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Civil and Structural Engineering

Highlights

- Effect of Seismic Load
- Utilizing Finite Element Method
- Column Forces in RC Structures
- Seismic Behaviour of Tall Structures

Discovering Thoughts, Inventing Future

VOLUME 23 ISSUE 3 VERSION 1.0

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Effect of Seismic Load on Column Forces in RC Structures by Response Spectrum Analysis

By Mahdi Hosseini
Nanjing Forestry University

Abstract- In the present research work 30 story building with different type of RC Shear wall at the center in concrete frame structure with fixed support conditions under different type of soil for high seismic zone are analyzed.

This paper aims to study the effect of seismic load on column forces in different type of RC shear walls in concrete frame structures under different type of soil condition and different load combination. Estimation of column forces such as; column axial force, column moment, column shear force, column torsion, time period and frequency and modal load participation ratios is carried out. In dynamic analysis; Response Spectrum method is used. It was found that the axial force and moment in the column increases when the type of soil changes from hard to medium and medium to soft. Since the column moment increase as the soil type changes, soil structure interaction must be suitably considered while designing frames for seismic force.

Keywords: *seismic load, linear dynamics analysis, column forces, high seismic zone.*

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EFFECTOFSEISMICLOADONCOLUMNFORCESINRCSTRUCTURESBYRESPONSESPECTRUMANALYSIS

Strictly as per the compliance and regulations of:

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Keywords: seismic load, linear dynamics analysis, column forces, high seismic zone.

I. Introduction

a) Structural Systems

In the earliest structures at the beginning of the 20th century, structural members were assumed to carry primarily the gravity loads. Today, however, by the advances in structural design/systems and high-strength materials, building height is increased, which necessitates taking into consideration mainly the lateral loads such as wind and earthquake. Understandably, especially for the tall buildings, as the slenderness, and so the flexibility increases, buildings suffer from the lateral loads resulting from wind and earthquake more and more. As a general rule, when other things being equal, the taller the building, the more necessary it is to identify the proper structural system for resisting the lateral loads. Currently, there are many structural systems that can be used for the lateral resistance of tall buildings[2,3].

Structural systems of tall buildings can be divided into two broad categories: interior structures and exterior structures.

This classification is based on the distribution of the components of the primary lateral load-resisting system over the building.

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b) Shear Wall Structure

Shear Wall–Frame Systems (Dual Systems), The system consists of reinforced concrete frames interacting with reinforced concrete shear walls are adequate for resisting both the vertical and the horizontal loads acting on them.

c) Necessity of Shear Walls

Shear wall system has two distinct advantages over a frame system.

- It provides adequate strength to resist large lateral loads with-out excessive additional cost.
- It provides adequate stiffness to resist lateral displacements to permissible limits, thus reducing risk of non-structural damage.

d) Seismic Load

The seismic weight of building is the sum of seismic weight of all the floors [8]. The seismic weight of each floor is its full dead load plus appropriate amount of imposed load, the latter being that part of the imposed loads that may reasonably be expected to be attached to the structure at the time of earthquake shaking. Earthquake forces experienced by a building result from ground motions (accelerations) which are also fluctuating or dynamic in nature, in fact they reverse direction somewhat chaotically[2,3]. In theory and practice, the lateral force that a building experiences from an earthquake increases in direct proportion with the acceleration of ground motion at the building site and the mass of the building. As the ground accelerates back and forth during an earthquake it imparts back-and-forth (cyclic) forces to a building through its foundation which is forced to move with the ground [1].

e) Geo-Technical Consideration

The seismic motion that reaches a structure on the surface of the earth is influenced by local soil conditions. The subsurface soil layers underlying the building foundation may amplify the response of the building to earthquake motions originating in the bedrock.

Bearing Capacity of Foundation Soil

Three soil types are considered here:

I. Hard - Those soils, which have an allowable bearing capacity of more than 10t/m2.
II. Medium - Those soils, which have an allowable bearing capacity less than or equal to 10t/m2.

III. Soft - Those soils, which are liable to large differential settlement or liquefaction during an earthquake.

The allowable bearing pressure shall be determined in accordance with IS: 1888-1982 load test (Revision 1992).

II. Methodology

a) To understand and evaluation building structures and aims to the effect of Seismic load on column Forces in Different Type of RC Shear Walls in Concrete Frame Structures under Different Type of Soil Condition with seismic loading.
b) Modeling a G+29 story high building for five different cases [9-11].
c) Analyzing the building dynamic analysis using linear, i.e. Response Spectrum Analysis [1-3].
d) Analyzing the results and arriving at conclusions.

a) Dynamic Analysis

Dynamic analysis may be executed to get the design seismic force, and its spread in different levels through the height of the building, and also various lateral load resisting element[1-2-3,8].

b) Response Spectrum Method

This method is executed to design spectrum, where as it is specified with a code for specific- site design can be used for a project site for the purposes of dynamic of steel and reinforce concrete buildings, the values of damping for building may be taken as 2 and 5 percent of the critical, respectively. response spectrum method is typically implemented in linear elastic procedures and also very much easier to use. This also called as or mode superposition method or model method, It also made on the idea of the superposition of responses given by the building through various modes of vibrations, each vibration modes is recorded as with its own particular deformed shape, with its own modal damping and its own frequency [7,8].

III. Modeling of Building

a) Details of the Building

A symmetrical building[15] of plan 38.5m X 35.5m located with location in high Seismic zone considered. Four bays of length 7.5m & one bays of length 8.5m along X - direction and four bays of length 7.5m & one bays of length 5.5m along Y - direction are provided. Shear is provided the center inner core of model building.

Struct I: G+29 story'stall building with Plus shape RC shear wall at the center of structure.
Struct II: G+29 story'stall building with Box shape RC shear wall at the center of structure.
Struct III: G+29 story'stall building with C- shape RC shear wall at the center of structure.
Struct IV: G+29 story'stall building with E- shape RC shear wall at the center of structure.
Struct V: G+29 story'stall building with I- shape RC shear wall at the center of structure.

b) Load Combinations

As per IS 1893 (Part 1): 2002 Clause no. 6.3.1.2, the following load cases have to be considered for analysis:

"1.2 (DL + IL ± EL)"

"1.5 (DL ± EL)"

"EQXP&EQYP"

Earthquake load must be considered for +X, -X, +Y and –Y Directions [5-7].

c) The Building Details

Type of frame: Special RC moment resisting frame fixed at the base, Number of storeys: G+29, Floor height: 3.5 m, Depth of Slab: 225 mm, Size of beam: (300 × 600) mm, Size of column (exterior): (1250×1250) mm up to story five, Size of column (exterior): (900×900) mm Above story five, Size of column (interior): (1250×1250) mm up to story ten, Size of column (interior): (900×900) mm Above story ten, Live load on floor: 4 KN/m2, Floor finish: 2.5 KN/m2, Wall load: 25 KN/m, Grade of Concrete: M 50 concrete, Grade of Steel: Fe 500, Thickness of shear wall: 450 mm, Seismic zone: V, Important Factor: 1.5, Density of concrete: 25 KN/m3, Type of soil: Type I=Soft Soil, Type II=Medium Soil, Type III= Hard Soil, Response spectra: As per IS 1893(Part-1):2002, Damping of structure: 5 percent & All the analyses has been carried out as per the Indian Standard code books [4-8].

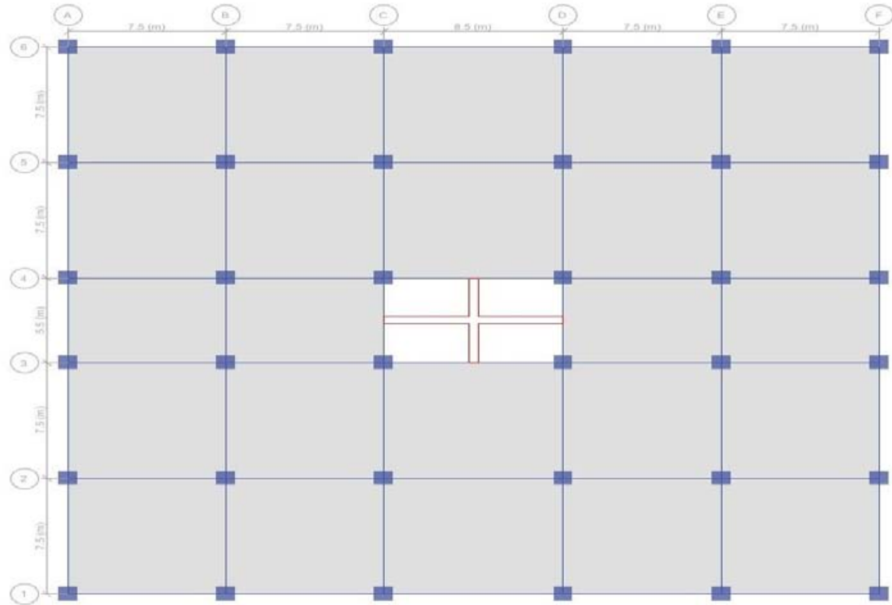

Figure 1: Plan of the Structure I

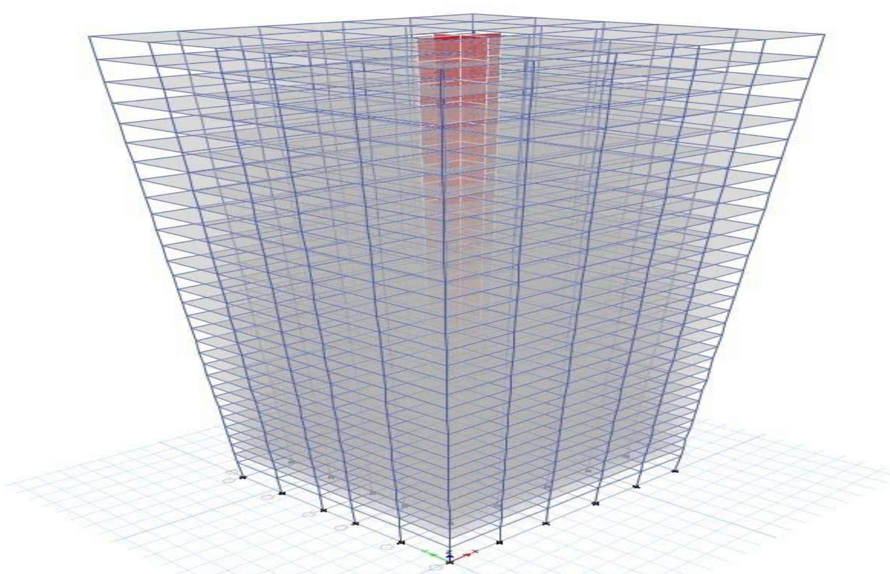

Figure 2: 3D view showing shear wall location for Structure I

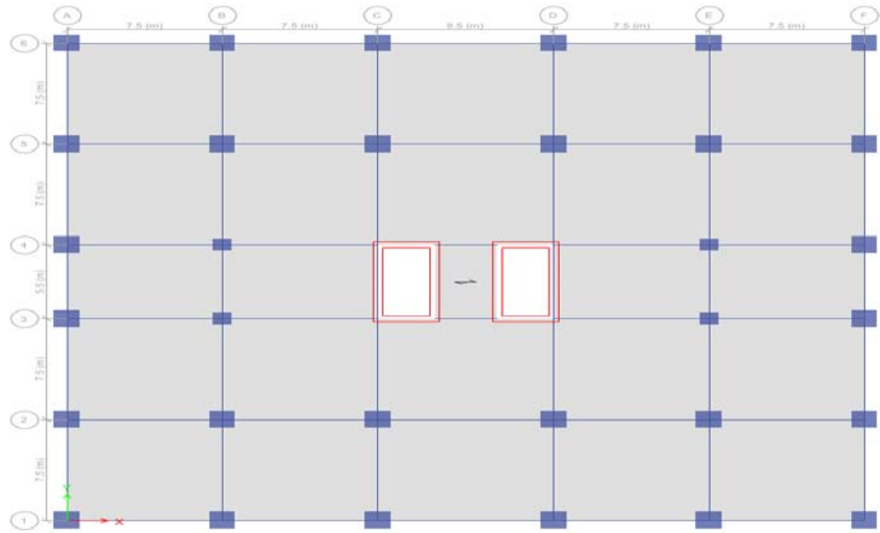

Figure 3: Plan of the Structure II

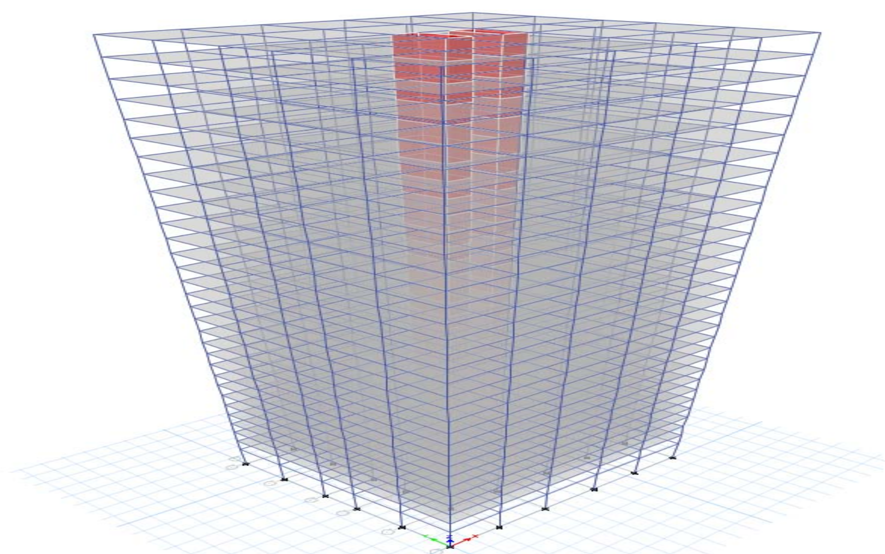

Figure 4: 3D view showing shear wall location for Structure II

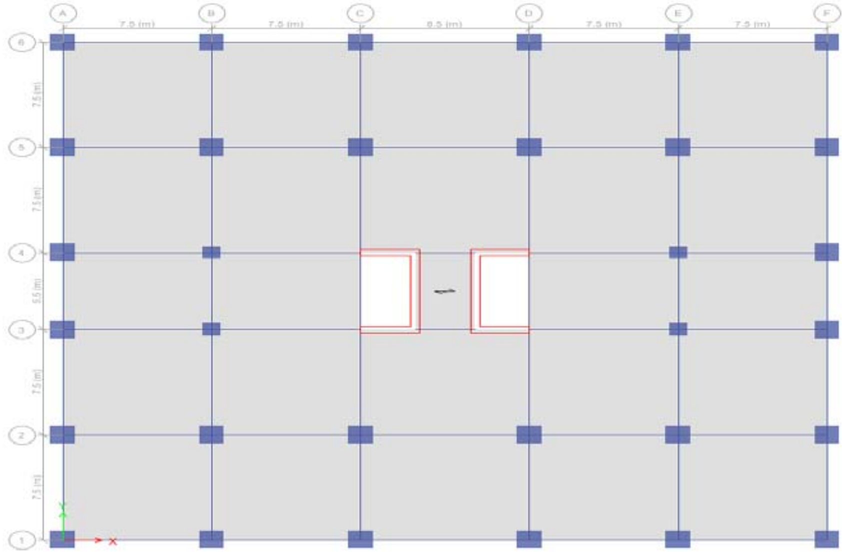

Figure 5: Plan of the Structure III

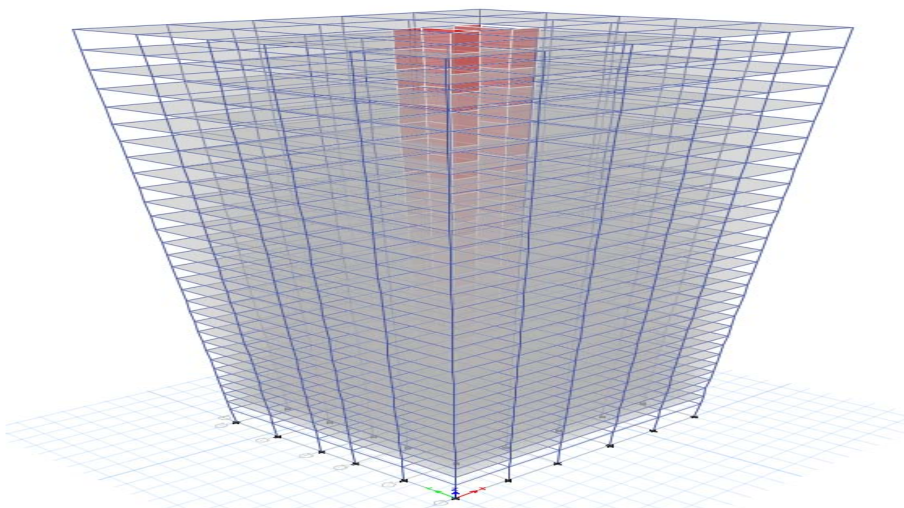

Figure 6: 3D view showing shear wall location for Structure III

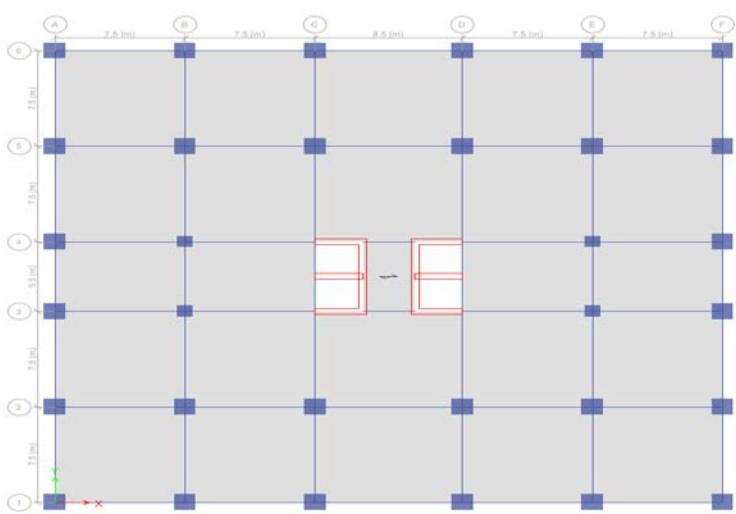

Figure 7: Plan of the Structure IV

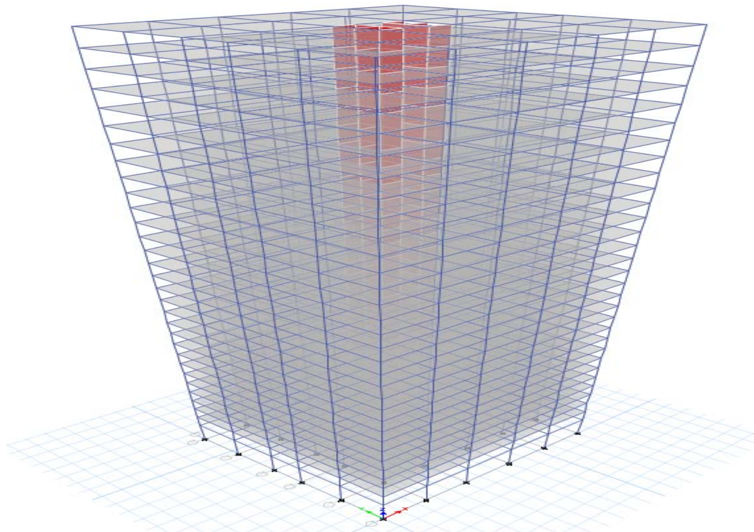

Figure 8: 3D view showing shear wall location for Structure IV

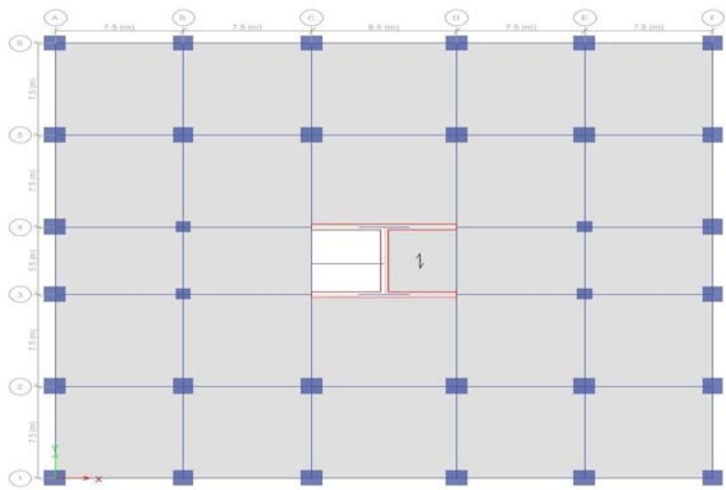

Figure 9: Plan of the Structure V

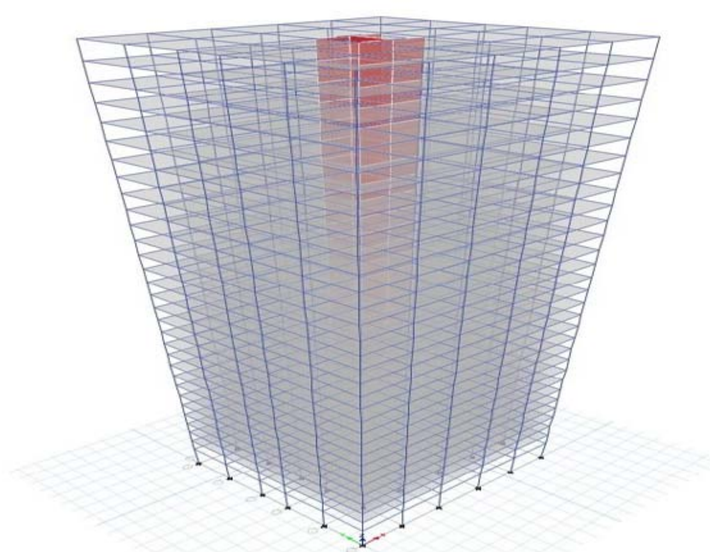

Figure 10: 3D view showing shear wall location for Structure V

IV. Results and Discussions

Parametric results in column forces such as column axial force, column moment, column shear force & column torsion with different load combination/load Cases such as 1.2 (DL+LL+EQXP), 1.2 (DL+LL+EQYP), 1.5 (DL+EQXP), 1.5 (DL+EQYP), EQXP & EQYP in different type of soil conditions (soft, medium and hard) were considered, in this regard we compared all column forces in different type of soil condition of structures II, III, IV, V with structure I (plus shape shear wall), also compared forces in hard and medium soils with soft soil for all five structures.

