	Types Of Staging Arrangement	Moment (KN-M)
1	0.5	8	Normal	47.7437
2			Cross	27.2853
3			Hexagonal	26.3764
4				
5		10	Normal	47.4438
6			Cross	33.8603
7			Hexagonal	33.85325
8				
9		12	Normal	38.4604
10			Cross	29.8042
11			Hexagonal	31.497
13	0.6	8	Normal	46.9255
14			Cross	24.9904
15			Hexagonal	24.1264
16				
17		10	Normal	44.2298
18			Cross	29.709
19			Hexagonal	26.8698
20				
21		12	Normal	36.658
22			Cross	26.9874
23			Hexagonal	27.84
25	0.7	8	Normal	45.6247
26			Cross	23.6457
27			Hexagonal	24.1242
28		10	Normal	43.0537
29			Cross	28.1204
30			Hexagonal	28.0339
31				
32		12	Normal	35.8548
33			Cross	27.362
34			Hexagonal	28.3035



Char2.8-Maximum Moment-Y Force on Each Column (Full Tank)

2.1Pushover Curve: Demand Capacity Curve by Atc40 Method (Empty Tank)

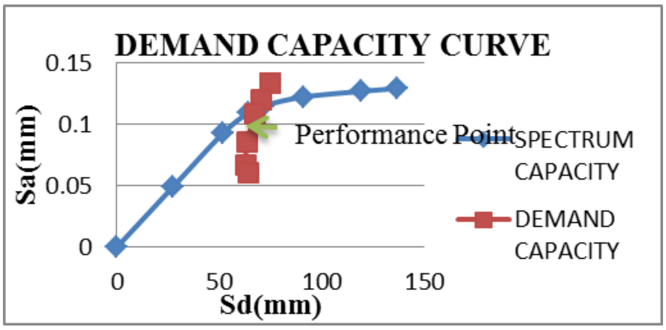


Chart-2.1.1Pushover Curve for Demand Capacity-ATC40 (h/d=0.5, 8 Number of Columns, Normal staging)

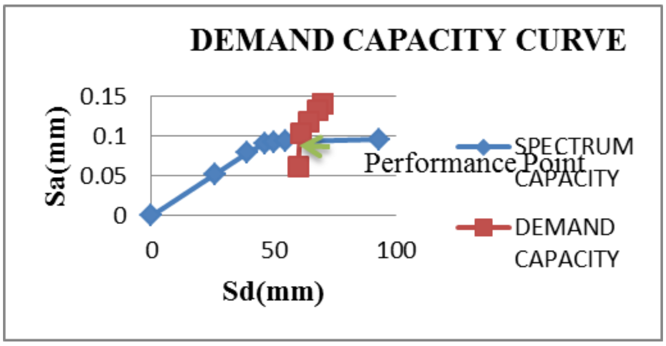


Chart-2.1.2 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 8 Number of Columns, Cross staging)

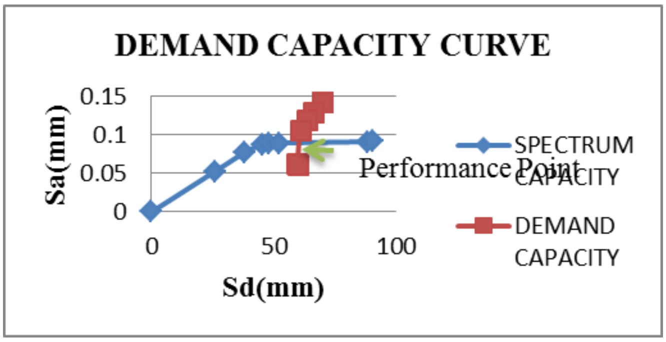


Chart-2.1.3 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 8 Number of Columns, Hexagonal staging)

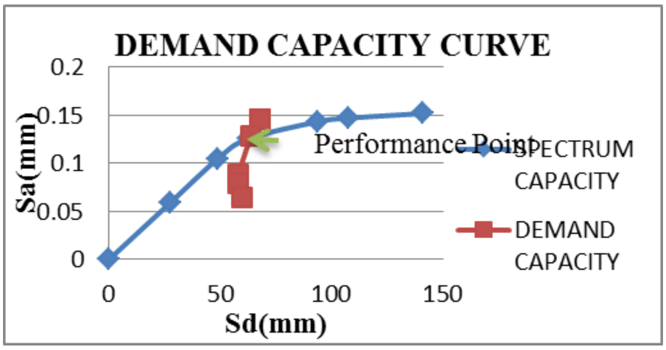


Chart-2.1.4 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 10 Number of Columns, Normal staging)