Table 1: Column Axial Force, P for structures with the load combination 1.2 (DL+LL+EQXP) & 1.2 (DL+LL+EQYP), All value in "kN"

Column Axial Force, P in Soft Soil					Struct I	Struct II	Struct III	Struct IV	Struct V
Story	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"P"	"P"	"P"	"P"	"P"
1ST	C34	67	1.2(DL+LL+EQXP)	0	-24171.0618	-24285.0493	-24629.8602	-24381.5444	-24398.1773
1ST	C34	67	1.2(DL+LL+EQXP)	1.45	-24103.093	-24217.0806	-24561.8915	-24313.5757	-24330.2086
1ST	C34	67	1.2(DL+LL+EQXP)	2.9	-24035.1243	-24149.1118	-24493.9227	-24245.6069	-24262.2398
1ST	C34	67	1.2(DL+LL+EQYP)	0	-23630.6382	-23276.1711	-23447.6424	-23345.1752	-23441.1649
1ST	C34	67	1.2(DL+LL+EQYP)	1.45	-23562.6694	-23208.2023	-23379.6736	-23277.2065	-23373.1961
1ST	C34	67	1.2(DL+LL+EQYP)	2.9	-23494.7007	-23140.2336	-23311.7049	-23209.2377	-23305.2274
Column Axial Force, P in Medium Soil									
1ST	C34	67	1.2(DL+LL+EQXP)	0	-24937.4993	-25121.0698	-25571.6279	-25446.3503	-25240.6514
1ST	C34	67	1.2(DL+LL+EQXP)	1.45	-24869.5305	-25053.1011	-25503.6591	-25378.3816	-25172.6826
1ST	C34	67	1.2(DL+LL+EQXP)	2.9	-24801.5618	-24985.1323	-25435.6904	-25310.4128	-25104.7139
1ST	C34	67	1.2(DL+LL+EQYP)	0	-24202.5232	-23748.9954	-23963.8116	-23949.6572	-23939.1144
1ST	C34	67	1.2(DL+LL+EQYP)	1.45	-24134.5545	-23681.0267	-23895.8428	-23881.6884	-23871.1456
1ST	C34	67	1.2(DL+LL+EQYP)	2.9	-24066.5857	-23613.0579	-23827.8741	-23813.7197	-23803.1769
Column Axial Force, P in Hard Soil									
1ST	C34	67	1.2(DL+LL+EQXP)	0	-25597.4871	-25840.9764	-26382.5944	-26235.5482	-25966.1151
1ST	C34	67	1.2(DL+LL+EQXP)	1.45	-25529.5184	-25773.0076	-26314.6257	-26167.5794	-25898.1464
1ST	C34	67	1.2(DL+LL+EQXP)	2.9	-25461.5496	-25705.0389	-26246.6569	-26099.6107	-25830.1776
1ST	C34	67	1.2(DL+LL+EQYP)	0	-24694.9798	-24156.1497	-24408.2906	-24397.697	-24367.9043
1ST	C34	67	1.2(DL+LL+EQYP)	1.45	-24627.011	-24088.181	-24340.3219	-24329.7283	-24299.9355
1ST	C34	67	1.2(DL+LL+EQYP)	2.9	-24559.0423	-24020.2122	-24272.3531	-24261.7595	-24231.9668

Table 2: Column Moment, M for structures with the load combination 1.2 (DL+LL+EQXP) &1.2 (DL+LL+EQYP), All value in "kN-m"

Column Moment, M in Soft Soil					Struct I	Struct I	Struct II	Struct II	Struct III	Struct III	Struct IV	Struct IV	Struct V	Struct V
Story	Column	Unique Name	Load Case/Combo	Station	"M2"	"M3"	"M2"	"M3"	"M2"	"M3"	"M2"	"M3"	"M2"	"M3"
1ST	C34	67	1.2(DL+LL+EQXP)	0	-244.0118	979.4715	-171.6774	1061.1112	-251.8641	1421.2435	-239.9922	1271.7973	-249.7758	971.7283
1ST	C34	67	1.2(DL+LL+EQXP)	1.45	-146.2684	805.6993	-84.4168	912.7196	-151.3927	1219.8181	-142.186	1095.4925	-150.8748	826.9906
1ST	C34	67	1.2(DL+LL+EQXP)	2.9	-48.5251	631.9271	2.8438	764.328	-50.9213	1018.3927	-44.3799	919.1878	-51.9738	682.2529
1ST	C34	67	1.2(DL+LL+EQYP)	0	1727.5733	-24.7075	1026.407	-134.6353	1218.6199	-173.1854	1153.6344	-157.4043	1174.9664	-74.8523
1ST	C34	67	1.2(DL+LL+EQYP)	1.45	1393.6416	-70.5194	893.9723	-94.628	1027.4053	-112.2758	974.8851	-107.0072	954.7475	-81.4083
1ST	C34	67	1.2(DL+LL+EQYP)	2.9	1059.71	-116.3313	761.5375	-54.6207	836.1907	-51.3663	796.1358	-56.6101	734.5287	-87.9644
Column Moment, M in Medium Soil														
1ST	C34	67	1.2(DL+LL+EQXP)	0	-312.5242	1329.5266	-216.79	1461.8423	-325.8538	1958.0803	-325.927	1862.7469	-322.5699	1328.7543
1ST	C34	67	1.2(DL+LL+EQXP)	1.45	-197.6708	1112.7719	-115.9939	1264.1942	-207.082	1683.6228	-206.7527	1610.877	-205.9796	1142.9081
1ST	C34	67	1.2(DL+LL+EQXP)	2.9	-82.8175	896.0172	-15.1978	1066.5461	-88.3102	1409.1652	-87.5785	1359.0072	-89.3893	957.0619
1ST	C34	67	1.2(DL+LL+EQYP)	0	2368.8316	-36.1568	1412.6049	-164.3729	1674.0045	-210.3429	1686.2828	-200.7817	1615.0795	-94.5952
1ST	C34	67	1.2(DL+LL+EQYP)	1.45	1896.6069	-78.8855	1214.6153	-105.7985	1396.0833	-128.025	1406.1652	-125.3418	1297.6668	-92.5144
1ST	C34	67	1.2(DL+LL+EQYP)	2.9	1424.3822	-121.6142	1016.6256	-47.2242	1118.1621	-45.707	1126.0477	-49.9019	980.2541	-90.4336
Column Moment, M in Hard Soil														
1ST	C34	67	1.2(DL+LL+EQXP)	0	-371.5209	1630.9629	-255.6369	1806.9164	-389.5671	2420.3565	-389.6526	2300.9465	-385.2537	1636.1935
1ST	C34	67	1.2(DL+LL+EQXP)	1.45	-241.934	1377.1956	-143.1853	1566.8529	-255.0367	2083.0102	-254.632	1993.0377	-253.431	1414.9482
1ST	C34	67	1.2(DL+LL+EQXP)	2.9	-112.3471	1123.4282	-30.7336	1326.7894	-120.5062	1745.6638	-119.6113	1685.1289	-121.6082	1193.703
1ST	C34	67	1.2(DL+LL+EQYP)	0	2921.0262	-46.0159	1745.1642	-189.9802	2066.1412	-242.3397	2081.2226	-232.9453	1994.0659	-111.5961
1ST	C34	67	1.2(DL+LL+EQYP)	1.45	2329.7158	-86.0897	1490.7245	-115.4176	1713.556	-141.5867	1725.9364	-138.9369	1592.9584	-102.078
1ST	C34	67	1.2(DL+LL+EQYP)	2.9	1738.4055	-126.1634	1236.2848	-40.855	1360.9708	-40.8338	1370.6502	-44.9285	1191.851	-92.5599

Table 3: Column Shear, V for structures with the load combination 1.2 (DL+LL+EQXP) & 1.2 (DL+LL+EQYP), All value in "KN"

Column Shear, V in Soft Soil					Struct I	Struct I	Struct II	Struct II	Struct III	Struct III	Struct IV	Struct IV	Struct V	Struct V
Story	Column	Unique Name	Load Case/Combo	Station m	"V2"	"V3"	"V2"	"V3"	"V2"	"V3"	"V2"	"V3"	"V2"	"V3"
1ST	C34	67	1.2(DL+LL+EQXP)	0	119.8429	-67.4092	102.339	-60.1798	138.9141	-69.2906	121.5895	-67.4525	99.8191	-68.2076
1ST	C34	67	1.2(DL+LL+EQXP)	1.45	119.8429	-67.4092	102.339	-60.1798	138.9141	-69.2906	121.5895	-67.4525	99.8191	-68.2076
1ST	C34	67	1.2(DL+LL+EQXP)	2.9	119.8429	-67.4092	102.339	-60.1798	138.9141	-69.2906	121.5895	-67.4525	99.8191	-68.2076
1ST	C34	67	1.2(DL+LL+EQYP)	0	31.5944	230.2977	-27.5912	91.3343	-42.0066	131.8722	-34.7566	123.2754	4.5214	151.8751
1ST	C34	67	1.2(DL+LL+EQYP)	1.45	31.5944	230.2977	-27.5912	91.3343	-42.0066	131.8722	-34.7566	123.2754	4.5214	151.8751
1ST	C34	67	1.2(DL+LL+EQYP)	2.9	31.5944	230.2977	-27.5912	91.3343	-42.0066	131.8722	-34.7566	123.2754	4.5214	151.8751
Column Shear, V in Medium Soil														
1ST	C34	67	1.2(DL+LL+EQXP)	0	149.486	-79.2092	136.3091	-69.5145	189.2811	-81.9116	173.7034	-82.1892	128.1698	-80.4071
1ST	C34	67	1.2(DL+LL+EQXP)	1.45	149.486	-79.2092	136.3091	-69.5145	189.2811	-81.9116	173.7034	-82.1892	128.1698	-80.4071
1ST	C34	67	1.2(DL+LL+EQXP)	2.9	149.486	-79.2092	136.3091	-69.5145	189.2811	-81.9116	173.7034	-82.1892	128.1698	-80.4071
1ST	C34	67	1.2(DL+LL+EQYP)	0	29.4681	325.6722	-40.3961	136.5446	-56.771	191.6698	-52.0275	193.1845	-1.435	218.9053
1ST	C34	67	1.2(DL+LL+EQYP)	1.45	29.4681	325.6722	-40.3961	136.5446	-56.771	191.6698	-52.0275	193.1845	-1.435	218.9053
1ST	C34	67	1.2(DL+LL+EQYP)	2.9	29.4681	325.6722	-40.3961	136.5446	-56.771	191.6698	-52.0275	193.1845	-1.435	218.9053
Column Shear, V in Hard Soil														
1ST	C34	67	1.2(DL+LL+EQXP)	0	175.012	-89.3703	165.561	-77.5528	232.6527	-92.7796	212.3509	-93.1177	152.5829	-90.9122
1ST	C34	67	1.2(DL+LL+EQXP)	1.45	175.012	-89.3703	165.561	-77.5528	232.6527	-92.7796	212.3509	-93.1177	152.5829	-90.9122
1ST	C34	67	1.2(DL+LL+EQXP)	2.9	175.012	-89.3703	165.561	-77.5528	232.6527	-92.7796	212.3509	-93.1177	152.5829	-90.9122
1ST	C34	67	1.2(DL+LL+EQYP)	0	27.6371	407.8002	-51.4225	175.4757	-69.4848	243.1622	-64.8334	245.025	-6.5642	276.6258
1ST	C34	67	1.2(DL+LL+EQYP)	1.45	27.6371	407.8002	-51.4225	175.4757	-69.4848	243.1622	-64.8334	245.025	-6.5642	276.6258
1ST	C34	67	1.2(DL+LL+EQYP)	2.9	27.6371	407.8002	-51.4225	175.4757	-69.4848	243.1622	-64.8334	245.025	-6.5642	276.6258

Table 4: Column Torsion, T for structures with the load combination 1.2 (DL+LL+EQXP) & 1.2 (DL+LL+EQYP), All value in "kN-m"

Column Torsion, T in Soft Soil					Struct I	Struct II	Struct III	Struct IV	Struct V
Story	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"T"	"T"	"T"	"T"	"T"
1ST	C34	67	1.2(DL+LL+EQXP)	0	-41.6175	-29.3334	-44.901	-42.3525	-43.8436
1ST	C34	67	1.2(DL+LL+EQXP)	1.45	-41.6175	-29.3334	-44.901	-42.3525	-43.8436
1ST	C34	67	1.2(DL+LL+EQXP)	2.9	-41.6175	-29.3334	-44.901	-42.3525	-43.8436
1ST	C34	67	1.2(DL+LL+EQYP)	0	45.3145	31.9525	48.8724	46.1375	48.5638
1ST	C34	67	1.2(DL+LL+EQYP)	1.45	45.3145	31.9525	48.8724	46.1375	48.5638
1ST	C34	67	1.2(DL+LL+EQYP)	2.9	45.3145	31.9525	48.8724	46.1375	48.5638
Column Torsion, T in Medium Soil									
1ST	C34	67	1.2(DL+LL+EQXP)	0	-56.5981	-39.8539	-61.0208	-61.1008	-59.584
1ST	C34	67	1.2(DL+LL+EQXP)	1.45	-56.5981	-39.8539	-61.0208	-61.1008	-59.584
1ST	C34	67	1.2(DL+LL+EQXP)	2.9	-56.5981	-39.8539	-61.0208	-61.1008	-59.584
1ST	C34	67	1.2(DL+LL+EQYP)	0	61.6294	43.4949	66.5111	66.66	66.09
1ST	C34	67	1.2(DL+LL+EQYP)	1.45	61.6294	43.4949	66.5111	66.66	66.09
1ST	C34	67	1.2(DL+LL+EQYP)	2.9	61.6294	43.4949	66.5111	66.66	66.09
Column Torsion, T in Hard Soil									
1ST	C34	67	1.2(DL+LL+EQXP)	0	-69.4981	-48.9132	-74.9017	-75.004	-73.1383
1ST	C34	67	1.2(DL+LL+EQXP)	1.45	-69.4981	-48.9132	-74.9017	-75.004	-73.1383
1ST	C34	67	1.2(DL+LL+EQXP)	2.9	-69.4981	-48.9132	-74.9017	-75.004	-73.1383
1ST	C34	67	1.2(DL+LL+EQYP)	0	75.6784	53.4342	81.6999	81.8788	81.182
1ST	C34	67	1.2(DL+LL+EQYP)	1.45	75.6784	53.4342	81.6999	81.8788	81.182
1ST	C34	67	1.2(DL+LL+EQYP)	2.9	75.6784	53.4342	81.6999	81.8788	81.182

Table 5: Column Axial Force, P for structures with the load combination 1.5 (DL+EQXP) & 1.5 (DL+EQYP), All value in "kN"

Column Axial Force, Pin Soft Soil					Struct I	Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"P"	"P"	"P"	"P"	"P"
1ST	C34	67	1.5(DL+EQXP)	0	-25183.8699	-25355.396	-25767.3656	-25468.0736	-25450.8356
1ST	C34	67	1.5(DL+EQXP)	1.45	-25098.9089	-25270.435	-25682.4047	-25383.1127	-25365.8747
1ST	C34	67	1.5(DL+EQXP)	2.9	-25013.948	-25185.4741	-25597.4437	-25298.1518	-25280.9137
1ST	C34	67	1.5(DL+EQYP)	0	-24508.3404	-24094.2982	-24289.5933	-24172.6121	-24254.57
1ST	C34	67	1.5(DL+EQYP)	1.45	-24423.3794	-24009.3372	-24204.6324	-24087.6512	-24169.6091
1ST	C34	67	1.5(DL+EQYP)	2.9	-24338.4185	-23924.3763	-24119.6714	-24002.6903	-24084.6481
Column Axial Force, P in Medium Soil									
1ST	C34	67	1.5(DL+EQXP)	0	-26141.9168	-26400.4216	-26944.5752	-26799.081	-26503.9282
1ST	C34	67	1.5(DL+EQXP)	1.45	-26056.9558	-26315.4607	-26859.6142	-26714.1201	-26418.9672
1ST	C34	67	1.5(DL+EQXP)	2.9	-25971.9949	-26230.4998	-26774.6533	-26629.1591	-26334.0063
1ST	C34	67	1.5(DL+EQYP)	0	-25223.1967	-24685.3286	-24934.8048	-24928.2146	-24877.0069
1ST	C34	67	1.5(DL+EQYP)	1.45	-25138.2357	-24600.3677	-24849.8439	-24843.2537	-24792.046
1ST	C34	67	1.5(DL+EQYP)	2.9	-25053.2748	-24515.4068	-24764.8829	-24758.2927	-24707.0851
Column Axial Force, P in Hard Soil									
1ST	C34	67	1.5(DL+EQXP)	0	-26966.9016	-27300.3048	-27958.2834	-27785.5783	-27410.7578
1ST	C34	67	1.5(DL+EQXP)	1.45	-26881.9407	-27215.3439	-27873.3224	-27700.6174	-27325.7969
1ST	C34	67	1.5(DL+EQXP)	2.9	-26796.9797	-27130.383	-27788.3615	-27615.6564	-27240.836
1ST	C34	67	1.5(DL+EQYP)	0	-25838.7674	-25194.2715	-25490.4036	-25488.2644	-25412.9943
1ST	C34	67	1.5(DL+EQYP)	1.45	-25753.8064	-25109.3106	-25405.4426	-25403.3035	-25328.0334
1ST	C34	67	1.5(DL+EQYP)	2.9	-25668.8455	-25024.3496	-25320.4817	-25318.3425	-25243.0724

Table 6: Column Moment, M for structures with the load combination 1.5 (DL +EQXP) & 1.5 (DL+EQYP), All value in "kN-m"

Column Moment, M in Soft Soil					Struct I	Struct I	Struct II	Struct II	Struct III	Struct III	Struct IV	Struct IV	Struct V	Struct V
"Story"	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"M2"	"M3"	"M2"	"M3"	"M2"	"M3"	"M2"	"M3"	"M2"	"M3"
1ST	C34	67	1.5(DL+EQXP)	0	-300.9713	1225.747	-213.58	1343.434	-313.8242	1800.2079	-298.9771	1609.5397	-311.2144	1219.4677
1ST	C34	67	1.5(DL+EQXP)	1.45	-185.7663	1027.6976	-111.2483	1165.8496	-194.9693	1551.5389	-183.4603	1395.0708	-194.3203	1051.1982
1ST	C34	67	1.5(DL+EQXP)	2.9	-70.5614	829.6482	-8.9167	988.2653	-76.1145	1302.8699	-67.9436	1180.6019	-77.4263	882.9288
1ST	C34	67	1.5(DL+EQYP)	0	2163.5101	-29.4766	1284.0256	-151.2491	1524.2808	-192.8282	1443.0562	-176.9623	1469.7135	-88.758
1ST	C34	67	1.5(DL+EQYP)	1.45	1739.1213	-67.5757	1111.738	-93.3349	1278.5282	-113.5785	1212.8786	-108.0539	1187.7076	-84.3004
1ST	C34	67	1.5(DL+EQYP)	2.9	1314.7324	-105.6748	939.4504	-35.4206	1032.7756	-34.3288	982.7011	-39.1454	905.7018	-79.8429
Column Moment, M in Medium Soil														
1ST	C34	67	1.5(DL+EQXP)	0	-386.6118	1663.3159	-269.9707	1844.3479	-406.3113	2471.254	-406.3956	2348.2268	-402.207	1665.7503
1ST	C34	67	1.5(DL+EQXP)	1.45	-250.0193	1411.5384	-150.7197	1605.1929	-264.581	2131.2948	-264.1687	2039.3015	-263.2013	1446.0951
1ST	C34	67	1.5(DL+EQXP)	2.9	-113.4269	1159.7609	-31.4687	1366.0378	-122.8506	1791.3356	-121.9418	1730.3762	-124.1957	1226.44
1ST	C34	67	1.5(DL+EQYP)	0	2965.0829	-43.7883	1766.7729	-188.4211	2093.5115	-239.2751	2108.8666	-231.184	2019.8549	-113.4367
1ST	C34	67	1.5(DL+EQYP)	1.45	2367.8278	-78.0334	1512.5417	-107.2981	1739.3757	-133.2649	1751.9788	-130.972	1616.3567	-98.183
1ST	C34	67	1.5(DL+EQYP)	2.9	1770.5727	-112.2785	1258.3105	-26.175	1385.2398	-27.2547	1395.0909	-30.7601	1212.8586	-82.9294
Column Moment, M in Hard Soil														
1ST	C34	67	1.5(DL+EQXP)	0	-460.3577	2040.1114	-318.5293	2275.6905	-485.953	3049.0992	-486.0526	2895.9762	-480.5617	2050.0492
1ST	C34	67	1.5(DL+EQXP)	1.45	-305.3483	1742.068	-184.7089	1983.5162	-324.5243	2630.529	-324.0177	2517.0023	-322.5155	1786.1453
1ST	C34	67	1.5(DL+EQXP)	2.9	-150.3389	1444.0245	-50.8885	1691.342	-163.0956	2211.9588	-161.9828	2138.0283	-164.4693	1522.2413
1ST	C34	67	1.5(DL+EQYP)	0	3655.3261	-56.1122	2182.472	-220.4303	2583.6823	-279.2711	2602.5414	-271.3885	2493.5878	-134.6877
1ST	C34	67	1.5(DL+EQYP)	1.45	2909.214	-87.0386	1857.6783	-119.3219	2136.2165	-150.2171	2151.6928	-147.9659	1985.4712	-110.1375
1ST	C34	67	1.5(DL+EQYP)	2.9	2163.1019	-117.965	1532.8845	-18.2135	1688.7508	-21.1632	1700.8441	-24.5434	1477.3547	-85.5873

Table 7: Column Shear, V for structures with the load combination 1.5 (DL+EQXP) & 1.5 (DL+EQYP), All value in "kN"