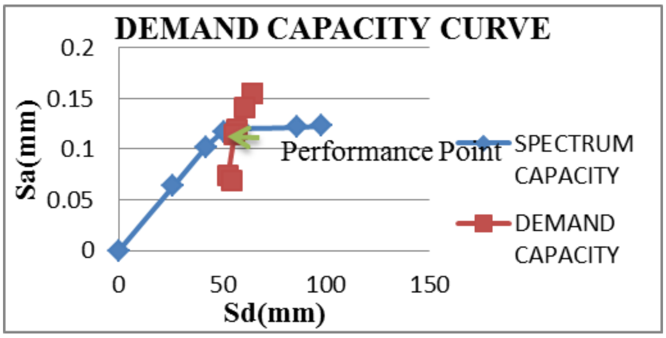


Chart-2.1.5 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 10 Number of Columns, Cross staging)

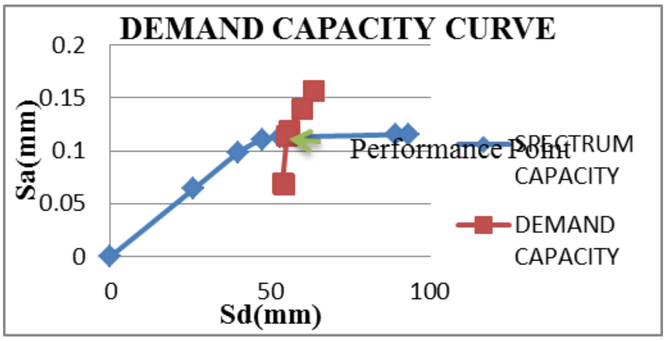


Chart-2.1.6 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 10 Number of Columns, Hexagonal staging)

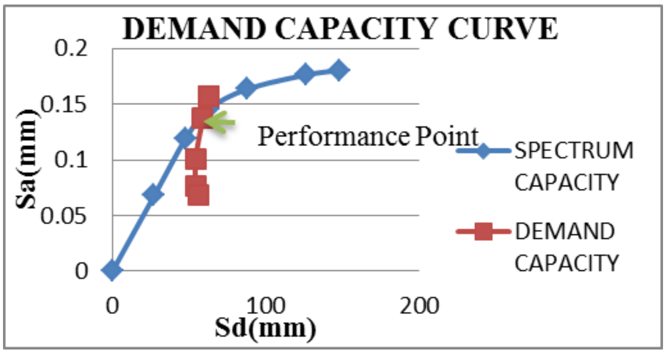


Chart-2.1.7 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 12 Number of Columns, Normal staging)

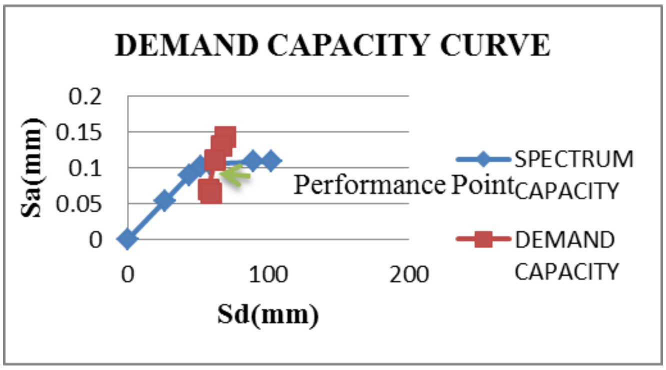


Chart-2.1.8 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 12 Number of Columns, Cross staging)

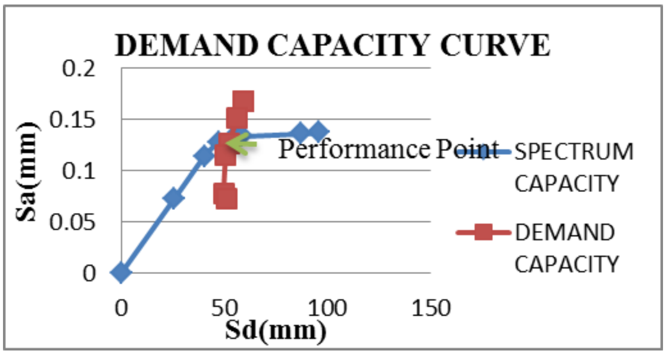


Chart-2.1.9 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 12 Number of Columns, Hexagonal staging)