Column Shear, V in Soft Soil					Struct I	Struct I	Struct II	Struct II	Struct III	Struct III	Struct IV	Struct IV	Struct V	Struct V
"Story"	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"V2"	"V3"	"V2"	"V3"	"V2"	"V3"	"V2"	"V3"	"V2"	"V3"
1ST	C34	67	1.5(DL+EQXP)	0	136.5858	-79.4517	122.472	-70.5736	171.4959	-81.9689	147.9096	-79.6667	116.0479	-80.6166
1ST	C34	67	1.5(DL+EQXP)	1.45	136.5858	-79.4517	122.472	-70.5736	171.4959	-81.9689	147.9096	-79.6667	116.0479	-80.6166
1ST	C34	67	1.5(DL+EQXP)	2.9	136.5858	-79.4517	122.472	-70.5736	171.4959	-81.9689	147.9096	-79.6667	116.0479	-80.6166
1ST	C34	67	1.5(DL+EQYP)	0	26.2752	292.6819	-39.9409	118.819	-54.6549	169.4846	-47.5231	158.7431	-3.0742	194.4868
1ST	C34	67	1.5(DL+EQYP)	1.45	26.2752	292.6819	-39.9409	118.819	-54.6549	169.4846	-47.5231	158.7431	-3.0742	194.4868
1ST	C34	67	1.5(DL+EQYP)	2.9	26.2752	292.6819	-39.9409	118.819	-54.6549	169.4846	-47.5231	158.7431	-3.0742	194.4868
Column Shear, V in Medium Soil														
1ST	C34	67	1.5(DL+EQXP)	0	173.6397	-94.2017	164.9345	-82.2421	234.4546	-97.7451	213.0519	-98.0875	151.4863	-95.866
1ST	C34	67	1.5(DL+EQXP)	1.45	173.6397	-94.2017	164.9345	-82.2421	234.4546	-97.7451	213.0519	-98.0875	151.4863	-95.866
1ST	C34	67	1.5(DL+EQXP)	2.9	173.6397	-94.2017	164.9345	-82.2421	234.4546	-97.7451	213.0519	-98.0875	151.4863	-95.866
1ST	C34	67	1.5(DL+EQYP)	0	23.6173	411.9001	-55.9469	175.3319	-73.1105	244.2316	-69.1117	246.1296	-10.5197	278.2746
1ST	C34	67	1.5(DL+EQYP)	1.45	23.6173	411.9001	-55.9469	175.3319	-73.1105	244.2316	-69.1117	246.1296	-10.5197	278.2746
1ST	C34	67	1.5(DL+EQYP)	2.9	23.6173	411.9001	-55.9469	175.3319	-73.1105	244.2316	-69.1117	246.1296	-10.5197	278.2746
Column Shear, V in Hard Soil														
1ST	C34	67	1.5(DL+EQXP)	0	205.5472	-106.9031	201.4995	-92.2899	288.6691	-111.3302	261.3613	-111.7482	182.0027	-108.9974
1ST	C34	67	1.5(DL+EQXP)	1.45	205.5472	-106.9031	201.4995	-92.2899	288.6691	-111.3302	261.3613	-111.7482	182.0027	-108.9974
1ST	C34	67	1.5(DL+EQXP)	2.9	205.5472	-106.9031	201.4995	-92.2899	288.6691	-111.3302	261.3613	-111.7482	182.0027	-108.9974
1ST	C34	67	1.5(DL+EQYP)	0	21.3285	514.5601	-69.7299	223.9957	-89.0027	308.5971	-85.119	310.9301	-16.9312	350.4252
1ST	C34	67	1.5(DL+EQYP)	1.45	21.3285	514.5601	-69.7299	223.9957	-89.0027	308.5971	-85.119	310.9301	-16.9312	350.4252
1ST	C34	67	1.5(DL+EQYP)	2.9	21.3285	514.5601	-69.7299	223.9957	-89.0027	308.5971	-85.119	310.9301	-16.9312	350.4252

Table 8: Column Torsion, T for structures with the load combination 1.5 (DL+EQXP) & 1.5 (DL+EQYP), All value in "kN-m"

Column Torsion, T in Soft Soil					Struct I	Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"T"	"T"	"T"	"T"	"T"
1ST	C34	67	1.5(DL+EQXP)	0	-52.0172	-36.6355	-56.0881	-52.909	-54.7871
1ST	C34	67	1.5(DL+EQXP)	1.45	-52.0172	-36.6355	-56.0881	-52.909	-54.7871
1ST	C34	67	1.5(DL+EQXP)	2.9	-52.0172	-36.6355	-56.0881	-52.909	-54.7871
1ST	C34	67	1.5(DL+EQYP)	0	56.6478	39.9718	61.1286	57.7035	60.7221
1ST	C34	67	1.5(DL+EQYP)	1.45	56.6478	39.9718	61.1286	57.7035	60.7221
1ST	C34	67	1.5(DL+EQYP)	2.9	56.6478	39.9718	61.1286	57.7035	60.7221
Column Torsion, T in Medium Soil									
1ST	C34	67	1.5(DL+EQXP)	0	-70.743	-49.7861	-76.2378	-76.3444	-74.4626
1ST	C34	67	1.5(DL+EQXP)	1.45	-70.743	-49.7861	-76.2378	-76.3444	-74.4626
1ST	C34	67	1.5(DL+EQXP)	2.9	-70.743	-49.7861	-76.2378	-76.3444	-74.4626
1ST	C34	67	1.5(DL+EQYP)	0	77.0414	54.3999	83.1769	83.3566	82.6299
1ST	C34	67	1.5(DL+EQYP)	1.45	77.0414	54.3999	83.1769	83.3566	82.6299
1ST	C34	67	1.5(DL+EQYP)	2.9	77.0414	54.3999	83.1769	83.3566	82.6299
Column Torsion, T in Hard Soil									
1ST	C34	67	1.5(DL+EQXP)	0	-86.8679	-61.1102	-93.589	-93.7234	-91.4055
1ST	C34	67	1.5(DL+EQXP)	1.45	-86.8679	-61.1102	-93.589	-93.7234	-91.4055
1ST	C34	67	1.5(DL+EQXP)	2.9	-86.8679	-61.1102	-93.589	-93.7234	-91.4055
1ST	C34	67	1.5(DL+EQYP)	0	94.6026	66.824	102.1629	102.3801	101.4949
1ST	C34	67	1.5(DL+EQYP)	1.45	94.6026	66.824	102.1629	102.3801	101.4949
1ST	C34	67	1.5(DL+EQYP)	2.9	94.6026	66.824	102.1629	102.3801	101.4949

Table 9: Column Axial Force, P for structures with the load Cases EQXP & EQYP, All value in "kN"

Column Axial Force, P in Soft Soil					Struct I	Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"P"	"P"	"P"	"P"	"P"
1ST	C34	67	EQXP	0	-1774.1609	-1935.2327	-2180.0176	-1997.9011	-1950.1714
1ST	C34	67	EQXP	1.45	-1774.1609	-1935.2327	-2180.0176	-1997.9011	-1950.1714
1ST	C34	67	EQXP	2.9	-1774.1609	-1935.2327	-2180.0176	-1997.9011	-1950.1714
1ST	C34	67	EQYP	0	-1323.8079	-1094.5008	-1194.8361	-1134.2601	-1152.661
1ST	C34	67	EQYP	1.45	-1323.8079	-1094.5008	-1194.8361	-1134.2601	-1152.661
1ST	C34	67	EQYP	2.9	-1323.8079	-1094.5008	-1194.8361	-1134.2601	-1152.661
Column Axial Force, P in Medium Soil									
1ST	C34	67	EQXP	0	-2412.8589	-2631.9165	-2964.824	-2885.2394	-2652.2331
1ST	C34	67	EQXP	1.45	-2412.8589	-2631.9165	-2964.824	-2885.2394	-2652.2331
1ST	C34	67	EQXP	2.9	-2412.8589	-2631.9165	-2964.824	-2885.2394	-2652.2331
1ST	C34	67	EQYP	0	-1800.3788	-1488.5211	-1624.9771	-1637.9951	-1567.6189
1ST	C34	67	EQYP	1.45	-1800.3788	-1488.5211	-1624.9771	-1637.9951	-1567.6189
1ST	C34	67	EQYP	2.9	-1800.3788	-1488.5211	-1624.9771	-1637.9951	-1567.6189
Column Axial Force, P in Hard Soil									
1ST	C34	67	EQXP	0	-2962.8488	-3231.8386	-3640.6295	-3542.9042	-3256.7862
1ST	C34	67	EQXP	1.45	-2962.8488	-3231.8386	-3640.6295	-3542.9042	-3256.7862
1ST	C34	67	EQXP	2.9	-2962.8488	-3231.8386	-3640.6295	-3542.9042	-3256.7862
1ST	C34	67	EQYP	0	-2210.7593	-1827.8164	-1995.3763	-2011.3616	-1924.9438
1ST	C34	67	EQYP	1.45	-2210.7593	-1827.8164	-1995.3763	-2011.3616	-1924.9438
1ST	C34	67	EQYP	2.9	-2210.7593	-1827.8164	-1995.3763	-2011.3616	-1924.9438

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Table 10: Column Moment, M for structures with the load Cases EQXP & EQYP, All value in "kN-m"

Column Moment, M in Soft Soil					Struct I	Struct I	Struct II	Struct II	Struct III	Struct III	Struct IV	Struct IV	Struct V	Struct V
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"M2"	"M3"	"M2"	"M3"	"M2"	"M3"	"M2"	"M3"	"M2"	"M3"
1ST	C34	67	EQXP	0	-158.5935	810.3128	-104.4272	927.6184	-171.2725	1242.6779	-161.363	1109.5618	-168.5048	826.4492
1ST	C34	67	EQXP	1.45	-118.987	710.8162	-73.0951	813.5986	-128.9104	1073.6219	-121.2367	967.6594	-127.5574	731.2906
1ST	C34	67	EQXP	2.9	-79.3805	611.3197	-41.763	699.5788	-86.5484	904.566	-81.1104	825.7569	-86.6099	636.1319
1ST	C34	67	EQYP	0	1484.3941	-26.503	893.9766	-68.837	1054.1309	-86.0128	999.9925	-81.4395	1018.7804	-45.7012
1ST	C34	67	EQYP	1.45	1164.2714	-19.366	742.2291	-25.8578	853.4212	-36.4563	809.6559	-34.4238	793.7946	-25.7085
1ST	C34	67	EQYP	2.9	844.1487	-12.229	590.4817	17.1215	652.7116	13.1002	619.3193	12.592	568.8088	-5.7158
Column Moment, M in Medium Soil														
1ST	C34	67	EQXP	0	-215.6871	1102.0254	-142.0209	1261.561	-232.9306	1690.0419	-232.9754	1602.0199	-229.1666	1123.971
1ST	C34	67	EQXP	1.45	-161.8223	966.7101	-99.4093	1106.4941	-175.3182	1460.1258	-175.0423	1397.1465	-173.478	994.5552
1ST	C34	67	EQXP	2.9	-107.9575	831.3948	-56.7977	951.4271	-117.7058	1230.2098	-117.1093	1192.273	-117.7895	865.1394
1ST	C34	67	EQYP	0	2018.776	-36.0441	1215.8081	-93.6183	1433.618	-116.9775	1443.8661	-117.5873	1385.5413	-62.1537
1ST	C34	67	EQYP	1.45	1583.4091	-26.3378	1009.4316	-35.1666	1160.6529	-49.5806	1169.056	-49.7025	1079.5607	-34.9636
1ST	C34	67	EQYP	2.9	1148.0422	-16.6314	803.0551	23.2852	887.6878	17.8162	894.2459	18.1822	773.58	-7.7735
Column Moment, M in Hard Soil														
1ST	C34	67	EQXP	0	-264.8511	1353.2223	-174.3934	1549.1227	-286.0251	2075.2721	-286.08	1967.1862	-281.4031	1380.1702
1ST	C34	67	EQXP	1.45	-198.7083	1187.0631	-122.0688	1358.7096	-215.2804	1792.9486	-214.9417	1715.6137	-213.0208	1221.2553
1ST	C34	67	EQXP	2.9	-132.5655	1020.9039	-69.7443	1168.2965	-144.5358	1510.6252	-143.8033	1464.0411	-144.6386	1062.3403
1ST	C34	67	EQYP	0	2478.9381	-44.26	1492.9409	-114.9578	1760.3985	-143.6414	1772.9827	-144.3903	1701.3633	-76.321
1ST	C34	67	EQYP	1.45	1944.3332	-32.3412	1239.5226	-43.1825	1425.2135	-60.8821	1435.532	-61.0318	1325.637	-42.9332
1ST	C34	67	EQYP	2.9	1409.7283	-20.4224	986.1044	28.5929	1090.0284	21.8773	1098.0813	22.3267	949.9107	-9.5454

Table 11: Column Shear, V for structures with the load Cases EQXP & EQYP, All value in "kN"

Column Shear, V in Soft Soil					Struct I	Struct I	Struct II	Struct II	Struct III	Struct III	Struct IV	Struct IV	Struct V	Struct V
"Story"	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"V2"	"V3"	"V2"	"V3"	"V2"	"V3"	"V2"	"V3"	"V2"	"V3"
1ST	C34	67	EQXP	0	68.6183	-27.3148	78.6344	-21.6083	116.5903	-29.2152	97.8638	-27.6733	65.6267	-28.2396
1ST	C34	67	EQXP	1.45	68.6183	-27.3148	78.6344	-21.6083	116.5903	-29.2152	97.8638	-27.6733	65.6267	-28.2396
1ST	C34	67	EQXP	2.9	68.6183	-27.3148	78.6344	-21.6083	116.5903	-29.2152	97.8638	-27.6733	65.6267	-28.2396
1ST	C34	67	EQYP	0	-4.9221	220.7743	-29.6409	104.6534	-34.1769	138.4204	-32.4246	131.2666	-13.7881	155.1626
1ST	C34	67	EQYP	1.45	-4.9221	220.7743	-29.6409	104.6534	-34.1769	138.4204	-32.4246	131.2666	-13.7881	155.1626
1ST	C34	67	EQYP	2.9	-4.9221	220.7743	-29.6409	104.6534	-34.1769	138.4204	-32.4246	131.2666	-13.7881	155.1626
Column Shear, V in Medium Soil														
1ST	C34	67	EQXP	0	93.3209	-37.1481	106.9427	-29.3873	158.5628	-39.7327	141.292	-39.9538	89.2523	-38.4059
1ST	C34	67	EQXP	1.45	93.3209	-37.1481	106.9427	-29.3873	158.5628	-39.7327	141.292	-39.9538	89.2523	-38.4059
1ST	C34	67	EQXP	2.9	93.3209	-37.1481	106.9427	-29.3873	158.5628	-39.7327	141.292	-39.9538	89.2523	-38.4059
1ST	C34	67	EQYP	0	-6.694	300.253	-40.3116	142.3286	-46.4806	188.2518	-46.8171	189.5242	-18.7518	211.0212
1ST	C34	67	EQYP	1.45	-6.694	300.253	-40.3116	142.3286	-46.4806	188.2518	-46.8171	189.5242	-18.7518	211.0212
1ST	C34	67	EQYP	2.9	-6.694	300.253	-40.3116	142.3286	-46.4806	188.2518	-46.8171	189.5242	-18.7518	211.0212
Column Shear, V in Hard Soil														
1ST	C34	67	EQXP	0	114.5926	-45.6157	131.3194	-36.0859	194.7058	-48.7894	173.4983	-49.0609	109.5965	-47.1602
1ST	C34	67	EQXP	1.45	114.5926	-45.6157	131.3194	-36.0859	194.7058	-48.7894	173.4983	-49.0609	109.5965	-47.1602
1ST	C34	67	EQXP	2.9	114.5926	-45.6157	131.3194	-36.0859	194.7058	-48.7894	173.4983	-49.0609	109.5965	-47.1602
1ST	C34	67	EQYP	0	-8.2199	368.693	-49.5002	174.7712	-57.0754	231.1621	-57.4886	232.7246	-23.0261	259.1216
1ST	C34	67	EQYP	1.45	-8.2199	368.693	-49.5002	174.7712	-57.0754	231.1621	-57.4886	232.7246	-23.0261	259.1216
1ST	C34	67	EQYP	2.9	-8.2199	368.693	-49.5002	174.7712	-57.0754	231.1621	-57.4886	232.7246	-23.0261	259.1216

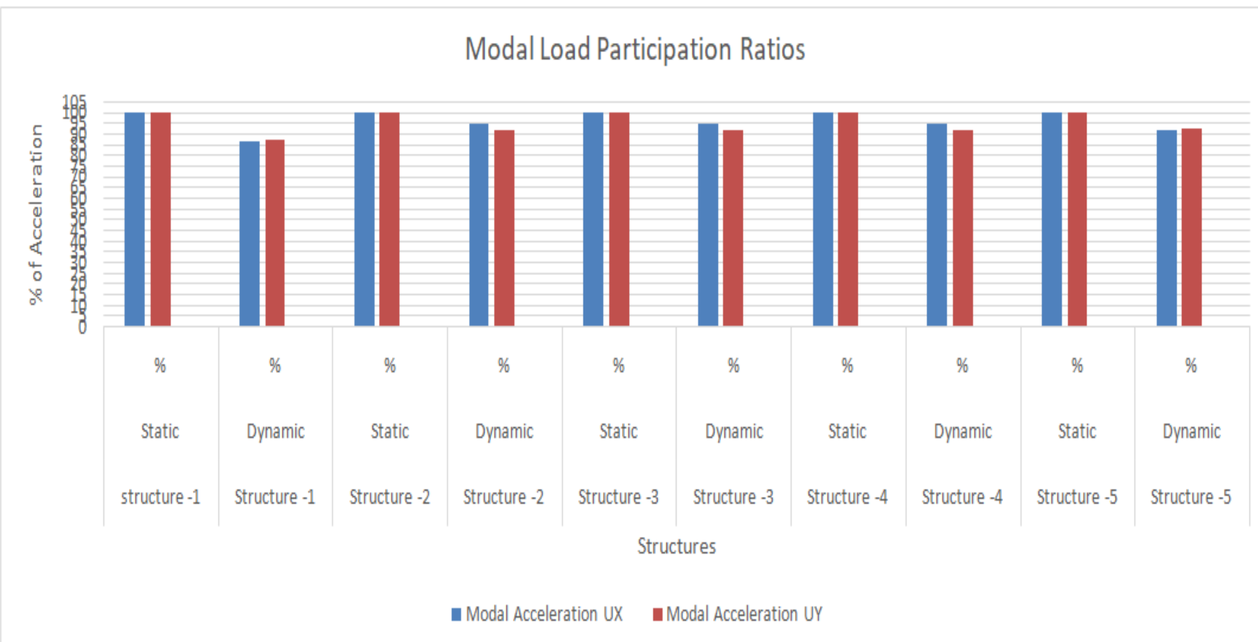
Table 12: Column Torsion, T for structures with the load Cases EQXP & EQYP, All value in "kN-m"

Column Torsion, T in Soft Soil					Struct I	Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"T"	"T"	"T"	"T"	"T"
1ST	C34	67	EQXP	0	-34.6774	-24.353	-37.3143	-35.2051	-36.4362
1ST	C34	67	EQXP	1.45	-34.6774	-24.353	-37.3143	-35.2051	-36.4362
1ST	C34	67	EQXP	2.9	-34.6774	-24.353	-37.3143	-35.2051	-36.4362
1ST	C34	67	EQYP	0	37.766	26.7186	40.8301	38.5365	40.5699
1ST	C34	67	EQYP	1.45	37.766	26.7186	40.8301	38.5365	40.5699
1ST	C34	67	EQYP	2.9	37.766	26.7186	40.8301	38.5365	40.5699
Column Torsion, T in Medium Soil									
1ST	C34	67	EQXP	0	-47.1612	-33.12	-50.7475	-50.8287	-49.5533
1ST	C34	67	EQXP	1.45	-47.1612	-33.12	-50.7475	-50.8287	-49.5533
1ST	C34	67	EQXP	2.9	-47.1612	-33.12	-50.7475	-50.8287	-49.5533
1ST	C34	67	EQYP	0	51.3617	36.3373	55.529	55.6386	55.1751
1ST	C34	67	EQYP	1.45	51.3617	36.3373	55.529	55.6386	55.1751
1ST	C34	67	EQYP	2.9	51.3617	36.3373	55.529	55.6386	55.1751
Column Torsion, T in Hard Soil									
1ST	C34	67	EQXP	0	-57.9112	-40.6695	-62.315	-62.4147	-60.8485
1ST	C34	67	EQXP	1.45	-57.9112	-40.6695	-62.315	-62.4147	-60.8485
1ST	C34	67	EQXP	2.9	-57.9112	-40.6695	-62.315	-62.4147	-60.8485

1ST	C34	67	EQYP	0	63.0692	44.62	68.1863	68.321	67.7517
1ST	C34	67	EQYP	1.45	63.0692	44.62	68.1863	68.321	67.7517
1ST	C34	67	EQYP	2.9	63.0692	44.62	68.1863	68.321	67.7517