2.2 Demand Capacity Curve by Atc40 Method (Full Tank)

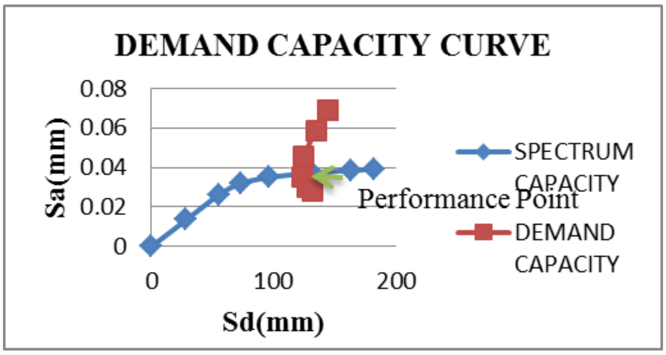


Chart-2.2.1 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 8 Number of Columns, Normal staging)

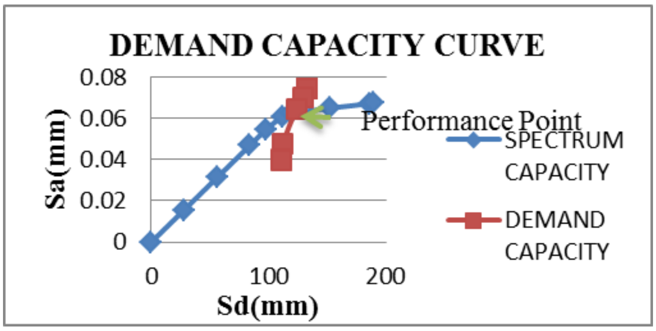


Chart-2.2.2 Pushover Curve for Demand Capacity - ATC40 (h/d=0.6, 8 Number of Columns, Cross staging)

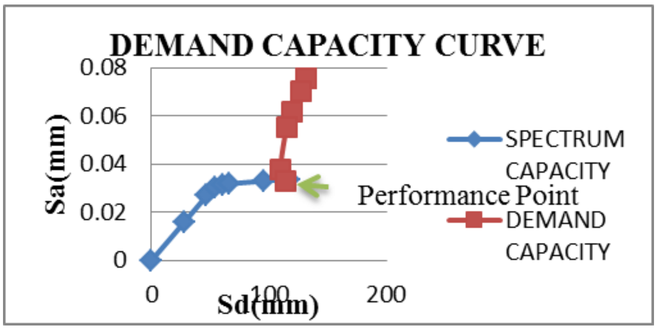


Chart-2-2-3 Pushover Curve for Demand Capacity - ATC40 (h/d=0.6, 8 Number of Columns, Hexagonal staging)

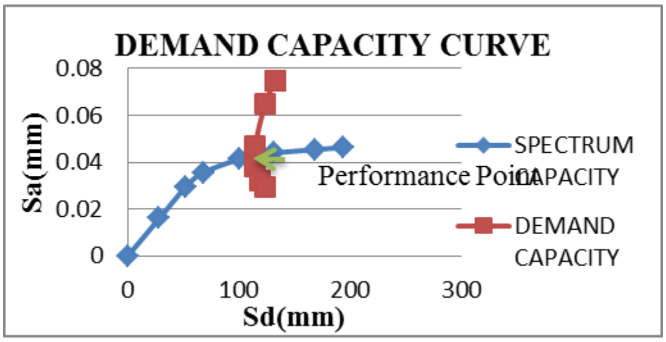


Chart-2.2.4 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 10 Number of Columns, Normal staging)

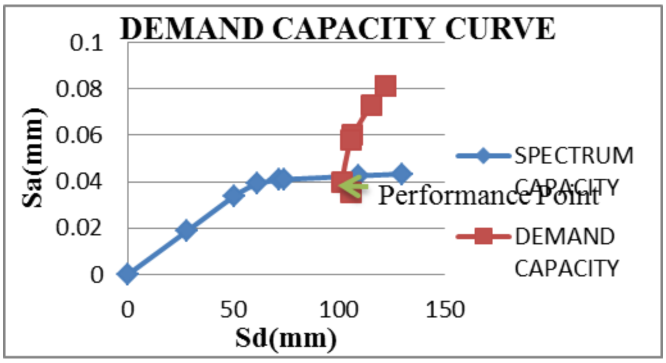


Chart-2.2.5 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, Number of Columns, 10 Cross staging)

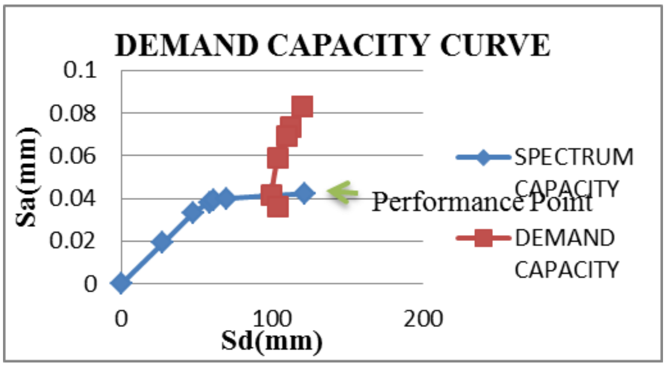


Chart-2.2.6 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 10 Number of Columns, Hexagonal staging)

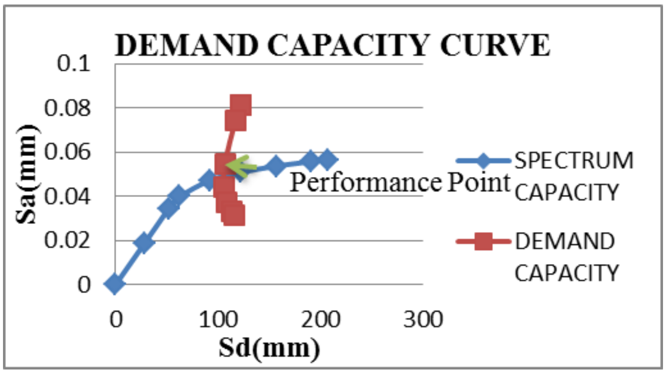


Chart-2.2.7 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 12 Number of Columns, Normal staging)

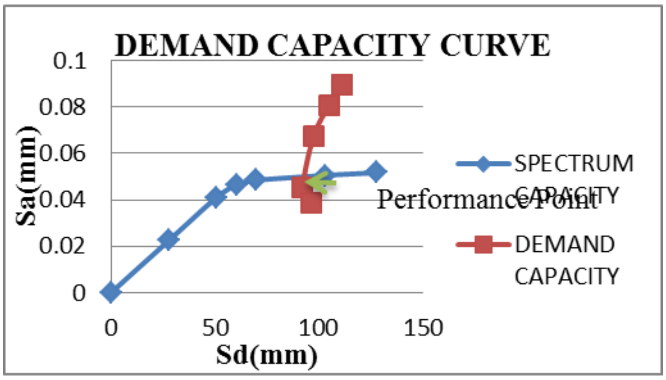


Chart-2.2.8 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 12 Number of Columns, Cross staging)

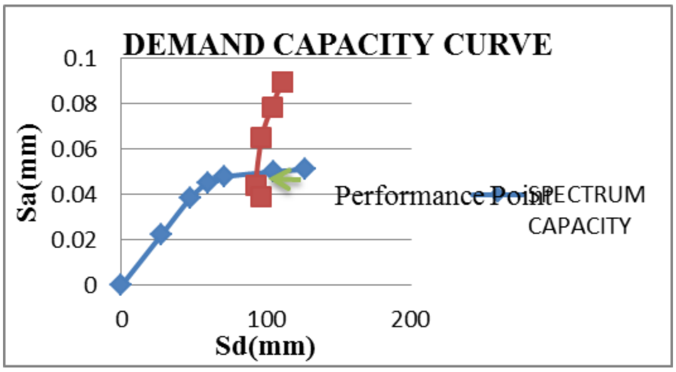


Chart-2.2.9 Pushover Curve for Demand Capacity - ATC40 (h/d=0.5, 12 Number of Columns, Hexagonal staging)

2.3 Pushover Curve – Roof Displacement Vs Base Shear (Empty Tank)

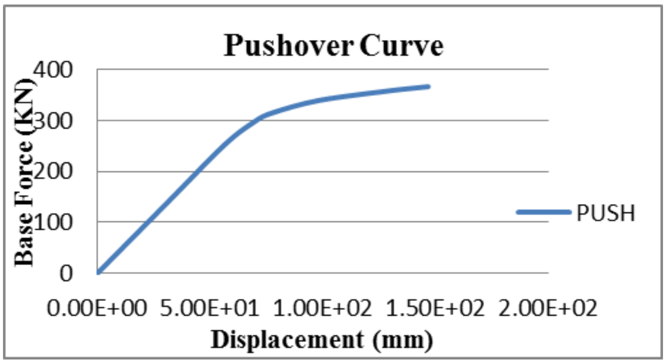


Chart-2.3.1 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 8 Number of Columns, Normal Staging)