Table 13: Modal Load Participation Ratios

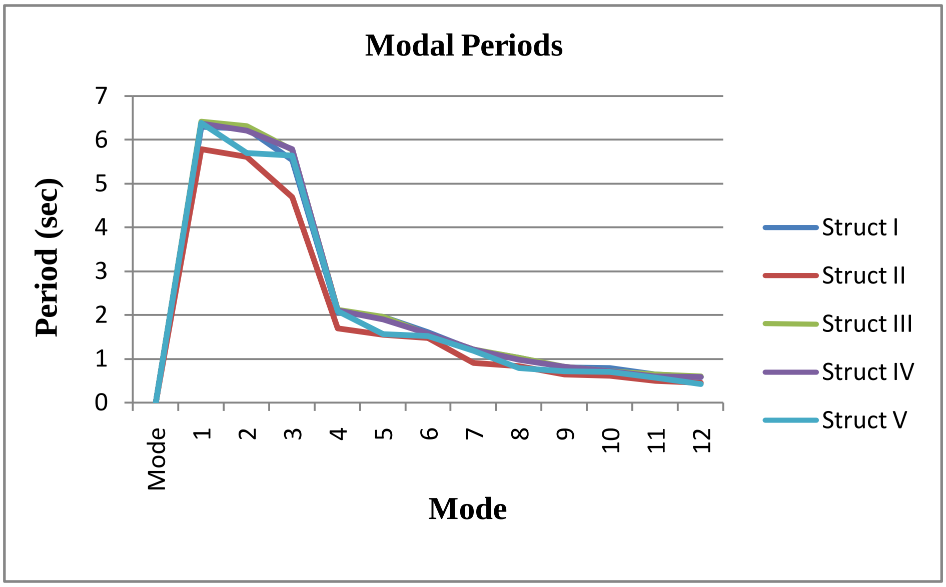
Modal Load Participation Ratios			Struct I	Struct I	Struct II	Struct II	Struct III	Struct III	Struct IV	Struct IV	Struct V	Struct V
"Case"	"Item Type"	"Item"	"Static"	"Dynamic"	"Static"	"Dynamic	"Static"	"Dynamic"	"Static"	"Dynamic"	"Static"	"Dynamic"
			%	%	%	%	%	%	%	%	%	%
Modal	Acceleration	UX	99.82	86.71	99.99	94.7	99.98	94.59	99.99	94.54	99.97	91.54
Modal	Acceleration	UY	99.79	87.46	99.98	91.46	99.97	91.85	99.97	91.83	99.97	92.51
Modal	Acceleration	UZ	0	0	0	0	0	0	0	0	0	0



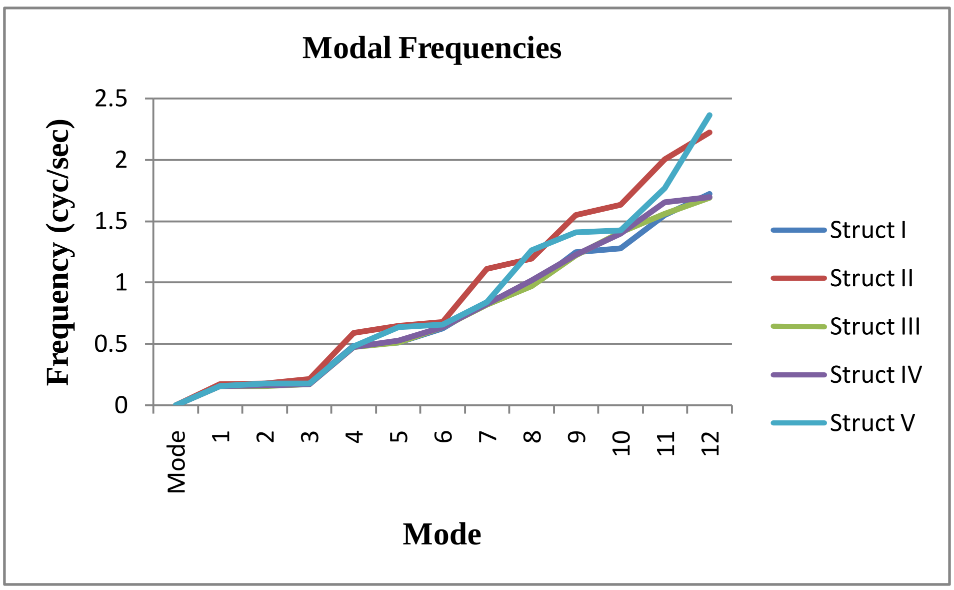
Graph 1: Modal Load Participation Ratios of Structures

Table 14: Modal Periods and Frequencies

		Struct I		Struct II		Struct III		Struct IV		Struct V	
Case	Mode	Period	Frequency	Period	Frequency	Period	Frequency	Period	Frequency	Period	Frequency
		sec	cyc/sec	sec	cyc/sec	sec	cyc/sec	sec	cyc/sec	sec	cyc/sec
Modal	1	6.298	0.159	5.785	0.173	6.415	0.156	6.375	0.157	6.382	0.157
Modal	2	6.248	0.16	5.606	0.178	6.32	0.158	6.21	0.161	5.694	0.176
Modal	3	5.545	0.18	4.684	0.213	5.767	0.173	5.792	0.173	5.642	0.177
Modal	4	2.062	0.485	1.701	0.588	2.114	0.473	2.102	0.476	2.088	0.479
Modal	5	1.952	0.512	1.547	0.646	1.958	0.511	1.901	0.526	1.565	0.639
Modal	6	1.603	0.624	1.475	0.678	1.568	0.638	1.575	0.635	1.524	0.656
Modal	7	1.191	0.84	0.9	1.112	1.219	0.82	1.212	0.825	1.19	0.84
Modal	8	1.027	0.974	0.838	1.193	1.028	0.972	0.983	1.017	0.791	1.264
Modal	9	0.803	1.245	0.645	1.551	0.82	1.22	0.815	1.226	0.711	1.406
Modal	10	0.782	1.279	0.613	1.632	0.711	1.406	0.714	1.401	0.703	1.423
Modal	11	0.645	1.55	0.5	2.002	0.641	1.56	0.604	1.656	0.565	1.769
Modal	12	0.581	1.72	0.45	2.222	0.592	1.689	0.589	1.697	0.423	2.363



Graph 2: Modal Periods and Frequencies



Graph 3: Modal Frequencies

Table 15: Compared of column axial forces in soft soil of structures II, III, IV, V with structure I

Column axial forces "P"					Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"P"	"P"	"P"	"P"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	0%	2%	1%	1%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	-2%	-1%	-1%	-1%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	1%	2%	1%	1%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	-2%	-1%	-1%	-1%
1ST	C34	67	EQXP	0,1.45,2.9	8%	19%	11%	9%
1ST	C34	67	EQYP	0,1.45,2.9	-21%	-11%	-17%	-15%

Table 16: Compared of column axial forces in medium soil of structures II, III, IV, V with structure I

Column axial forces "P"					Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"P"	"P"	"P"	"P"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	1%	2%	2%	1%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	-2%	-1%	-1%	-1%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	1%	3%	2%	1%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	-2%	-1%	-1%	-1%
1ST	C34	67	EQXP	0,1.45,2.9	8%	19%	16%	9%
1ST	C34	67	EQYP	0,1.45,2.9	-21%	-11%	-10%	-15%

Table 17: Compared of column axial forces in hard soil of structures II, III, IV, V with structure I

Column axial forces "P"					Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"P"	"P"	"P"	"P"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	1%	3%	2%	1%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	-2%	-1%	-1%	-1%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	1%	4%	3%	2%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	-3%	-1%	-1%	-2%
1ST	C34	67	EQXP	0,1.45,2.9	8%	19%	16%	9%
1ST	C34	67	EQYP	0,1.45,2.9	-21%	-11%	-10%	-15%

Table 18: Compared of column moment in soft soil of structures II, III, IV, V with structure I

Column moment forces "M"					Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"M"	"M"	"M"	"M"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	564%	4%	-5%	4%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	-54%	-35%	-42%	-46%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	-54%	4%	-1%	4%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	-62%	-39%	-47%	-47%
1ST	C34	67	EQXP	0,1.45,2.9	0%	45%	41%	44%
1ST	C34	67	EQYP	0,1.45,2.9	0%	13%	8%	5%

Table 19: Compared of column moment in medium soil of structures II, III, IV, V with structure I

Column moment forces "M"					Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"M"	"M"	"M"	"M"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	-187%	5%	5%	5%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	-55%	-35%	-34%	-46%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	-55%	5%	5%	4%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	-62%	-39%	-38%	-47%
1ST	C34	67	EQXP	0,1.45,2.9	0%	45%	45%	44%
1ST	C34	67	EQYP	0,1.45,2.9	0%	13%	13%	5%

Table 20: Compared of column moment in hard soil of structures II, III, IV, V with structure I

Column moment forces "M"					Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"M"	"M"	"M"	"M"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	-127%	6%	5%	5%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	-55%	-35%	-34%	-46%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	-55%	6%	6%	5%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	-62%	-39%	-38%	-47%
1ST	C34	67	EQXP	0,1.45,2.9	0%	45%	45%	44%
1ST	C34	67	EQYP	0,1.45,2.9	0%	13%	13%	5%

Table 21: Compared of column shear in soft soil of structures II, III, IV, V with structure I

Column shear forces "V"					Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"V"	"V"	"V"	"V"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	-17%	14%	1%	-20%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	215%	175%	191%	-599%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	-12%	20%	8%	-18%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	166%	148%	155%	955%
1ST	C34	67	EQXP	0,1.45,2.9	13%	41%	30%	-5%
1ST	C34	67	EQYP	0,1.45,2.9	83%	86%	85%	64%

Table 22: Compared of column shear in medium soil of structures II, III, IV, V with structure I

Column shear forces "V"					Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"V"	"V"	"V"	"V"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	-10%	21%	14%	-17%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	173%	152%	157%	2154%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	-5%	26%	18%	-15%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	142%	132%	134%	325%
1ST	C34	67	EQXP	0,1.45,2.9	13%	41%	34%	-5%
1ST	C34	67	EQYP	0,1.45,2.9	83%	86%	86%	64%

Table 23: Compared of column shear in hard soil of structures II, III, IV, V with structure I

Column shear forces "V"					Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"V"	"V"	"V"	"V"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	-6%	25%	18%	-15%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	154%	140%	143%	521%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	-2%	29%	21%	-13%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	131%	124%	125%	226%
1ST	C34	67	EQXP	0,1.45,2.9	13%	41%	34%	-5%
1ST	C34	67	EQYP	0,1.45,2.9	83%	86%	86%	64%

Table 24: Compared of column torsion in soft soil of structures II, III, IV, V with structure I

Column torsion forces "T"					Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"T"	"T"	"T"	"T"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	-42%	7%	2%	5%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	-42%	7%	2%	7%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	-42%	7%	2%	5%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	-42%	7%	2%	7%
1ST	C34	67	EQXP	0,1.45,2.9	-42%	7%	1%	5%
1ST	C34	67	EQYP	0,1.45,2.9	-41%	8%	2%	7%

Table 25: Compared of column torsion in medium soil of structures II, III, IV, V with structure I

Column torsion forces "T"					Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"T"	"T"	"T"	"T"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	-42%	7%	7%	5%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	-42%	7%	8%	7%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	-42%	7%	7%	5%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	-42%	7%	8%	7%
1ST	C34	67	EQXP	0,1.45,2.9	-42%	7%	7%	5%
1ST	C34	67	EQYP	0,1.45,2.9	-41%	8%	8%	7%

Table 26: Compared of column torsion in hard soil of structures II, III, IV, V with structure I

Column torsion forces "T"					Struct II	Struct III	Struct IV	Struct V
"Story"	"Column"	"Unique - Name"	"Load Case-Combo"	"Station"m	"T"	"T"	"T"	"T"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	-42%	7%	7%	5%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	-42%	7%	8%	7%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	-42%	7%	7%	5%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	-42%	7%	8%	7%
1ST	C34	67	EQXP	0,1.45,2.9	-42%	7%	7%	5%
1ST	C34	67	EQYP	0,1.45,2.9	-41%	8%	8%	7%

Table 27: Compared of column axial forces of medium soil and hard soil with soft soil for Structure -I

Column Axial Forces "P"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique- Name"	"Load Case-Combo"	"Station"m	"P"	"P"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	3%	6%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	2%	4%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	4%	7%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	3%	5%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 28: Compared of column axial forces of medium soil and hard soil with soft soil for Structure -II

Column Axial Forces "P"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"P"	"P"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	3%	6%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	2%	4%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	4%	7%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	2%	4%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 29: Compared of column axial forces of medium soil and hard soil with soft soil for Structure -III

Column Axial Forces "P"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"P"	"P"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	4%	7%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	2%	4%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	4%	8%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	3%	5%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 30: Compared of column axial forces of medium soil and hard soil with soft soil for Structure -IV

Column Axial Forces "P"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique- Name"	"Load Case-Combo"	"Station"m	"P"	"P"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	4%	7%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	3%	4%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	5%	8%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	3%	5%
1ST	C34	67	EQXP	0,1.45,2.9	31%	44%
1ST	C34	67	EQYP	0,1.45,2.9	31%	44%

Table 31: Compared of column axial forces of medium soil and hard soil with soft soil for Structure -V

Column Axial Forces "P"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"P"	"P"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	3%	6%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	2%	4%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	4%	7%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	3%	5%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 32: Compared of column moment of medium soil and hard soil with soft soil for Structure -I

Column Moment Forces "M"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"M"	"M"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	20%	32%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	-7%	-14%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	21%	34%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	-11%	-23%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 33: Compared of column moment of medium soil and hard soil with soft soil for Structure -II

Column Moment Forces "M"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"M"	"M"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	25%	38%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	32%	46%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	26%	39%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	29%	43%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 34: Compared of column moment of medium soil and hard soil with soft soil for Structure -III

Column Moment Forces "M"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"M"	"M"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	27%	40%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	26%	40%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	27%	41%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	25%	39%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 35: Compared of column moment of medium soil and hard soil with soft soil for Structure -IV

Column Moment Forces "M"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"M"	"M"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	30%	43%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	33%	46%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	31%	43%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	31%	44%
1ST	C34	67	EQXP	0,1.45,2.9	31%	44%
1ST	C34	67	EQYP	0,1.45,2.9	31%	44%

Table 36: Compared of column moment of medium soil and hard soil with soft soil for Structure -V

Column Moment Forces "M"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"M"	"M"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	22%	35%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	415%	169%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	23%	36%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	71%	82%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 37: Compared of column shear of medium soil and hard soil with soft soil for Structure -I

Column Shear Forces "V"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"V"	"V"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	30%	44%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	26%	40%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	29%	42%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	26%	40%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 38: Compared of column shear of medium soil and hard soil with soft soil for Structure -II

Column Shear Forces "V"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"V"	"V"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	56%	61%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	26%	40%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	40%	52%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	26%	40%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 39: Compared of column shear of medium soil and hard soil with soft soil for Structure -III

Column Shear Forces "V"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"V"	"V"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	31%	45%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	26%	40%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	29%	43%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	26%	40%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 40: Compared of column shear of medium soil and hard soil with soft soil for Structure -IV

Column Shear Forces "V"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"V"	"V"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	36%	48%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	31%	43%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	34%	47%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	31%	43%
1ST	C34	67	EQXP	0,1.45,2.9	31%	44%
1ST	C34	67	EQYP	0,1.45,2.9	31%	44%

Table 41: Compared of column shear of medium soil and hard soil with soft soil for Structure -V

Column Shear Forces "V"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"V"	"V"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	30%	44%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	26%	40%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	29%	43%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	26%	40%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 42: Compared of column torsion of medium soil and hard soil with soft soil for Structure -I

Column Torsion Forces "T"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"T"	"T"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	0%	0%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	26%	40%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	26%	40%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	26%	40%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 43: Compared of column torsion of medium soil and hard soil with soft soil for Structure -II

Column Torsion Forces "T"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"T"	"T"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	26%	40%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	27%	40%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	26%	40%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	27%	40%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 44: Compared of column torsion of medium soil and hard soil with soft soil for Structure -III

Column Torsion Forces "T"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"T"	"T"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	26%	40%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	27%	40%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	26%	40%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	27%	40%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

Table 45: Compared of column torsion of medium soil and hard soil with soft soil for Structure -IV

Column Torsion Forces "T"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"T"	"T"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	31%	44%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	31%	44%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	31%	44%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	31%	44%
1ST	C34	67	EQXP	0,1.45,2.9	31%	44%
1ST	C34	67	EQYP	0,1.45,2.9	31%	44%

Table 46: Compared of column torsion of medium soil and hard soil with soft soil for Structure -V

Column Torsion Forces "T"					"Medium soil"	"Hard soil"
"Story"	"Column"	"Unique-Name"	"Load Case-Combo"	"Station"m	"T"	"T"
1ST	C34	67	1.2(DL+LL+EQXP)	0,1.45,2.9	26%	40%
1ST	C34	67	1.2(DL+LL+EQYP)	0,1.45,2.9	27%	40%
1ST	C34	67	1.5(DL+EQXP)	0,1.45,2.9	26%	40%
1ST	C34	67	1.5(DL+EQYP)	0,1.45,2.9	27%	40%
1ST	C34	67	EQXP	0,1.45,2.9	26%	40%
1ST	C34	67	EQYP	0,1.45,2.9	26%	40%

a) Discussion on Results

When a structure is subjected to earthquake, it responds by vibrating. An example force can be resolved into three mutually perpendicular directions-two horizontal directions (X and Y directions) and the vertical direction (Z) [8]. This motion causes the structure to vibrate or shake in all three directions; the predominant direction of shaking is horizontal. All the structures are primarily designed for gravity loads-force equal to mass time's gravity in the vertical direction. Vertical acceleration should also be considered in structures with large spans those in which stability for design, or for overall stability analysis of structures. The basic intent of design theory for earthquake resistant structures is that buildings should be able to resist minor earthquakes without damage, resist moderate earthquakes without structural damage but with some non-structural damage. To avoid collapse during a major earthquake, Members must be ductile enough to absorb and dissipate energy by post elastic deformation. Redundancy in the structural system permits redistribution of internal forces in the event of the failure of key elements. When the primary element or system yields or fails, the lateral force can be redistributed to a secondary system to prevent progressive failure.

When a structure is subjected to an earthquake excitation, it interacts with the foundation and the soil, and thus changes the motion of the ground[2,8]. This means that the movement of the whole ground-structure system is influenced by the type of soil as well as by the type of structure. Understanding of soil structure interaction will enable the designer to design structures that will behave better during an earthquake.

V. Conclusions

From the above results and discussions, following conclusions can be drawn:

- The shear wall and it is position has a significant influenced on the time period, the time period is not influenced by the type of soil, in tall building with box shape Shear Walls is showing the low time period which shows a very significant performance.
- Shear is effected marginally by placing of the shear wall, grouping of shear wall and type of soil. The shear is increased by adding shear wall due to increase the seismic weight of the building.
- The Axial force and Moment in the column increases when the type of soil changes from hard to medium and medium to soft. Since the column moment increase as the soil type changes, soil structure interaction must be suitably considered while designing frames for seismic force.
- It is evident that the maximum column axial force is various with type of soil and placing of the shear wall.
- It is evident that the maximum column shear force in X-direction is influenced by the type of soil and placing of the shear wall.
- It is evident that the maximum column shear force in Y-direction has no influence on the type of soil and placing shear wall.
- It is evident that the maximum column torsion is same for all columns in a structure, but is influenced by the type of soil and placing shear wall.
- It is evident that the maximum column moment in X-direction has no influence on the type of soil and placing shear wall.
- It is evident that the maximum column moment in Y-direction is influenced by the type of soil and placing of shear wall.
- It is evident that the results from1.2 (DL + IL ± EL) combination load is closed to the 1.5 (DL + EL) and there is no more difference between these combination load.
- Based on the analysis and discussion, shear wall are very much suitable for resisting earthquake induced lateral forces in multistoried structural systems when compared to multistoried structural systems whit out shear walls. They can be made to behave in a ductile manner by adopting proper detailing techniques.
- According to IS-1893:2002 the number of modes to be used in the analysis should be such that the total sum of modal masses of all modes considered is at least 90 percent of the total seismic mass. Here the maximum mass is for the tall building with box shape RC shear wall.
- ETABS is the robust software which is utilized foranalyzing any kind of multi building structures.

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Conflict of Interest

The author declare no conflict of interest.

Data Availability Statement

All data generated or analysed during this study are included in this article.

References Références Referencias

1. *Earthquake Resistant Design of Structures,* Oxford University Press, New Delhi, 2010.
2. *Dynamics of Structures: Theory and Application to Earthquake Engineering*, Pearson Education, 4th edition, New Delhi, 2012.
3. *Structural Dynamics: Theory & computations*, (Second Edition), CBS Publishers & Distributors, New Delhi, 2004.
4. *Plain and Reinforced Concrete-Code of practice,* IS 456, New Delhi, India, 2000.
5. *Ductile detailing of reinforced concrete structures subjected to seismic forces— Code of Practice*, IS 13920, New Delhi, India., 1993.
6. *Dead loads on buildings and Structures*, IS 875 (part 1), New Delhi, India, 1987.
7. *Live loads on buildings and Structures,* IS 875 (part 2), New Delhi, India, 1987.
8. *Criteria for earthquake resistant design of structures General provisions and buildings,* IS 1893 (part 1), New Delhi, India, 2002.
9. Berkeley, "ETABS Integrated Building Design Software", Computers and Structure, Inc., California, USA, February 2003.
10. Makar Nageh, "How to Model and Design High Rise Building Using ETABS Program", scientific book house for publishing and distributing, Cairo, 2007.
11. Paulay, T. & Priestley, M. J. N. "Seismic Design of Reinforced Concrete and Masonry Buildings", JOHN WILEY & SONS, INC, New York. 1992.
12. J. L. Humar and S. Yavari "Design of concrete shear wall buildings for earthquake induced torsion", *14 structural conference of the Canadian society for civil engineering*, Canada, June, 2002.
13. Anand, N., Mightraj, C. and Prince Arulraj, G. "Seismic behaviour of RCC shear wall under different soil conditions", *Indian geotechnical conference*, pp 119-120, december 2010.

14. Gaikwad Ujwala Vithal, "Effect of Shear Wall on Seismic Behavior of Unsymmetrical Reinforced Concrete Structure", International Journal of Research and Scientific Innovation (IJRSI) Volume IV, Issue X, October 2017.
15. Mahantesh S Patil & R B Khadiranaikar, "Dynamic Analysis of High Rise RC Structure with Shear Walls and Coupled Shear Walls", International Journal of Advance Engineering and Research Development, Volume 2, Issue 8, August, 2015.
16. Durgesh C. Rai, Sudhir K. Jain and C. V. R. Murty, "Seismic Design of RC Structures", short course, *conducted by Department of Civil Engineering, IIT Kanpur, Ahmedabad, India*, Nov 25-30, 2012.

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A Novel Analytical Approach for Axial Load Capacity Evaluation of Stiffened Hollow Steel Columns Utilizing Finite Element Method

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Keywords: local buckling - stiffened hollow square sections – nonlinear analysis - slender hollow square columns - stiffener length.

GJRE-E Classification: FOR Code: 090506

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Keywords: local buckling - stiffened hollow square sections – nonlinear analysis - slender hollow square columns - stiffener length.