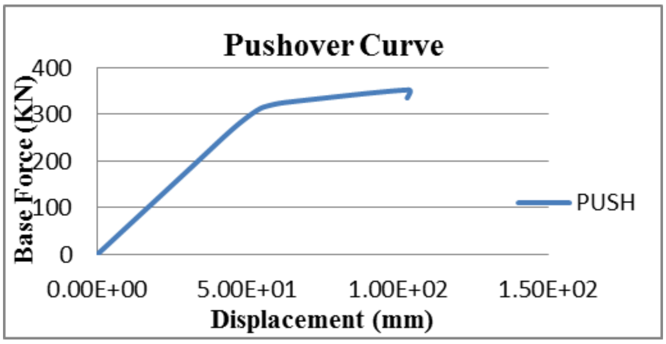


Chart-2.3.2 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 8 Number of Columns, Cross Staging)

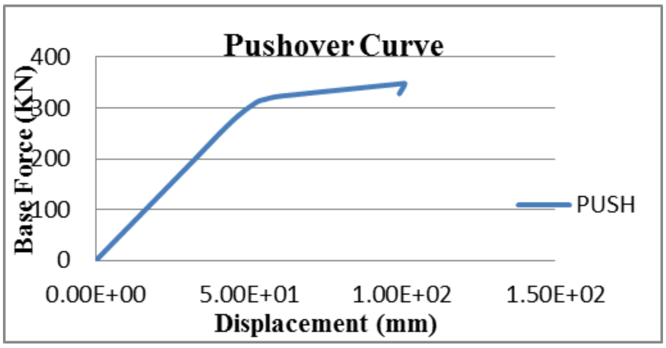


Chart-2.3.3 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 8 Number of Columns, Hexagonal Staging)

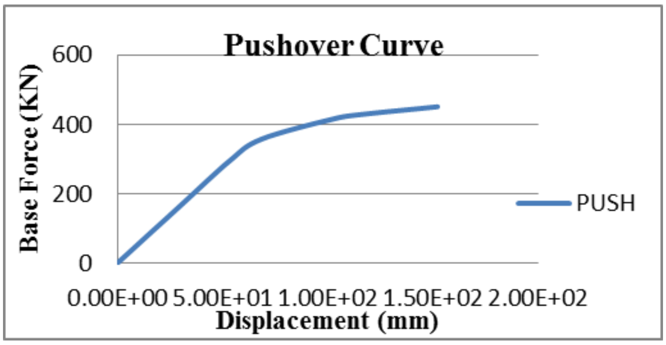


Chart-2.3.4 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 10 Number of Columns, Normal Staging)

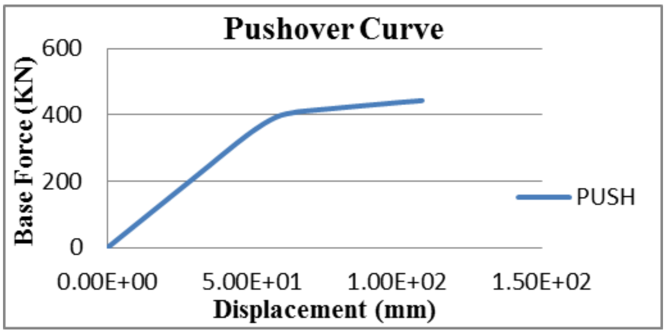


Chart-2.3.5 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 10 Number of Columns, Cross Staging)

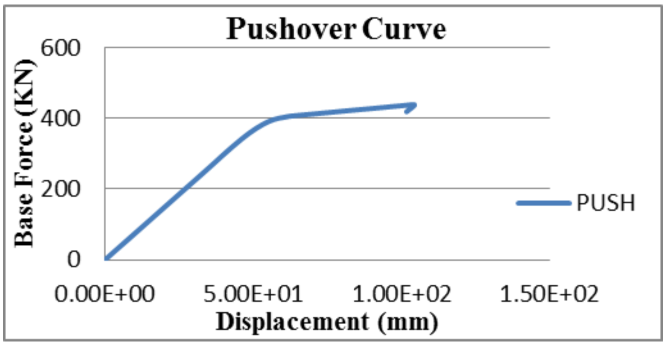


Chart-2.3.6 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 10 Number of Columns, Hexagonal Staging)

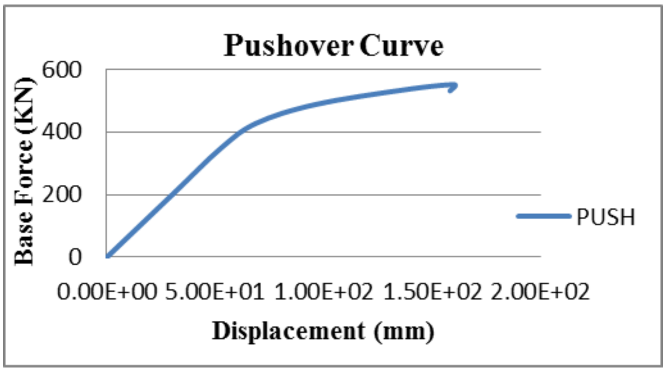


Chart-2.3.7 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 12 Number of Columns, Normal Staging)