I. Introduction

In industrial buildings, square hollow steel columns are regularly utilized, but they are employed more regularly in supporting structures for bridge design. These columns are produced in stiffened and unstiffened box hollow columns having compact, non-compact and slender cross sections. The global and local buckling are two different buckling modes that can occur in compression steel elements. The primary effect of local and global buckling is a reduction of the stiffening and loading capacity of the member. The local and global buckling mode is significant affected by the ratio B/t ratio, L_e/r ratio, and boundary conditions of the member. The initial imperfections, residual stress, and boundary conditions are critical factors in determining the ultimate strength of square hollow steel columns in compression members[1].

Many investigations on the behavior of square hollow steel columns have been conducted in the recent decades. The stiffened and unstiffened square hollow columns (SHC), rectangular hollow columns (RHC) were investigated by Tao et al. [2]. The stiffened square hollow columns has only two longitudinal stiffeners welded to its longer sides as opposed to the four longitudinal stiffeners that were once present on each side of the stiffened square hollow columns (SHC). One of the most important considerations was the ratio (B/t). The tubes also come with or without stiffeners. Comparing the ultimate strength of the experimental test results are presented.

A comparison experiment test study between unstiffened and stiffened stainless steel hollow columns was presented by Dabaon et al. [3]. The ratio of length-to-depth (L/B) was fixed at a value of 3, but the depth-to-thickness ratio fluctuated from 60 to 90. For stiffened and unstiffened sections, the ultimate strengths of this columns, buckling modes, and axial load verses axial strain are compared.

Somodi and Kövesdi [4] focuses on the experimental measurements of the residual stress on welded box steel hollow columns with different steel grades and different B/t ratios. The aim of this investigation is to estimate the residual stresses, to determine the maximum compressive and tensile residual stresses.

The experimental tests and finite element (FE) method of hollow long steel columns with non-compact and compact unstiffened sections were developed by Khan et al. [5]. The experimental test results concluded that the non-compact sections with $L_e/r > 24$ collapsed as a consequence of the combination of global and local buckling (G and L). Moreover, the compact cross-sections having L_e/r values between 35 to 109 collapsed in accordance with global buckling. According to the test data of estimation of slender non-compact box sections, it is necessary take into account that the reduction factor resulting from the global and local buckling effects.

Javidan et al.[6] studied the behavior and ultimate strength of an innovative steel hollow long column. The suggested innovative columns are made of mild steel plates that are joined at the corners to mild steel tubes. According the test and FE modeling, a special focus is given to the effect of fabrication initial imperfections, and residual stresses, and welding methods on the behavior of the suggested long hollow columns. Because of the compatibility between the steel

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plates and tubes in the column, the studied innovative steel hollow column specimens are demonstrated to have excellent compressive behavior, which significantly increases their strength and ductility.

El-Sayed et al. [7] presented a novel polymer-mortar system that strengthened square hollow columns, proving their behavior and strength. According to the square hollow short columns strengthened using polymer-mortar layer with the thickness equal to 6mm, a maximum axial strength improvement of 31.6% was achieved. For long columns, a polymer-mortar layer applied in 6 mm thickness on all four sides resulted in a ultimate strength gain of 76.7%.

Zheng et al. [8] studied the impacts of cold-forming in the behavior of stainless steel cold-formed hollow steel tube columns. In this investigation a total of 19 and 32 specimens were tested for short and long columns, respectively. The buckling modes of the experimental specimens included the global buckling, local buckling, local–global buckling, and material strain hardening after yielding. The experimental test specimens collapsed in four different modes: global, local, both local-global, and plastic strength after yielding.

Cold-formed hollow columns made of lean duplex stainless steel (LDSS) were designed and demonstrated by Anbarasu and Ashraf [9]. These columns that mainly collapsed due to the interaction of flexural and local buckling modes. In this study, the geometric parameters of the (LDSS) hollow column sections were selected so that the local and global buckling stresses are almost equal.

Nassirnia et al. [10] developed a novel hollow columns made of ultra-high-strength steel tubes and corrugated plates. The corrugated plates that make up the suggested novel produced columns are welded to ultra-high strength (UHS) steel tubes and have a yield stress of $f_y = 1250\,MPa$ at the edges. The yield stress of the steel tube The results demonstrated that the suggested novel columns are very efficient and ductile under axial compression loads.

The finite element (FE) investigation of the fixed ended LDSS slender hollow columns with square (SHC), and non-regular hollow columns (NRHCs) was developed by Patton and Singh [11]. The non-regular hollow columns (NRHCs) such as L-(LHC) and T-(THC) shaped cross-sections. The Abaqus software was used to create the finite element (FE) models was conducted to under pure axial compression. The the finite element (FE) results of square hollow columns and non-regular hollow columns were then compared with the design equations by the ASCE 8-02 and EN1993-1-4 requirements. The finite element results and code predictions have been demonstrated to agree significantly.

Schillo and Feldmann [12] investigated the both global and local buckling mods of the steel square hollow columns. The experiments were verified with the FE using Ansys software. The research presents an analytical method for determining a reduction factor that depends on slenderness. The finite element modeling of experimental tests on slender square hollow columns, subject to combined global and local buckling of steel plates was developed by Pavlovcic et al. [13]. The parametric investigation used in the FE analysis are the influence of different imperfections, the cross-section geometry for cold-formed and welded columns, and the columns length. According to the results of a study, the initial imperfection can reduce resistance by up to 45% compared with perfect column.

The nonlinear finite element (FE) analysis of the square hollow stiffened and unstiffened high strength stainless steel (HSS) columns was developed by Ellobody[14]. The column ultimate strengths, the axial load-shortening curves, and the collapsed modes were predicted for the unstiffened and stiffened columns. The main objective of this study was to investigate the effects of various section geometries on the columns strength. Hilo et al. [15] studied the FE analysis on the ultimate strength and behavior of polygonal hollow steel tube columns under axial compression load. In this investigation, different cross sections, including rectangular, circular, square, pentagonal, and hexagonal ones, have been provided. The finite element models have been analyzed to find the effect of the different cross-section shape, thickness, and length on the axial load behavior of the polygonal hollow steel tube columns.

The FE analysis on the ultimate strength and behavior of cold-formed steel rectangular and square hollow columns with two opposing circular holes in the center, at the height of the column was studied by Singh et al. [16]. The parametric analysis has been carried out, taking into account a wide range of cross-sectional slenderness and the size of the circular holes.

The mechanical performance of the hollow steel columns is significantly impacted by sectional residual stress. The sectional residual stress have been conducted by Ban et al. [17], Cao et al. [18], and other researchers. These investigation were carried out to study the effect of the residual stress on the behavior and ultimate strength of hollow steel columns. They concluded that the sectional residual stress has a significant effect on the buckling capacity and behavior of hollow columns under axial compression loads.

In case of the stiffened hollow steel columns, it is observed that there has been just a limited amount of study conducted under monotonic loading including the local and global buckling effects. The present study aims to investigate the performance and ultimate strength of stiffened square hollow columns in the short as well as long columns, under axial compression loads.

Based on the non-linear finite element (FE) analysis, this investigation was carry out to evaluate the influence of major steel tube columns parameters such as stiffener length, the ratio B/t, and yield strength on the hollow steel short column's performance. The main objective of the parametric study was to develop a novel mathematical equation to predict the ultimate strength of box steel sections, in addition the study was conducted on effect of the stiffeners length and propose a novel equation to calculate the optimal stiffeners length. The comparison between the current (FE) results and analytical methods is presented. In case of the long columns, a comparison was made for the stiffened and unstiffened sections to investigate how the stiffeners affect the columns ultimate strength. The numerical study is briefly described, with the variable parameters being KL_e/r and the ratio (B/t) equals to (50-12.5).

II. Finite Element Modeling

a) General Description

In this investigation, the finite element software ABAQUS [31] is used to create an accurate finite element model for estimating the behavior and ultimate strength of the steel tube columns with regard to axial compression loads.

b) Initial Imperfection

The initial imperfection of the hollow square columns was taken into account in the load-deflection analysis. It is assumed that the first buckling mode shape obtained from the eigen value buckling analysis is the shape of the local and global initial imperfections. The Japan Standard for Highway Bridges (JSHB) [19] prescribes maximum initial global displacement as $(L/1000)$. The AISC 360-05 [20] prescribes maximum initial displacement as $(L/1500)$. According to experimental measurements in [13], the global imperfection in the Y- and X-direction for hollow long columns appeared to be around $(H/1200 - H/1040 - H/1600)$. For square hollow columns in this study, the initial imperfection value was taken as $(0.01B)$ for local buckling and $(0.001L_e)$ for global buckling according to Chinese Standard GB50018-2002 [21].

c) Residual Stresses

In this paper, according to the experimental test result by Somodi and Kövesdi [4], To estimate the compressive residual stresses, two models of the residual stress are developed. Equations (1) and (2) were developed to provide the best approximation to the average compressive residual stresses that were measured. The “predefined field” for the initial stress option is available in FE software to model residual stress. The typical residual stress distribution of the steel square hollow stiffened and unstiffened sections are shown in Figure 1.

If $t \leq 5$ *mm:*

$$\sigma_{rc} = 70 - 2t + t^2 - (20900 - 3600\,t)\left(\frac{b}{t}\right)^{-1} \qquad MPa \tag{1}$$

If $t \geq 5$ *mm:*

$$\sigma_{rc} = 70 - 2t + t^2 - (4350 - 290\,t).\left(\frac{b}{t}\right)^{-1} \qquad MPa \tag{2}$$

Where $t\ (mm)$ and $b\ (mm)$ is the thickness and width of the steel box columns, respectively.

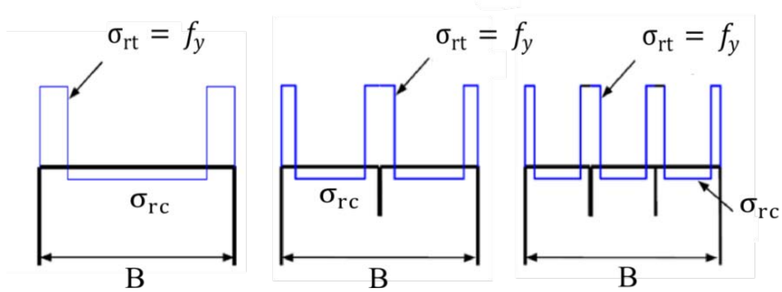


Figure 1: Residual stress distributions

d) Material Model

In this research, the hollow square columns was modeled by the elastic-plastic model, as shown in Figure 2. The Poisson's ratio was considered to be 0.3. In addition, the plastic zone is with a linear hardening and the hardening modulus was considered $0.005E_s$ with E_s is the elastic modulus of steel [22]. The ultimate strength is clearly not significantly affected by The use of $(\sigma\text{–}\varepsilon)$ steel relationship, and the load-deformation curve is only slightly affected. Only slightly affects the load-deformation curve at a later stage [23].

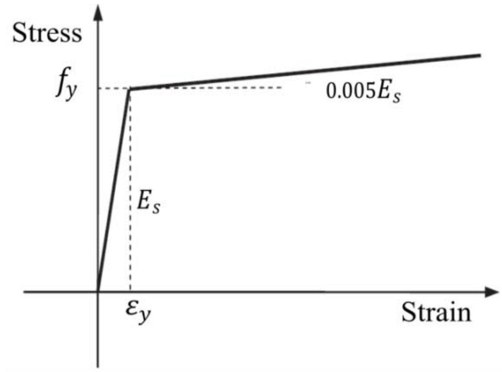


Figure 2: The stress-strain curve for steel tubes

III. Finite Element Modeling Validation

The FE model's accuracy in the present parametric study was verified using previous experimental test results. The verification study, was carried out on, two short square columns that were tested by Tao et al. [2] and four long columns that were tested by Khan et al. [5].

a) *Material and Geometric Properties*

For short columns, the steel material for the finite element models was assumed to be the elastic-plastic model as shown in Figure 2. The yield strength $f_y = 234.3\ MPa$, Elastic modulus $E_s = 208\ GPa$, yield strain (%)0.137, and the ultimate strength $F_{ult} = 343.7\ MPa$. The investigated specimens' labels and geometric properties are shown in Table 1 and Figure 3.

Table 1: Dimensions of the stiffened and unstiffened short columns tests in Tao et al. [2]

No.	Specimen label	B (mm)	L(mm)	D/t	$h_s \times t_s$
1	SS25	250	750	100	35 × 2.5
2	US25	250	750	100	---

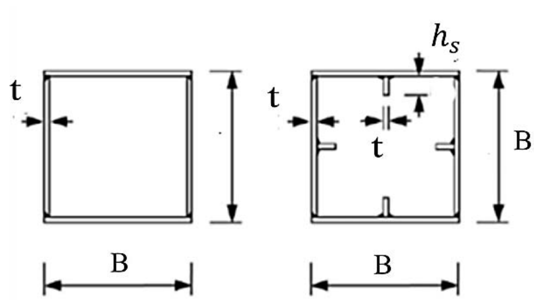


Figure 3: The specimens investigated by Tao et al. [2]

For long columns, the steel material for the finite element models was assumed to be an elastic-plastic model as shown in Figure 2. The yield strength $f_y = 762\ MPa$, The elastic modulus $E_s = 213\ GPa$, The yield strain $0.4157\ (\%)$, and the ultimate strength $F_{ult} = 819\ MPa$. The verification was performed for slender welded box sections with L_e/r= (77, 66, 28, and 59) and b_e/b= (1.0 and 0.8). The dimensions of test specimens are shown in Table 2 and the illustration of the experimental test layout is shown in Figure 4.

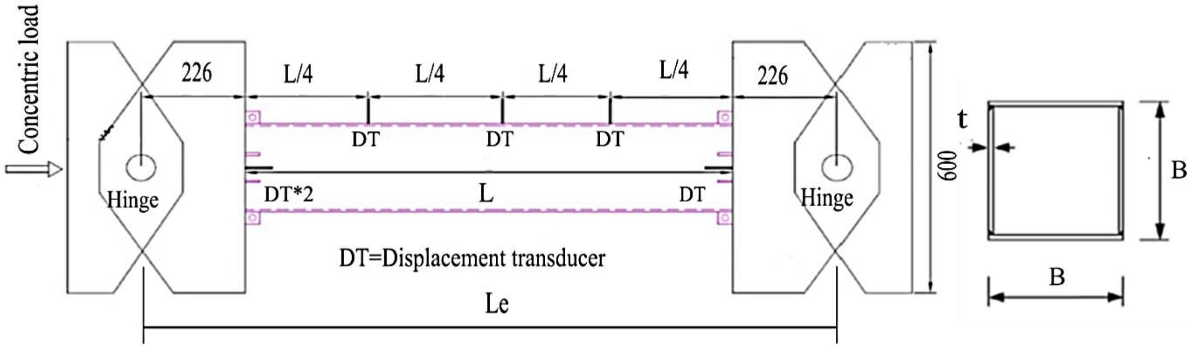


Figure 4: Illustration of the experimental test layout

Table 2: Dimensions of the test specimens for the long columns tested by Khan et al. [5]

Test specimens	B (mm)	t (mm)	B/t	L_e (mm)	L_e/r	b_e/b
HS15SL2	74.57	4.93	15	2512	77	1.0
HS25SL3	125.20	4.92	25	3512	66	0.8
HS25SL1	125.21	4.92	25	1512	28	0.8
HS20SL2	99.39	4.92	20	2512	59	1.0

b) Loading and Boundary Conditions

In fact, there are two types of loading application methods: force-controlled loading and displacement-controlled loading. In this paper, force-controlled loading technique was used. The square hollow columns were modeled using the Finite Element Analysis (FEA) under monotonic loading. In case of short columns, two loading plates coupled with a steel tube by tie constraints were used. The boundary condition of the finite element (FE) model was set at the loading plate, as shown in Figure 5. The axial load was applied by carrying out a distributed load on the loading plate.

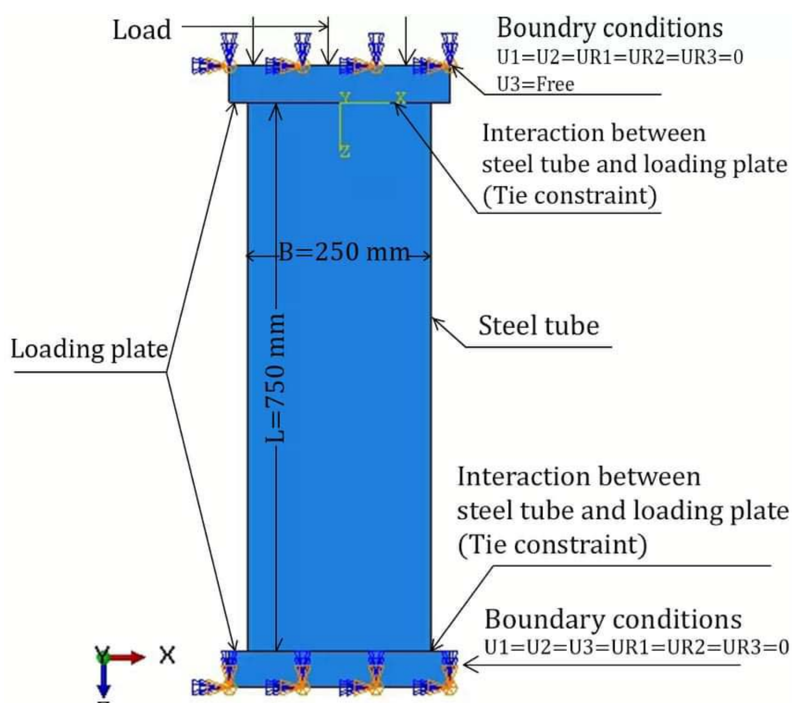


Figure 5: Modeling of the short columns

In the case of long columns, two reference points have been created and constrained to the loading plate of all hollow square columns specimens by rigid body constraints and set the boundary condition of the (FE) model at the reference point. Both column ends were modeled as pinned condition, i.e., both ends were free to rotate. While the upper end was unconstrained in the vertical axis to apply the external load. The square steel tube coupled with the loading plate by tie constraint is shown in Figure 6. The axial load was applied in the form of distributed load on the loading plate.

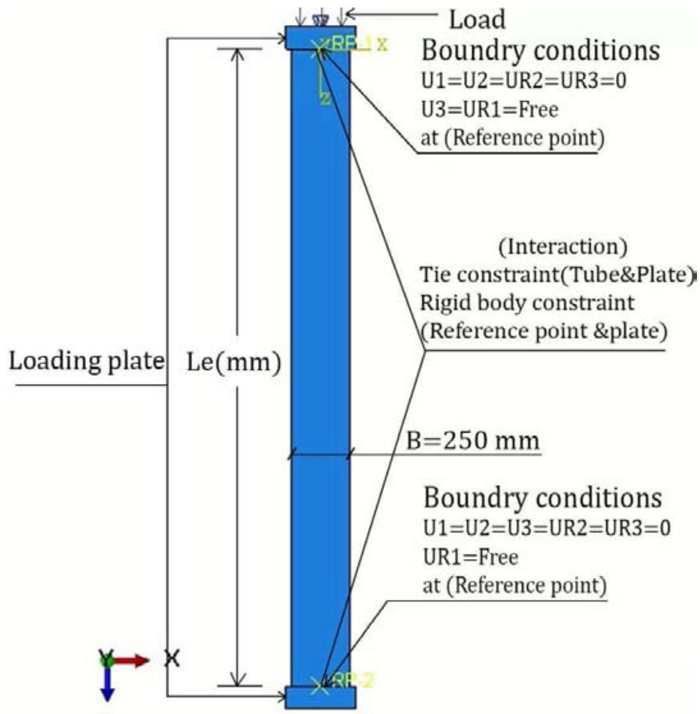


Figure 6: Modeling of the long columns

c) *Element Type and Mesh*

The short hollow columns in this study were modeled using 4-node reduced integration doubly curved thin or thick shell element (S4R). The loading plate was modeled using 4-node linear tetrahedron element. The approximate global element size 12 mm was used in this study. While in case of hollow steel long columns, the (C3D4) 4-node linear tetrahedron element was used. In addition, the approximate global size equal to 12 mm was used in this study.

d) *Accuracy of Adopted Models*

i. *Short Columns*

The comparison of the experimental test results and the finite element results for the US25 and SS25 specimens are shown in Figure 7 and Figure 8, respectively. The mean values of the ratio between axial load deduced by FE and test (N_{FEM}/N_{Test}) are 1.02, and 1.01 for the US25 and SS25 specimens, respectively. From this study, the predictions of ultimate strengths are very close to the test given by Tao et al. [2]. In addition, the mode of failure due to buckling obtained from the geometric nonlinear buckling FE analysis is shown in Figure 9.

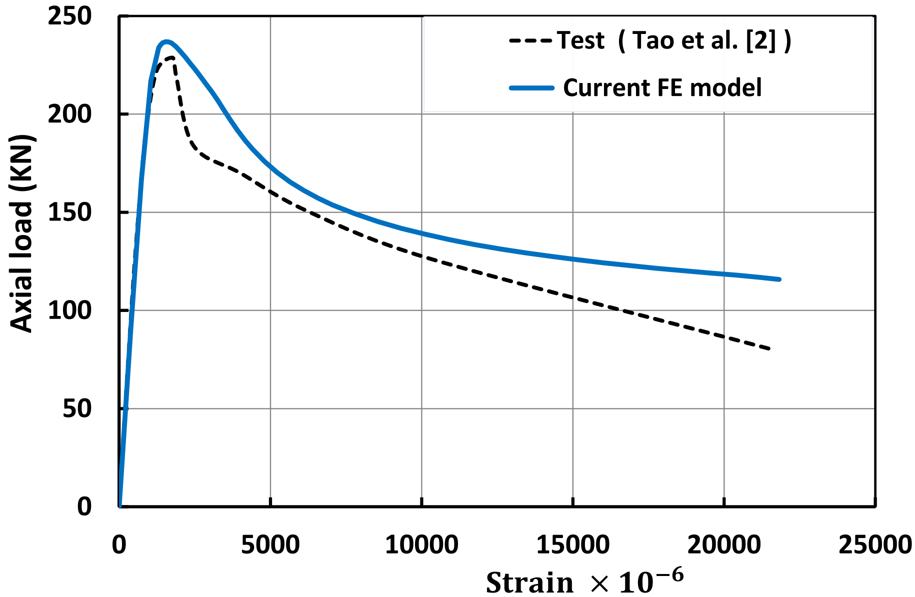


Figure 7: Comparison of the experimental test results and the finite element results for the (US25) specimen

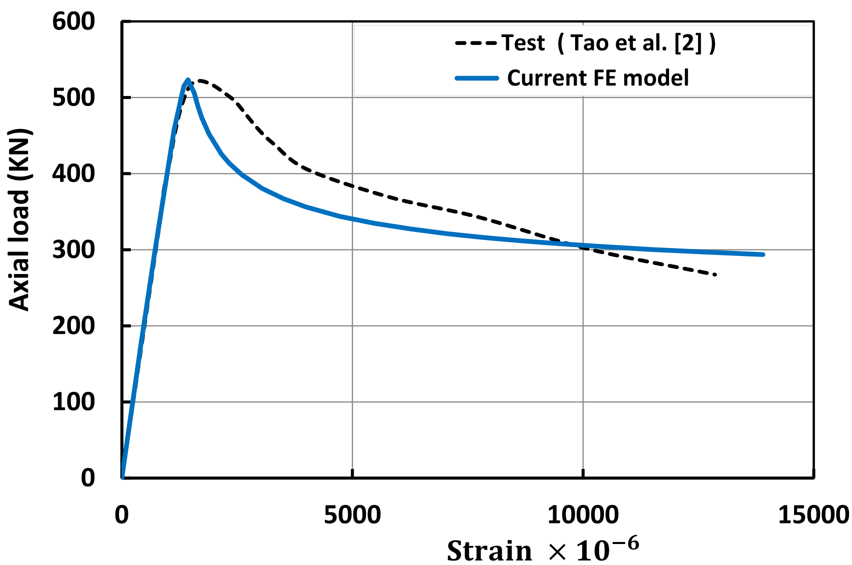


Figure 8: Comparison of the experimental test results and the finite element results for the (SS25) specimen

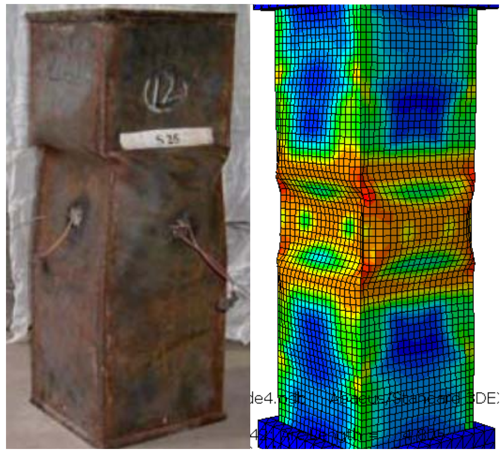


Figure 9: Comparison between the local buckling failure modes of the test and FE model for the (US25) specimen

ii. *Long Columns*

The comparison of the experimental test results and the finite element (FE) results for the HS15SL2, HS25SL3, HS25SL1, and HS20SL2 specimens are shown in Figure 10, Figure 11, Figure 12, and Figure 13, respectively. The mean values of N_{FEM}/N_{Test} are, respectively, 1.01, 1.03, 1.02, and 0.99 for the HS15SL2, HS25SL3, HS25SL1, and HS20SL2 specimens. From this study, the predicted ultimate strengths are very close to the given by tests in Khan et al. [5]. The HS15SL2 and HS20SL2 specimens with unstiffened compact section with $b_e/b = 1$ and $L_e/r=$ 77 and 59, respectively, failed due to global buckling only. The comparison of the buckling modes for the experimental test and FE model is shown in Figure 14 for the HS15SL2 specimen. The HS25SL3 and HS25SL1 specimens, with unstiffened slender sections with $b_e/b = 0.8$ and $L_e/r=$ 66 and 28, respectively, failed due to interaction between global and local buckling. The failure buckling modes for the HS25SL3 and HS25SL1 specimens are shown in Figure 15.

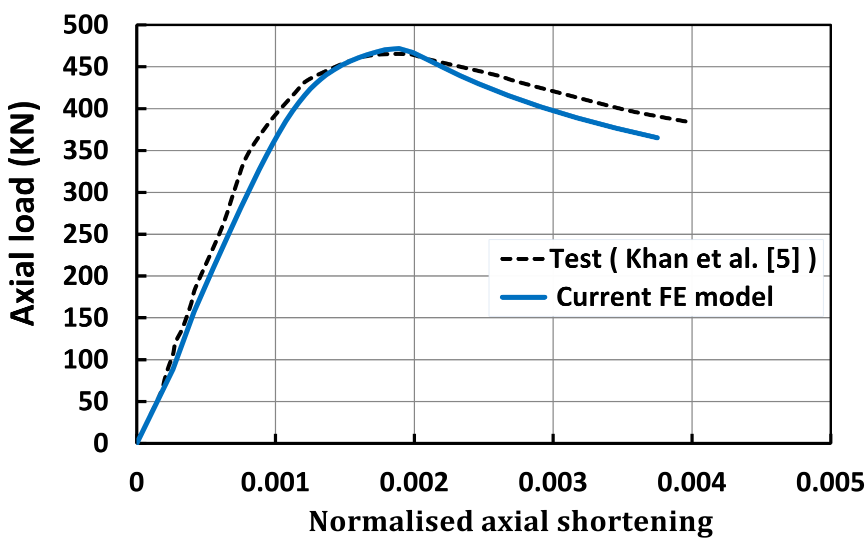


Figure 10: Comparison of the experimental test results and the finite element results for the HS15SL2 specimen

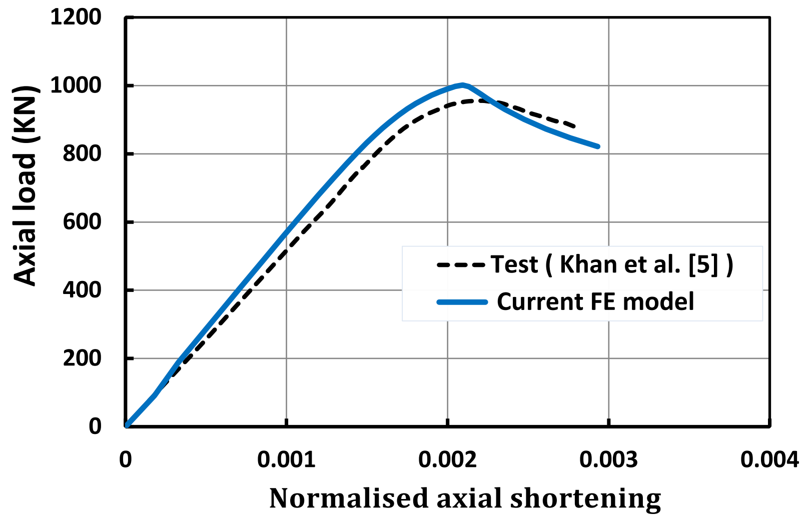


Figure 11: Comparison of the experimental test results and the finite element results for the HS25SL3 specimen

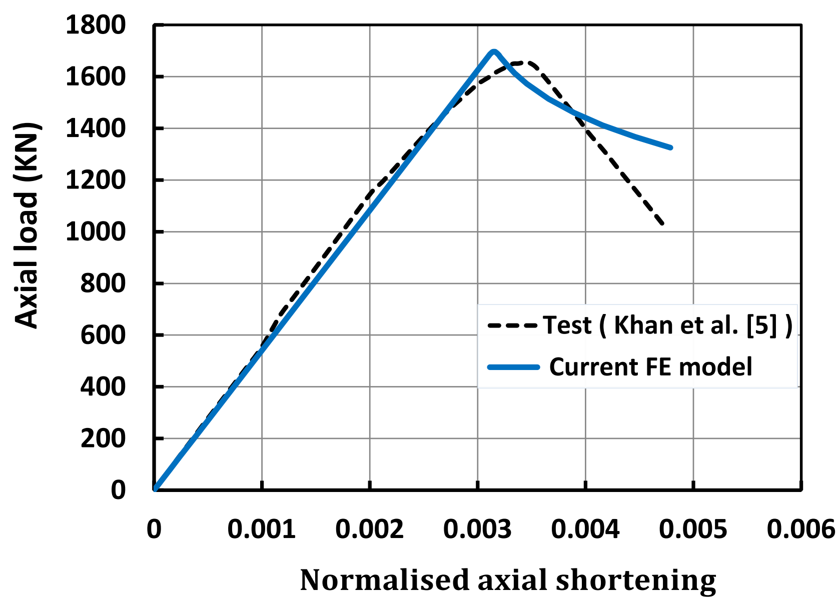


Figure 12: Comparison of the experimental test results and the finite element results for the HS25SL1 specimen

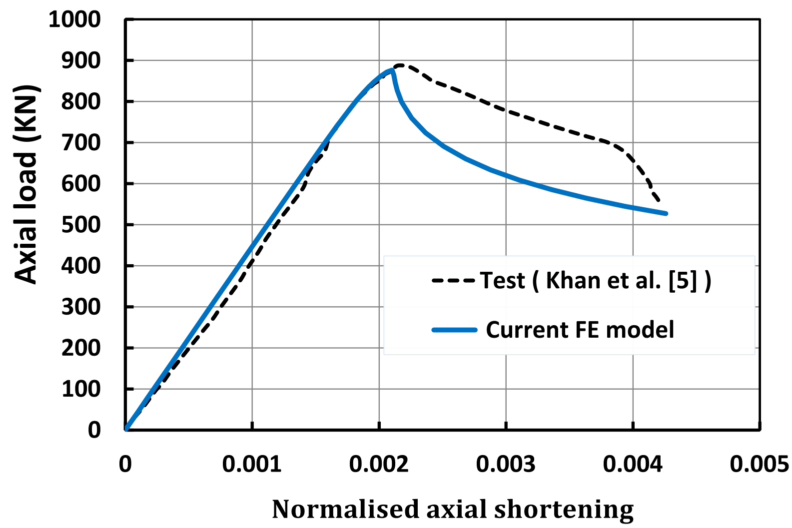


Figure 13: Comparison of the experimental test results and the finite element results for the HS20SL2 specimen

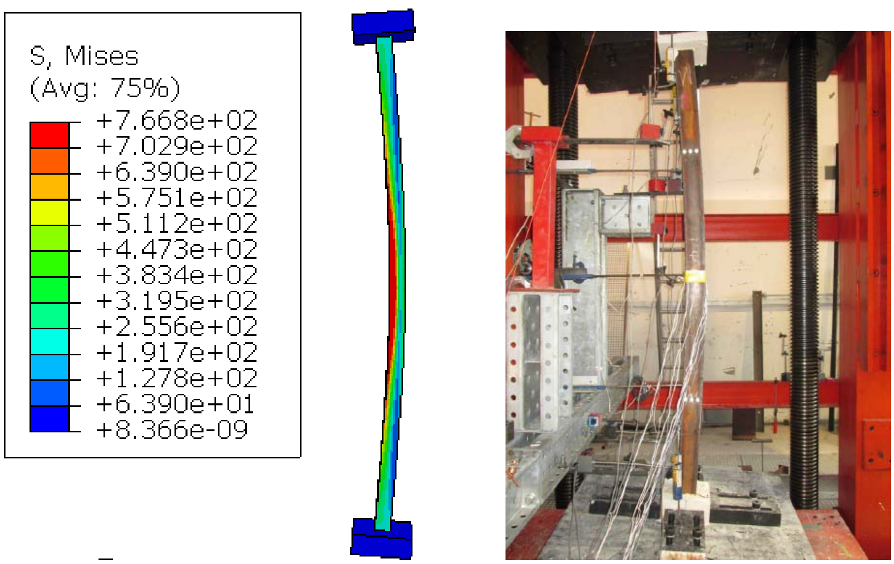
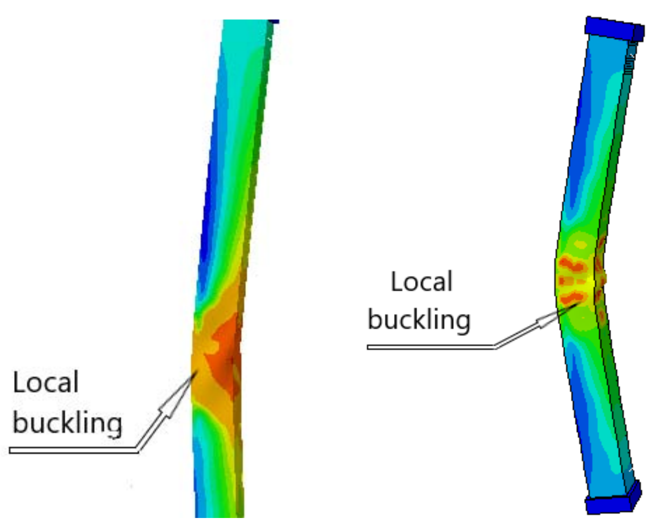


Figure 14: Comparison of the buckling mode for the experimental test and FE model for the HS15SL2 specimen



(a) HS25SL3 (b) HS25SL1

Figure 15: The global and local buckling modes for the unstiffened tube column

IV. Parametric Study

a) General Description

Based on the study of verification, A parametric investigation was carried out to create three-dimensional finite element models that simulate the stiffened and unstiffened hollow steel columns under axial compression. These models focus on the global and local buckling and were divided into two cases. Case 1 studies the local buckling's effects on the behavior and ultimate strength of hollow steel short columns. Case 2 studies the influence of stiffeners on the ultimate strength and performance of hollow steel long columns. The non-linear finite element (FE) analysis is used in the study to understand the effect of main structural parameters such as L_e/r, stiffener length, the ratio of width-to-thickness B/t, and the yield stress on the hollow steel column performance.

b) Columns Geometry

i. Short Columns

The steel material model for the finite elements was assumed to be an elastic-plastic model as shown in Figure 2, in addition taken as the hardening modulus equal to $0.005E_s$. The Young's modulus $E_s = 200000$ MPa and Poisson's ratio $\nu = 0.3$. The studied parameters were the yield strength $f_y = 240, 360, 460, 560,$ and 779 MPa, the stiffeners length (h_s), and the ratio B/t. The columns length is $L = 750\,mm$ and the columns width is $B = 250\,mm$ for all the specimens. The thickness of the stiffeners is considered same as the thickness of the tube, as listed in Tables (3 and 4). The shapes and dimensions of the investigated steel columns are shown in Figure 16. The specimen label shows the whether the sections is unstiffened (US), stiffened using single stiffener per section wall (SS), or stiffened using double stiffener per section wall (DS). In addition, the label suffixed by the thickness of the section walls in (mm).

The boundary condition as described previously and shown in Figure 5. For square hollow columns in these investigation, the initial local imperfection's value has been set to $0.01\,B$. In addition, this study used the distribution of residual stress shown in Figure 1. The columns in this study were modeled using 4-node shell elements (S4R) and the approximate global size of the mesh is about 12 mm.

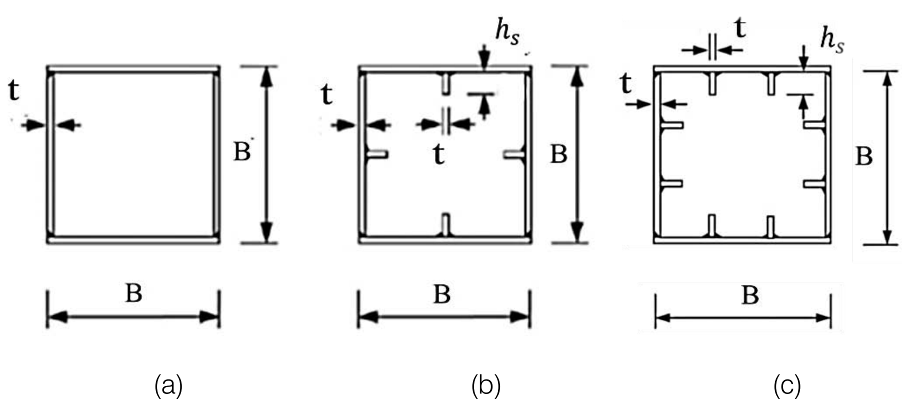


Figure 16: The investigated cross-sections' shapes and dimensions (a) Unstiffened sections US, (b) Stiffened sections with one stiffener SS, (c) Stiffened sections with two stiffeners DS

Table 3: The parameters and dimensions of hollow steel short columns used in the parametric study

Unstiffened sections (US)			Stiffened sections with one stiffener (SS)			Stiffened sections with two stiffeners (DS)		
t *mm*	f_y *MPa*	$\frac{B}{t}$	t *mm*	f_y *MPa*	*(B/t)*	t *mm*	f_y *MPa*	*(B/t)*
1	240	250	1	240	250	1	240	250
1.5	240	167	2	240	125	2.5	240	100
2	240	125	2.8	240	89	4	240	63
3.2	240	78	4.5	240	55	6	240	42
5.1	240	48	6.7	240	37	8	240	31
7.7	240	32	9	240	28	1	360	250
10	240	25	1	360	250	2.5	360	100
16	240	16	2	360	125	4	360	63
1	360	250	2.8	360	89	6	360	42
1.5	360	167	4.5	360	55	8	360	31
2	360	125	6.7	360	37	1	460	250
3.2	360	78	9	360	28	2.5	460	100

5.1	360	48	1	460	250	4	460	63
7.7	360	32	2	460	125	6	460	42
10	360	25	2.8	460	89	8	460	31
16	360	16	4.5	460	55	1	560	250
1	460	250	6.7	460	37	2.5	560	100
1.5	460	167	9	460	28	4	560	63
2	460	125	1	560	250	6	560	42
3.2	460	78	2	560	125	8	560	31
5.1	460	48	2.8	560	89	1	779	250
7.7	460	32	4.5	560	55	2.5	779	100
10	460	25	6.7	560	37	4	779	63
16	460	16	9	560	28	6	779	42
1	560	250	1	779	250	8	779	31
1.5	560	167	2	779	125	-	-	-
2	560	125	2.8	779	89	-	-	-
3.2	560	78	4.5	779	55	-	-	-
5.1	560	48	6.7	779	37	-	-	-
7.7	560	32	9	779	28	-	-	-
10	560	25	11.3	779	22.1	-	-	-
16	560	16	12	779	20.8	-	-	-
Unstiffened sections (US)								
1	779	250	7.7	779	32	1	779	250
1.5	779	167	10	779	25	1.5	779	167
2	779	125	16	779	16	2	779	125
3.2	779	78	18	779	13.8	3.2	779	78
5.1	779	48	20	779	12.5	5.1	779	48

Table 4: The stiffeners length (h_s) of stiffened hollow steel short columns used in the parametric study, where $f_y = 779\ MPa$

Stiffened sections with one stiffener (SS)		Stiffened sections with one stiffener (SS)		Stiffened sections with two stiffeners (DS)		Stiffened sections with two stiffeners (DS)	
t mm	h_s mm	t mm	h_s mm	t mm	h_s mm	t mm	h_s mm
1	10	1	40	2	10	2	50
1.5	10	1.5	40	3.2	10	3.2	50
2	10	2	40	5.1	10	5.1	50
3.2	10	3.2	40	7.7	10	7.7	50
5.1	10	5.1	40	10	10	10	50
7.7	10	7.7	40	16	10	16	50
10	10	10	40	2	20	2	60
16	10	16	40	3.2	20	3.2	60
1	20	1	50	5.1	20	5.1	60
1.5	20	1.5	50	7.7	20	7.7	60
2	20	2	50	10	20	10	60
3.2	20	3.2	50	16	20	16	60
5.1	20	5.1	50	2	30	-	-
7.7	20	7.7	50	3.2	30	-	-
10	20	10	50	5.1	30	-	-
16	20	16	50	7.7	30	-	-
1	30	1	60	10	30	-	-
1.5	30	1.5	60	16	30	-	-
2	30	2	60	2	40	-	-
3.2	30	3.2	60	3.2	40	-	-
5.1	30	5.1	60	5.1	40	-	-
7.7	30	7.7	60	7.7	40	-	-
10	30	10	60	10	40	-	-
16	30	16	60	16	40	-	-

ii. *Long Columns*

The steel material for the finite element models was assumed to be an elastic-plastic with linear hardening model. In addition the hardening modulus has been set to equal to $0.005E_s$ as shown in Figure 2. The Young's modulus $E_s = 200000\ \mathrm{MPa}$ and the Poisson's ratio $\nu = 0.3$. The boundary condition as described previously and shown in Figure 6. For square hollow columns in these investigation, the initial global imperfection value was taken as $0.001L$. The studied parameters were the columns length (L) and the ratio (B/t), as listed in Tables (5 and 6). In addition, the columns width $B = 250\ mm$ for all specimens, the yield strength is used in this study $f_y = 779\ \mathrm{MPa}$, and the stiffeners length $h_s = 35\ \mathrm{mm}$. The thickness of the stiffener is the same as the thickness of the tube. The specimens investigated are shown in Figure 17. The specimens' labels are as follows:

1. (US – t - L) = (US) Unstiffened section - (t) thickness – (L) column length.
2. (SS – t - L) = (SS) Stiffened section with one stiffener-(t) thickness - (L) column length.