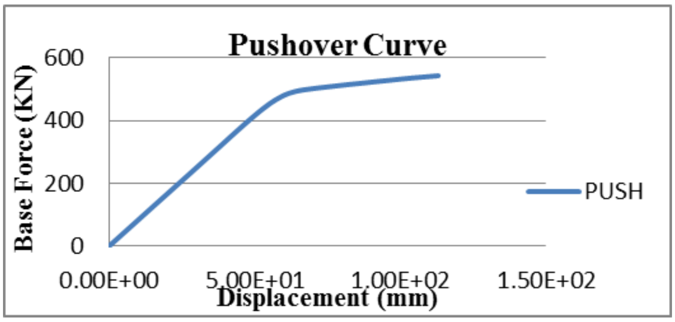


Chart-2.3.8 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 12 Number of Columns, Cross Staging)

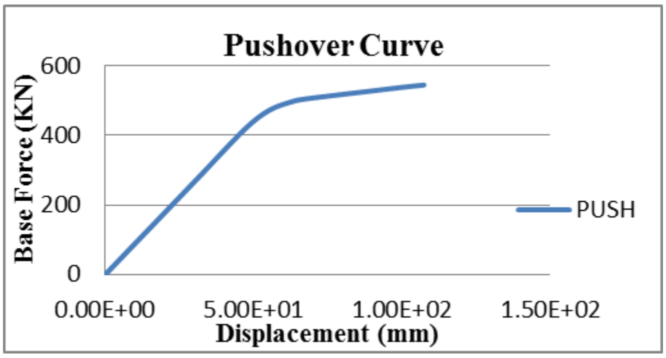


Chart-2.3.9 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio= 0.5, 12 Number of Columns, Hexagonal Staging)

2.4 Pushover Curve – Roof Displacement Vs Base Shear) Full Tank)

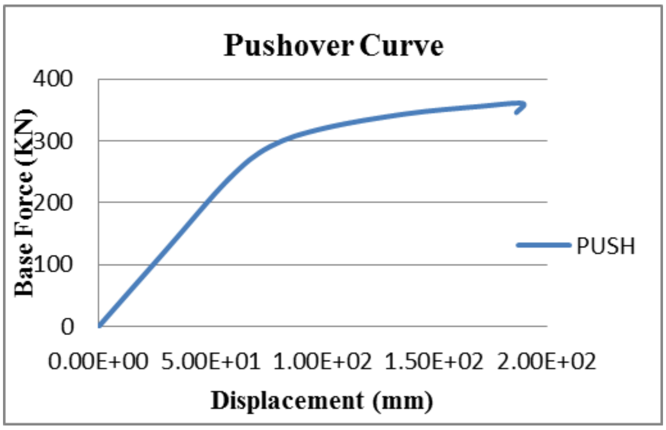


Chart-2.4.1 Pushover Curve Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 8 Number of Columns, Normal Staging)

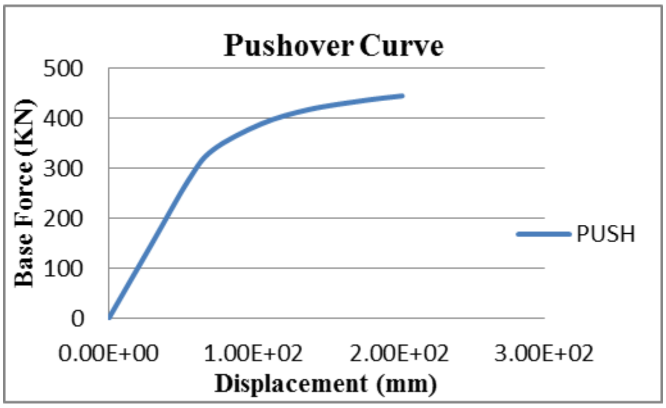


Chart-2.4.4 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 10 Number of Columns, Normal Staging)