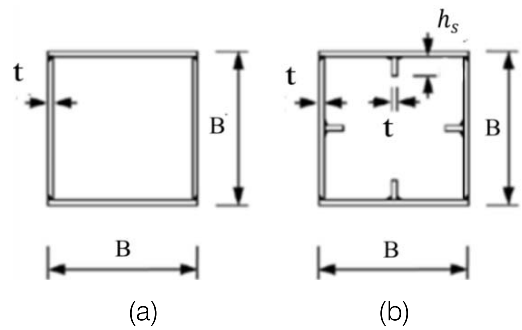


Figure 17: The cross-sections investigated in the current study and the manufacturing method (a) Unstiffened section, (b) Stiffened section with one stiffener per wall

Table 5: The dimensions of the unstiffened section, where the ratio $(B/t) = 12.5\ and\ 50$

No.	Specimen label	(B/t)	$\frac{KL_e}{r}$
1	US-20-2750	12.5	29.2
2	US-20-3000	12.5	31.8
3	US-20-4000	12.5	42.4
4	US-20-5000	12.5	53
5	US-20-6000	12.5	63.7
6	US-20-7000	12.5	74.3
7	US-20-8000	12.5	84.9
8	US-5-3000	50	30
9	US-5-4000	50	40
10	US-5-5000	50	50
11	US-5-6000	50	60
12	US-5-7000	50	70
13	US-5-8000	50	80
14	US-5-9000	50	90

Table 6: The dimensions of the stiffened sections with one stiffener, where the ratio $(B/t) = 12.5\ and\ 50$

No.	Specimen label	(B/t)	$\frac{KL_e}{r}$
1	SS-20-3000	12.5	33.1
2	SS-20-4000	12.5	44.1
3	SS-20-5000	12.5	55.1
4	SS-20-6000	12.5	66.2

5	SS-20-7000	12.5	77.2
6	SS-20-8000	12.5	88.2
7	SS-20-9000	12.5	99.2
8	SS-5-1000	50	10.3
9	SS-5-2000	50	20.6
10	SS-5-3000	50	30.9
11	SS-5-4000	50	41.2
12	SS-5-5000	50	51.5
13	SS-5-6000	50	61.8
14	SS-5-7000	50	72.1
15	SS-5-8000	50	82.4

c) Results and Discussion of Parametric Study

i. Unstiffened Short Columns FE Results against Analytical Methods

Most standards and specifications use the effective width approach to take into account the local buckling in case of the slender hollow steel tube cross-sections. This theory was developed based on redistribution of the stress on a steel tube with the average ultimate stress σ_u as shown in Figure 18. According to Von Karman et al. [28], the effective width b_e is the only part of the width that can resist the loading, but there is no loading on the plate's central part. The effective width is represented in Figure 18(b).

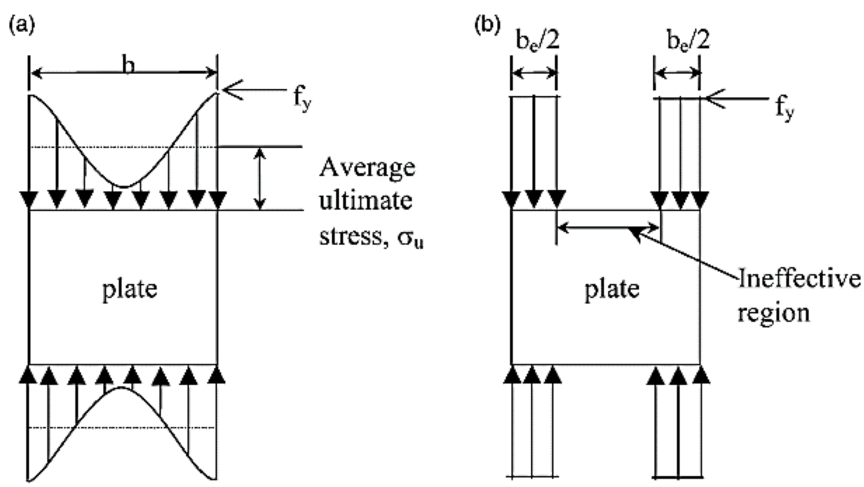


Figure 18: (a) Distribution of ultimate stress, (b) Concept of effective width in a compressed plate

The values of σ_{ult}/f_y in Table 7 give the reduction factors of the strength for the numerical models, where $\sigma_{ult} = N_s/A_s$. Where, N_s represents the ultimate loads, takes into account the reduction due to local buckling's effects according to the effective width approach by Uy[24]. The local buckling reduction factor (b_e/b) is determined using Eq. (3) and (4), where the ratio (b_e/b) is the effective tube width ratio to full tube width. When (b_e/b) equals 1.0, this means that the sections being compact.

$$\frac{b_e}{b} = \alpha\sqrt{\frac{\sigma_{ol}}{\sigma_y}} \tag{3}$$

Where $\alpha = 0.651$ for heavily welded tubes. Which accounts for geometric imperfections and residual stress. The stress of local buckling σ_{ol} is presents in Eq. (4), as shown below:

$$\sigma_{ol} = \frac{K\pi^2 E_S}{12(1-v^2)(b/t)^2} \tag{4}$$

Where the coefficient of plate buckling (K) can be considered as 4 for hollow sections and $N_s = (b_e/b)A_s f_y$. Von Karman et al. [28] developed the first effective width expression in 1932. This expression states that a width of plate (b) and effective width (b_e) can be used to evaluate the ultimate strength capacity. Von Karman's effective width can be written in terms of the yield stress σ_y and critical stress σ_{CR} as follows:

$$\frac{b_e}{b} = \sqrt{\frac{\sigma_{CR}}{\sigma_Y}} \tag{5}$$

Where:-

$$\sigma_{CR} = \frac{K\pi^2 E t^2}{12(1-v^2)b^2} \tag{6}$$

Where the buckling coefficient $K = 4$ in case of the simply supported plate. Winter [29] subsequently modified von Karman's equation to:

$$\frac{b_e}{b} = \sqrt{\frac{\sigma_{CR}}{\sigma_E}}\left(1 - 0.25\sqrt{\frac{\sigma_{CR}}{\sigma_E}}\right) \tag{7}$$

The second term within the bracket out Winter equation is mainly at the point where the applied edge stress σ_E and yield stress σ_Y are similar. According to the Direct Strength Method (DSM) by ANSI/AISI S100-16 [25], the theoretical equation to estimating the ultimate loads with take into account the local buckling as given in Eq. (8). Where the $P_{crl,T}$ is the critical elastic local buckling load of the square hollow columns and λ_l is the non- cross-section slenderness of the cross-section and equals to $\lambda_l = (f_y A_g / P_{crl,T})^{0.5}$.

$$N_{DSM} = \begin{cases} f_y \times A_g \ , \quad for \ \lambda_l \le 0.776 \\ \left(1 - \frac{0.15}{\lambda_l^{0.8}}\right)\frac{1}{\lambda_l^{0.8}} f_y \times A_g \ , for \ \lambda_l > 0.776 \end{cases} \tag{8}$$

Where $f_y \ in \ (MPa)$ and $A_g \ in \ (mm^2)$.

Fang and Chan [26] modified the direct strength method to give the predictions of safer strength for welded steel hollow columns, as shown in Eq. (9).

$$N_{DSM}^{\#} = \begin{cases} f_y \times A_g \ , \quad for \ \lambda_l \le 0.707 \\ \left(\frac{0.96}{\lambda_l^{0.9}} - \frac{0.22}{\lambda_l}\right) f_y \times A_g \ , for \ \lambda_l > 0.707 \end{cases} \tag{9}$$

In this investigation, the main objective of the analytical methods is to study the local buckling's effects on the steel tube ultimate strength and compared with the current (FE) results. Eight FE models of unstiffened short columns was used in this case, where the (B/t) ratio varying from 16 to 250. According to most of the international codes like ANSI/AISC 360-16 [30] the dimensions used in these investigation provide valuable data for slender, non-compact, and compact sections. The hollow steel sections, according to ANSI/AISC 360-16 are classified for local buckling.

If $\lambda \le \lambda_p$ The tube is a compact section

$\lambda_r \ge \lambda > \lambda_p$ The tube is a non-compact section

$\lambda > \lambda_r$ The tube is slender cross-sections

Where:

$$\lambda_p = 1.12\sqrt{E/F_y} \tag{10}$$

$$\lambda_r = 1.40\sqrt{E/F_y} \tag{11}$$

$$\lambda = B/t \tag{12}$$

The comparison of the analytical and the FE results for the unstiffened steel columns is summarized in Figure 19 and Table 7. According to this comparison, the present FE results produces conservative predictions of the steel tube ultimate. In addition that the average variation is around 4% between current FE models and the effective width approach by Uy[24]. As well as that, the average variation is around 6% between current FE models and modified (DSM). From this comparison, the results of present (FE) and the effective width method by Uy[24] approximately similar. This is because the current FE models and the effective width method by Uy[24] take into accounts for geometric imperfections and residual stress. Thus, it can be concluded that the proposed method can accurately predict the ultimate load capacity of short columns.

Table 7: Dimensions and the FE results of unstiffened sections (US), where $f_y = 779 \ MPa$

Specimen label	$\frac{B}{t}$	σ_{Ult}/f_y					
		Present FEM	Uy [24]	Modified DSM [26]	Winter [29]	DSM [25]	Von Karmans[28]
US-1	250	0.11	0.09	0.12	0.12	0.18	0.12
US-1.5	167	0.16	0.14	0.17	0.17	0.25	0.18
US-2	125	0.19	0.18	0.22	0.23	0.31	0.24
US-3.2	78	0.29	0.30	0.33	0.35	0.44	0.39
US-5.1	48	0.40	0.42	0.50	0.53	0.62	0.63
US-7.7	32	0.66	0.63	0.72	0.72	0.83	0.95
US-10	25	0.82	0.81	0.90	0.85	0.98	1.00
US-16	16	0.96	1.00	1.00	1.00	1.00	1.00

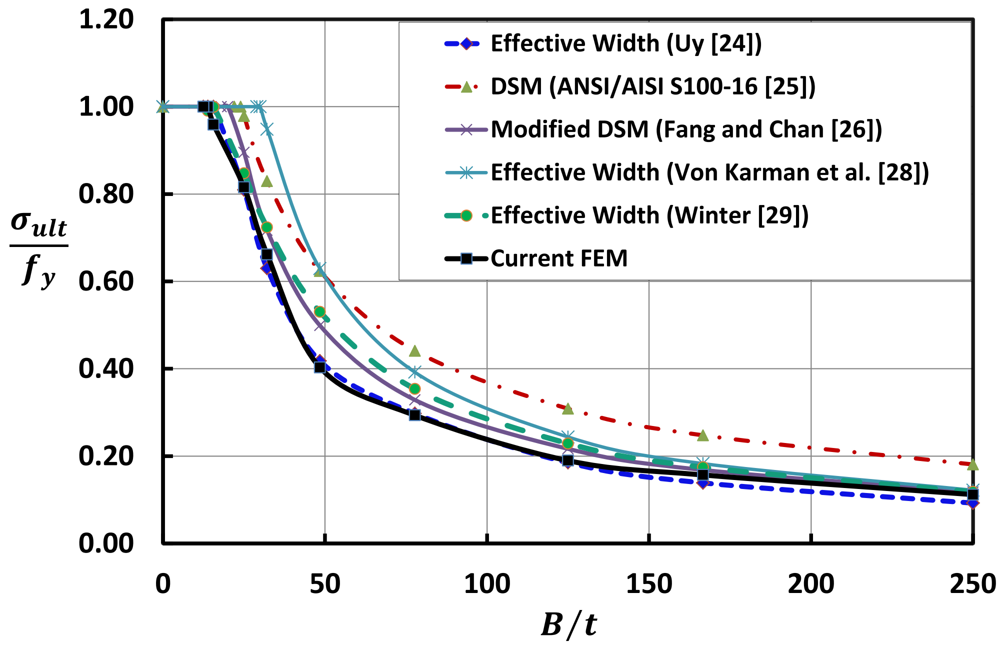


Figure 19: Comparison of the present FE results and analytical methods for unstiffened columns, where $f_y = 779\ MPa$

ii. *Stiffened Short Columns FE Results against Analytical Methods*

This case deals with stiffeners in steel tube fields subjected to axial stress. There are two primary types of stiffeners:

- Longitudinal stiffeners, that are aligned with the steel tube length direction.
- Transverse stiffeners, that are aligned normal to the length direction of the steel tube.

The stiffeners can be attached to the four walls of the tube, and it is used to control the local buckling this tubes. In this study, the steel tube is without transverse stiffeners, so it is possible that the stiffener could buckle locally or could be ineffective when the stiffener length is small. There are different formulas to account for stiffeners such as the effective plate width according to Norsok standard (N-004) [27]. This standard was developed depends on a steel tube's redistribution of stress as shown in Figure 20. The effective width s_e for the stiffened sections subjected to longitudinal stress is found from:

$$\frac{S_e}{S} C_{xs} C_{ys} C_{\tau s} \tag{13}$$

The reduction factor in the longitudinal direction, C_{xs}, is found from:

$$C_{xs} = \frac{\overline{\lambda}_p - 0.22}{\lambda_p^2} \quad , \text{if } \overline{\lambda}_p > 0.673 \tag{14}$$

$$C_{xs} = 1 \quad , \quad \text{if } \overline{\lambda}_p \leq 0.673 \tag{15}$$

Where: $\overline{\lambda}_p$

$$\overline{\lambda}_p = 0.525 \frac{s}{t} \sqrt{\frac{f_y}{E}} \tag{16}$$

C_{ys} is the reduction factor for compression stresses in the transverse direction.

$C_{\tau s}$ is the reduction factor for shear.

The comparison of the analytical results and the FE results is summarized in Figure 21 for the stiffened sections with one stiffener, where $h_s = 35$ mm and $f_y =$ 779 MPa. The Norsok standard does not consider the effect of the stiffeners' length in calculating the section capacity. In this case the stiffeners may be failed due to the local buckling. Therefore, the current FE results produce conservatively predictions of the steel tube ultimate strength for stiffened steel columns. In addition that the average variation is around 6% between current FE models and the effective width method by Norsok. In this case, where $B/t \leq 70$, the predictions of ultimate strengths by current FE are very close to the effective width method by Norsok. This is due to the stiffeners most likely not exhibiting any local buckling. In addition, where $B/t > 70$ the current FE results produce conservative predictions of the ultimate strength. This is due to the stiffeners most likely exhibiting local buckling.

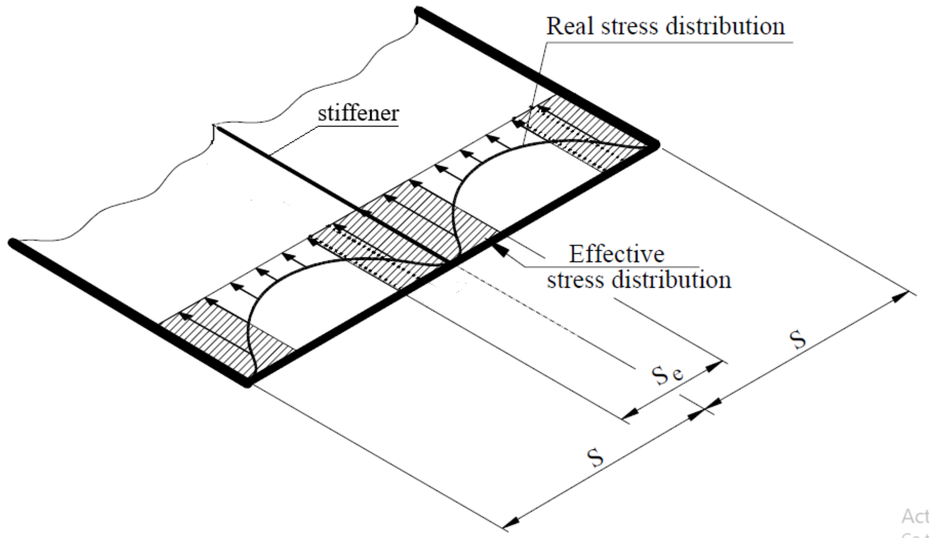


Figure 20: Effective width concept in stiffened plate under compression

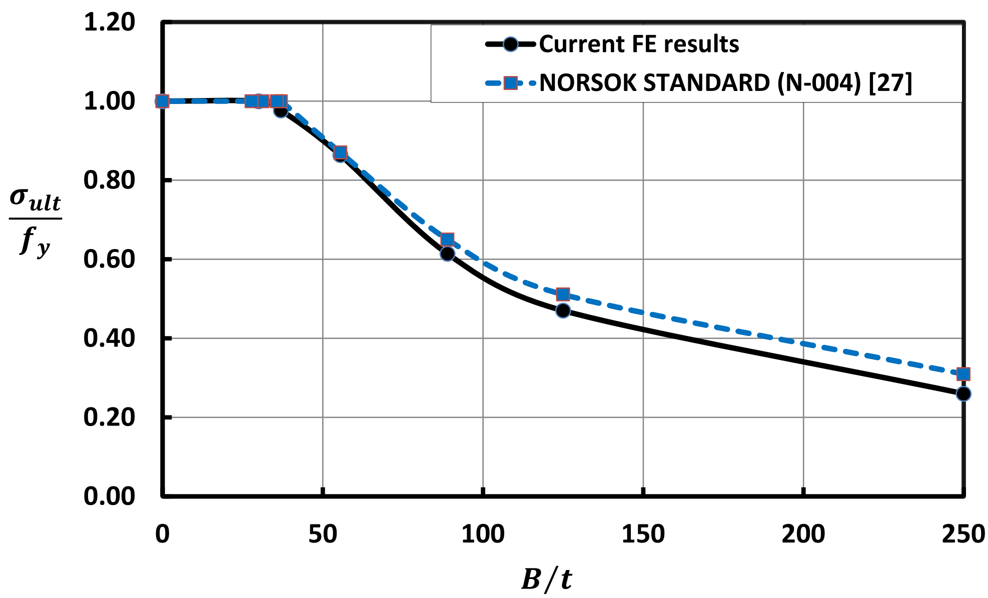


Figure 21: Comparison of the current FE results and analytical methods for the stiffened sections with one stiffener, where $h_s = 35$ mm and $f_y = 779$ MPa

iii. *Comparison between Stiffened and Unstiffened Hollow Short Steel Columns*

The proposed stiffening system may be improved by arranging the stiffeners properly, which can even change the strain softening properties. The steel tubes' dimensions were selected to provide relatively slender, non-compact, and compact sections. The numerical results for the unstiffened and stiffened steel hollow columns are summarized in Tables 8 and Tables 9, respectively. According this results, the strength of the stiffened steel tube hollow columns is remarkably higher than those of the unstiffened columns ones. The unstiffened and stiffened square steel tube columns primarily collapsed due to local buckling but at different modes, as shown in Figure 28 for US-4, SS-4, and DS-4 specimens, respectively. Figure 24 shows the ultimate strength curves of the US, SS, and the DS sections. The ultimate strength σ_{ult} are normalized by dividing by f_y. The stress distributions for the US-2.5, SS-2.5, and DS-2.5 specimens are shown in Figure 22 and Figure (23a and b), respectively. The proposed stiffening method can enhance the steel tube ultimate ductility and strength. The collapsed modes of the steel columns indicate that the stiffening scheme effectively delays local buckling.

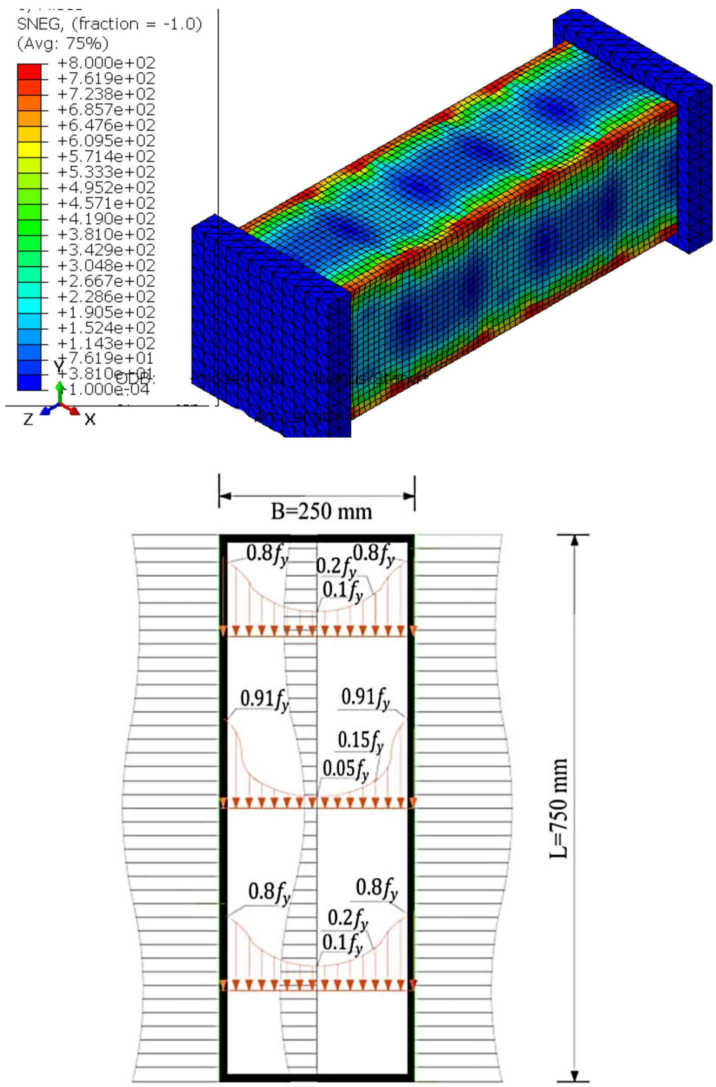
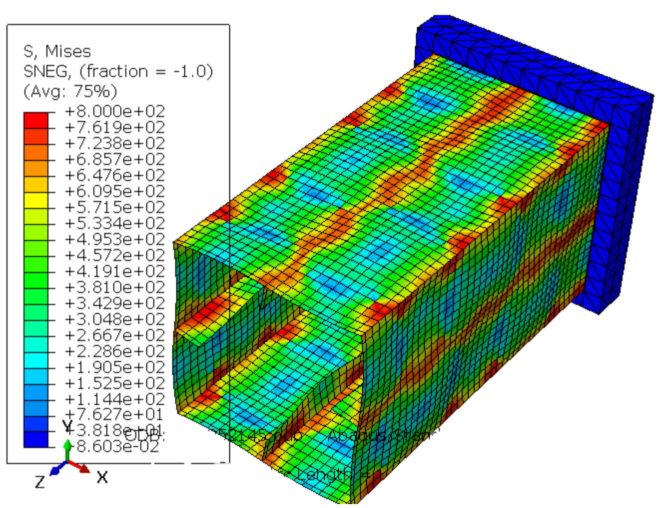
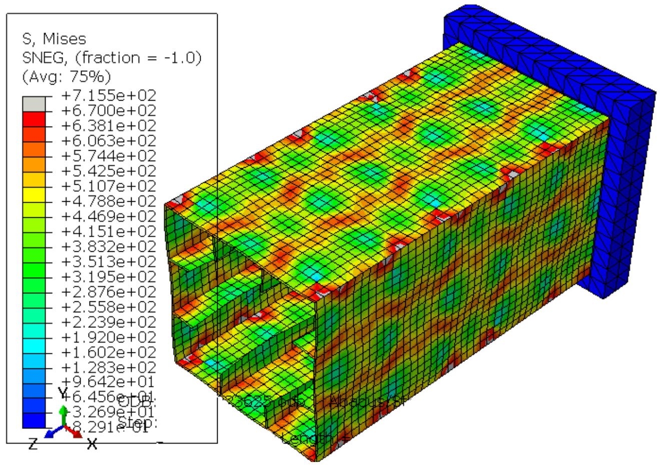