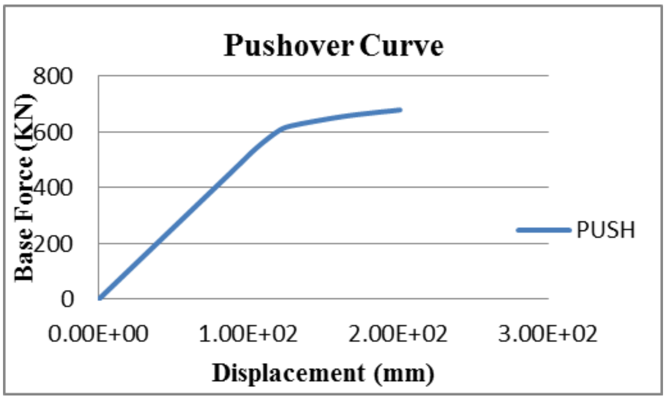


Chart-2.4.2 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 8 Number of Columns, Cross Staging)

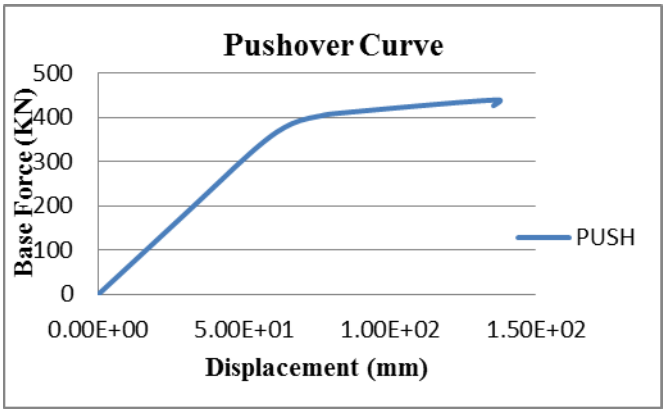


Chart-2.4.5 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 10 Number of Columns, Cross Staging)

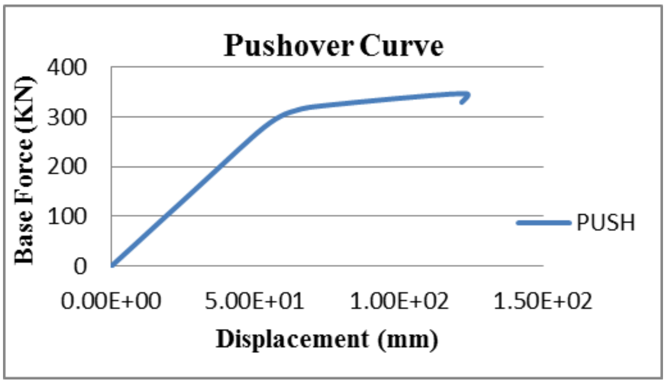


Chart-2.4.3 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 8 Number of Columns, Hexagonal Staging)

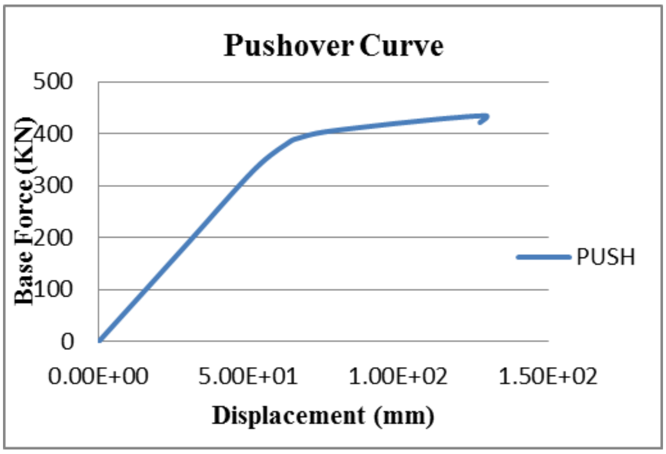


Chart-2.4.6 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 10 Number of Columns, Hexagonal Staging)

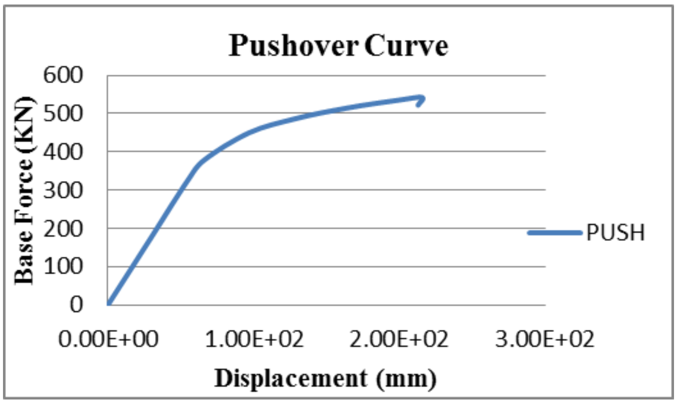


Chart-2.4.7 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 12 Number of Columns, Normal Staging)

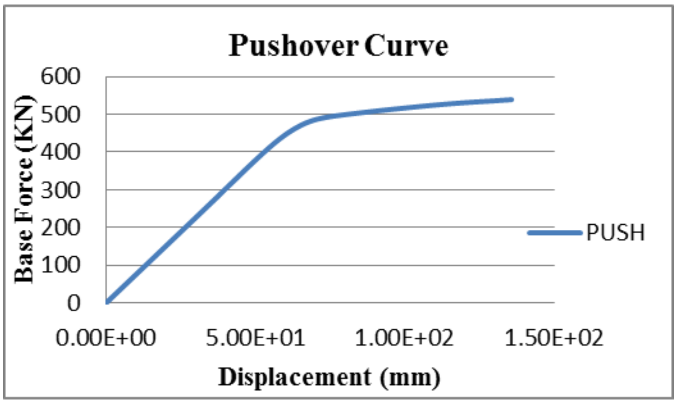


Chart-2.4.8 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 12 Number of Columns, Cross Staging)

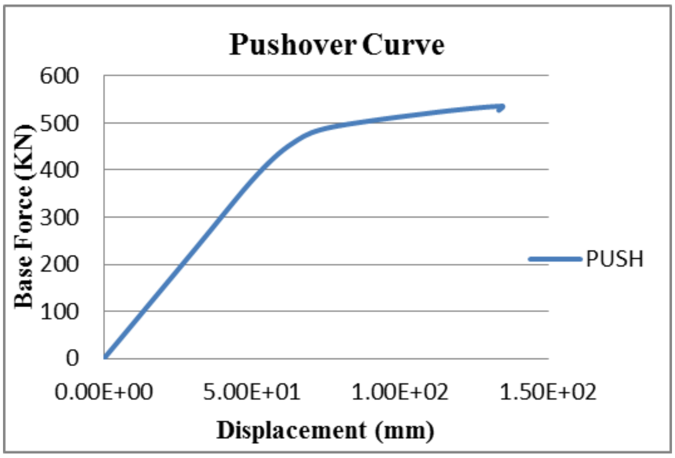


Chart-2.4.9 Pushover Curve – Roof Displacement Vs Base Shear (h/d Ratio = 0.5, 12 Number of Columns, Hexagonal Staging)

CONCLUSION

In this research work, using normal, cross and hexagonal staging arrangements, eight, ten, twelve number of columns and h/d ratio 0.5, 0.6, 0.7 following conclusions were drawn.

These are presented as:

1. Absolute Displacement
   - It is observed that h/d Ratio 0.7 gives minimum Absolute Displacement for Eight no of columns, hexagonal staging type as compare to other h/d Ratio.
   - It is observed that h/d Ratio 0.5 gives minimum Absolute Displacement for Ten no of columns, hexagonal staging type as compare to other h/d Ratio.
   - It is observed that h/d Ratio 0.7 gives minimum Absolute Displacement for Twelve no of columns, hexagonal staging type as compare to other h/d Ratio.
   - Deflection will be less for h/d ratio 0.7 hexagonal staging type for 8, 10 and 12 No of Columns as compare to other h/d Ratio.

2. Axial Force
   - It is observed that h/d Ratio 0.6 normal staging type gives minimum Axial Force for Eight, Ten and Twelve no of columns as compare to other h/d Ratio.

3. Moment - Y Direction
   - It is observed that h/d Ratio 0.7 cross staging type gives minimum Moment-Y for Eight no of column as compare to other h/d Ratio.
   - It is observed that h/d Ratio 0.7 hexagonal staging type gives minimum Moment-Y for Ten no of column as compare to other h/d Ratio.
   - It is observed that h/d Ratio 0.6 cross staging type gives minimum Moment-Y for Twelve no of column as compare to other h/d Ratio.

4. Moment – Z Direction
   - It is observed that h/d Ratio 0.7 cross staging type gives minimum Moment-Z for Eight no of column as compare to other h/d Ratio.
   - It is observed that h/d Ratio 0.7 cross staging type gives minimum Moment-Z for Ten no of column as compare to other h/d Ratio.
   - It is observed that h/d Ratio 0.6 hexagonal staging type gives minimum Moment-Z direction for Twelve no of column as compare to other h/d Ratio

5. For full tank and empty condition as the numbers of columns go on increases, base shear increase.
6. Base Shear is more for h/d ratio 0.5 normal staging type as compare to other h/d ratio and value of base shear is more for tank full condition than tank empty condition.
7. It concludes that for 0.7 h/d ratio cross staging type gives best performance for Absolute Displacement, Axial Force, Moment-Y and Moment-Z.

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