Figure 22: The stress distribution on the unstiffened columns at ultimate load for the US-2.5 specimen, where $f_y = 779\ MPa$



(a) SS-2.5 specimen



(b) DS-2.5 specimen

Figure 23: The stress distribution on the stiffened sections at ultimate load, where $f_y = 779\ MPa$ and stiffeners length $h_s = 35\ mm$

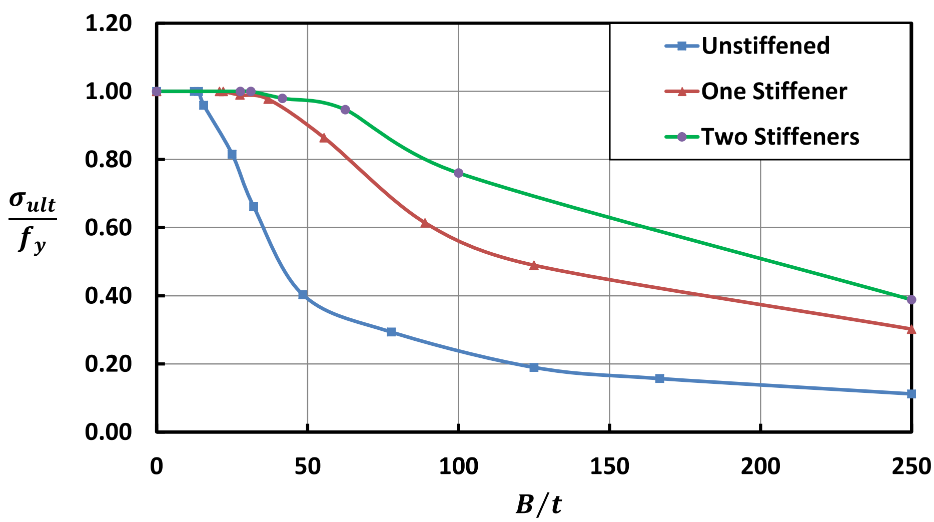


Figure 24: Comparison of the unstiffened and stiffened steel tube columns, where $h_s = 35\ mm$ and $f_y = 779\ MPa$

Table 8: The dimensions and FE results of the unstiffened columns

Specimen label	(B/t)	σ_{ult}/f_y at f_y(MPa)				
		240 MPa	360 MPa	460 MPa	560 MPa	779 MPa
US-1	250	0.17	0.14	0.12	0.11	0.11
US-1.5	167	0.25	0.20	0.18	0.16	0.16
US-2	125	0.33	0.27	0.24	0.22	0.19
US-3.2	78	0.54	0.44	0.39	0.35	0.29
US-5.1	48	0.75	0.61	0.54	0.49	0.40
US-7.7	32	0.99	0.93	0.82	0.74	0.66
US-10	25	1.00	1.00	1.00	0.95	0.82
US-16	16	1.00	1.00	1.00	1.00	0.96

Table 9: The dimensions and FE results of the stiffened sections with one and two stiffeners, where the stiffeners length $h_s = 35\ mm$

Specimen label	(B/t)	σ_{Ult}/f_y at f_y (MPa)				
		240 MPa	360 MPa	460 MPa	560 MPa	779 MPa
SS-1	250	0.46	0.41	0.39	0.34	0.3
SS-2	125	0.67	0.61	0.58	0.55	0.49
SS-2.8	89	0.81	0.75	0.71	0.66	0.61
SS-4.5	55	0.98	0.96	0.94	0.92	0.86
SS-6.7	37	0.99	0.98	0.96	0.99	0.98
SS-9	28	1.00	1.00	1.00	1.00	1.00
DS-1	250	0.61	0.56	0.53	0.49	0.39
DS-2.5	100	0.91	0.87	0.83	0.8	0.76
DS-4	63	1.00	0.99	0.98	0.96	0.95
DS-6	42	1.00	1.00	0.99	0.98	0.98
DS-8	31	1.00	1.00	1.00	1.00	1.00

iv. *Effect of Yield Strength of Hollow Short Steel Columns*

In recent years the yield strengths of structural steel have increased. This study aims to determine the influence of the yield strength on the normalized ultimate strength (σ_{ult}/f_y) for the stiffened and unstiffened hollow steel columns. The numerical simulations were carried out for yield strength equal to (240, 360, 460, 560, and 779 MPa). Figures (25, 26, and 27) show the results for the normalized ultimate strength (σ_{ult}/f_y) versus the ratio (B/t).

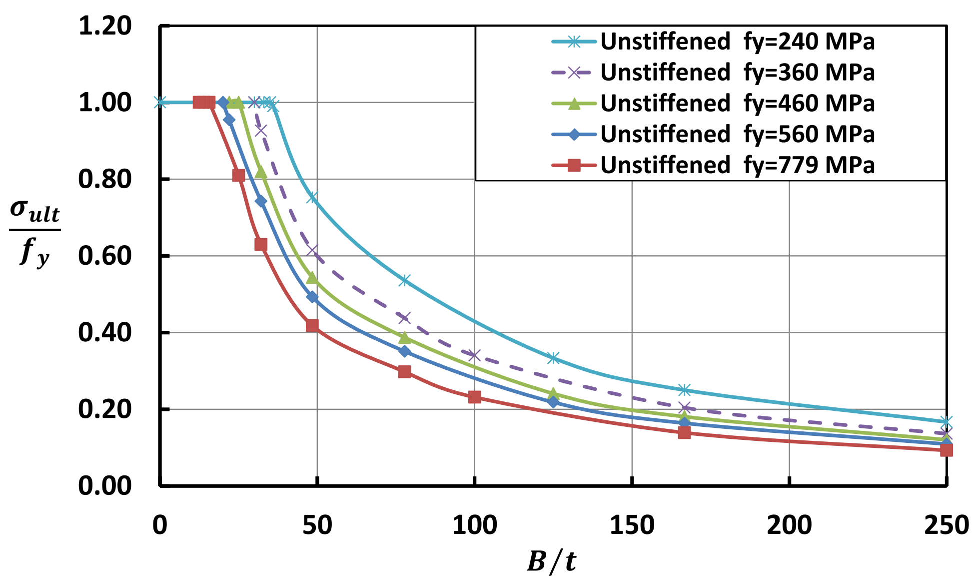


Figure 25: Effect of yield strength on the normalized ultimate strength (σ_{ult}/f_y) for unstiffened sections

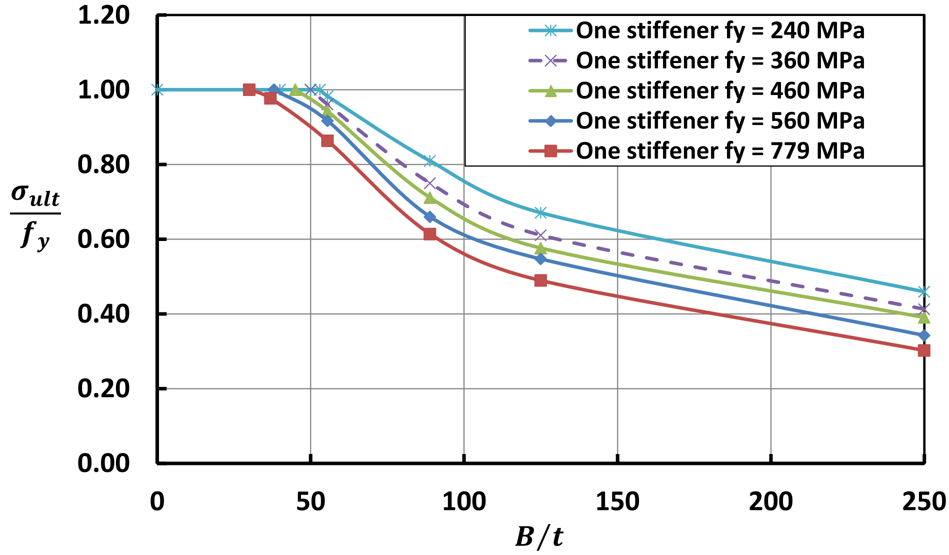


Figure 26: Effect of yield strength on the normalized ultimate strength (σ_{ult}/f_y) for the stiffened sections with one stiffener, where $h_s = 35\ mm$

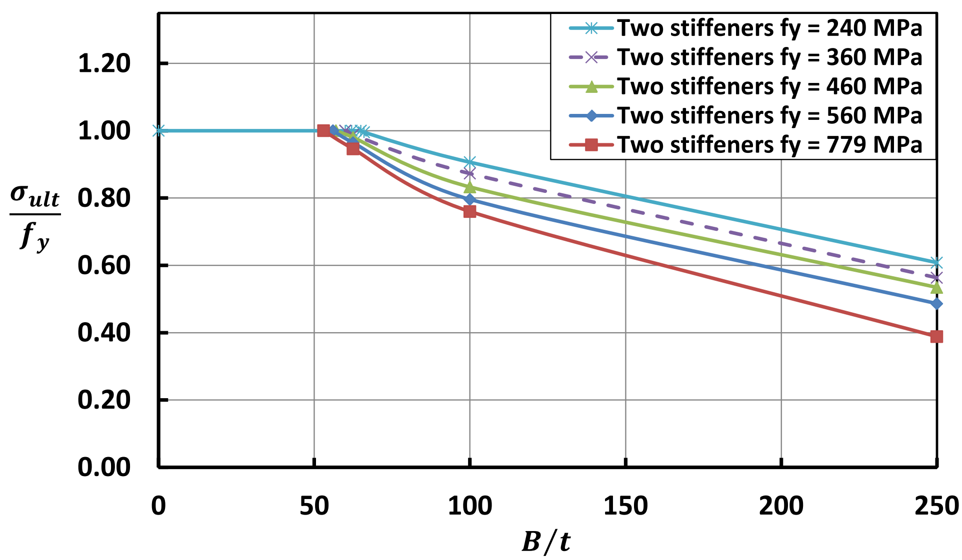
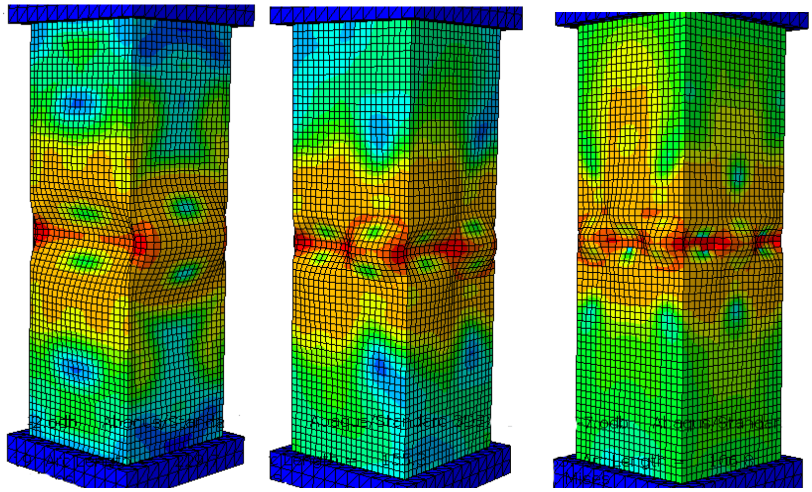


Figure 27: Effect of yield strength on the normalized ultimate strength (σ_{ult}/f_y) for the stiffened sections with two stiffeners, where $h_s = 35\ mm$

v. *Failure Modes*

For hollow short steel columns, in the linear buckling analysis, we studied a steel tube model that was undamaged and without any significant deformations, but now with non-linear buckling analysis, we will look at how the stiffeners affected on the capacity and buckling load of steel hollow columns. The local buckling mode should be plotted in form of deformation and stress, it is necessary for the mode that results in collapse. This is done to confirm that the buckling response is physical and that the square hollow steel columns have in real collapsed. The ultimate strength and the stress versus strain curve of model is the main output of the non-linear analysis. Figure 28 shows the buckling modes for the US-4, SS-4, and DS-4 specimens, respectively. The stiffeners can effectively constrain the local buckling of the steel tube. Finally, the buckling of the steel tube is less obvious with the increasing of the number of stiffeners, and the stiffened steel columns have greater serviceability advantages compared to those unstiffened columns.



(a) The (US-4) specimen, (b) The (SS-4) specimen, (c) The (DS-4) specimen

Figure 28: The local buckling modes for the stiffened and unstiffened columns

For long steel columns, the unstiffened compact sections with $(b_e/b = 1)$, width-to thickness ratio $(B/t = 12.5)$, and KL_e/r from 31 to 95 failed mainly due to the effect of global buckling without any local buckling. As well as when $KL_e/r < 31$, the columns failed due to the full plastic strength, as summarized in Table 13. For the stiffened sections with one stiffener with the tube thickness $t = 20\,mm$ and the KL_e/r from 44 to 99 collapsed due to the global buckling only without any local buckling. As well as when $(KL_e)\,/\,r\ < 44$ the columns failed due to the full plastic strength, as summarized in Table 12. The numerical specimens for unstiffened sections with width-to thickness ratio $B/t = 50$ and KL_e/r from 30 to 80 failed by both of global and local buckling (G and L) as summarized in Table 14. In addition, these columns failed due to the global buckling when $KL_e/r > 80$. For stiffened sections with one stiffener, when the columns with $(B/t = 50)$ and $KL_e/r < 30$ failed by predominantly local buckling (L). As well as these columns failed due transforms into a combination of the global and local buckling (L and G) when the $30 < KL_e/r < 51$, as summarized in Table 15. The buckling mode for the (US-5-4000) and (US-5-7000) specimens is shown in Figure 32 and Figure 33, respectively.

vi. *Effect of the Stiffener Length for Short Columns*

The effect of stiffener length on the stiffened sections with one and two stiffeners is shown in Figure 29 and Figure 30. The optimum stiffener length at different tube thickness is calculated using Eq. (17) and Eq. (18) for the stiffened columns with one (SS) and two (DS) stiffeners, respectively. The (B/t) ratio, the (h_s/B) ratio, and the finite element normalized stress results are shown in Table 10 and Table 11.

$$\frac{h_s}{B} = 0.005t^2 - 0.02t + 0.14 \quad (17)$$

$$\frac{h_s}{B} = 0.005t^2 - 0.05t + 0.32 \quad (18)$$

Table 10: The (B/t) ratio, the (h_s/B) ratio, and the FE normalized stress results for stiffened columns with one stiffener, where $f_y = 779\ MPa$

$\frac{B}{t}$	h_s/B					
	0.04	*0.08*	*0.12*	*0.16*	*0.2*	*0.24*
	σ_{Ult}/f_y					
250	0.20	0.26	0.30	0.32	0.31	0.25
167	0.27	0.34	0.39	0.41	0.40	0.35
125	0.33	0.41	0.47	0.50	0.49	0.45
78	0.46	0.56	0.63	0.67	0.66	0.62
48	0.63	0.76	0.85	0.89	0.91	0.83
32	0.84	0.99	1.00	1.00	1.00	1.00
25	0.99	1.00	1.00	1.00	1.00	1.00
16	1.00	1.00	1.00	1.00	1.00	1.00

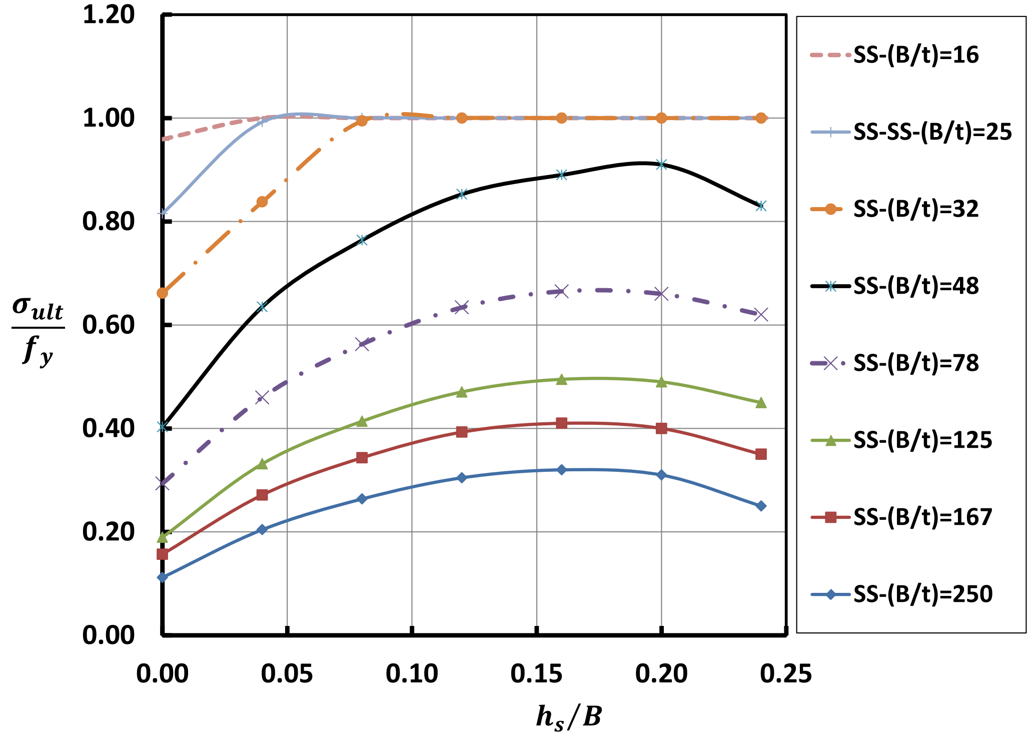


Figure 29: Effect of the stiffeners' length on the stiffened sections with one stiffener, where $f_y = 779\ MPa$

Table 11: The (B/t) ratio, the (h_s/B) ratio, and the FE normalized stress results for stiffened columns with two stiffeners, where $f_y = 779\ MPa$

(B/t)	h_s/B					
	0.04	0.08	0.12	0.16	0.2	0.24
	σ_{Ult}/f_y					
125	0.40	0.55	0.63	0.64	0.66	0.68
78	0.51	0.68	0.76	0.78	0.80	0.78
48	0.63	0.79	0.88	0.89	0.91	0.89
32	0.83	0.93	0.99	1.00	1.00	1.00
25	0.91	0.98	1.00	1.00	1.00	1.00
16	0.96	1.00	1.00	1.00	1.00	1.00

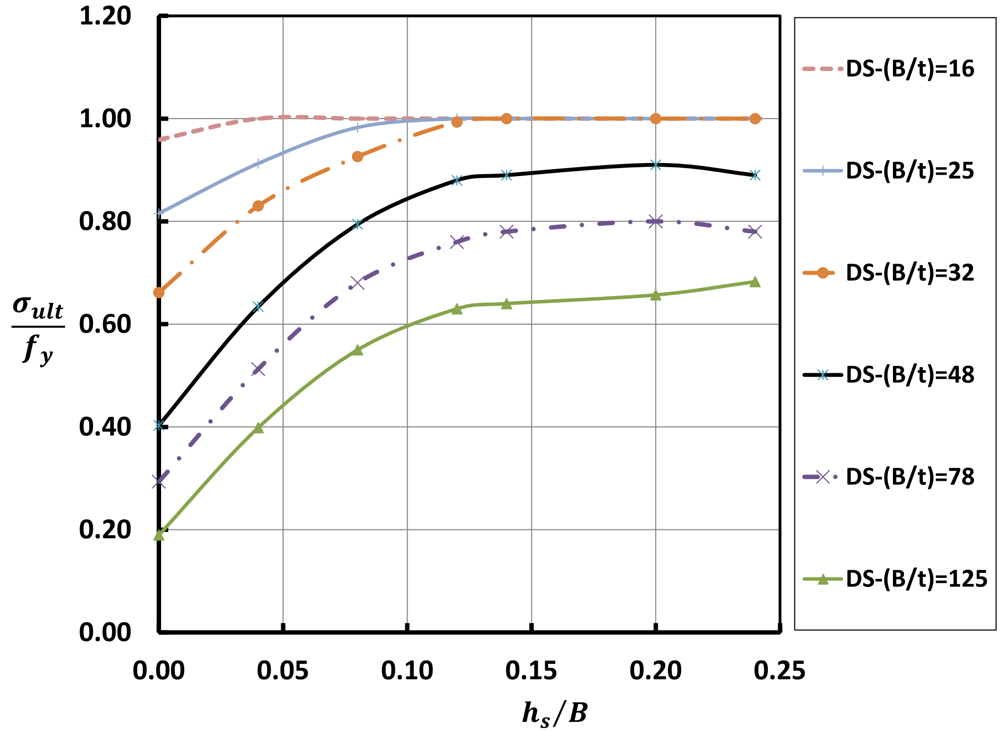


Figure 30: Effect of the stiffeners' length on the stiffened sections with two stiffeners, where yield strength $f_y = 779\ MPa$

vii. *The Stiffeners' Effect on Long Columns*

Figure 31 shows the comparison between normalized ultimate strength (σ_{ult}/f_y) for the stiffened and unstiffened sections obtained from FEA results, where the tube thickness $t = 20\ mm$ and $t = 5mm$. The measured normalized ultimate strength (σ_{ult}/f_y) for these columns is summarized in Tables (12 to 15). For the compact unstiffened sections when $t = 20\ mm$ and $KL_e/r \leq 29$, $\sigma_{ult}/f_y = 1$ this means that the steel columns mainly collapsed due to the full plastic strength. In addition, when $KL_e/r > 29$ the $\sigma_{ult}/f_y < 1$ this means that the steel columns mainly failed due to global buckling. Similarly, for stiffened sections with one stiffener when $t = 20\ mm$ and $KL_e/r \leq 33$, the $\sigma_{ult}/f_y = 1$ this means the columns failed due to the full plastic strength. In addition, when $KL_e/r > 29$ the $\sigma_{ult}/f_y < 1$ this means the columns failed due to global buckling. The ultimate strength curves for the stiffened and unstiffened sections, when $t = 20\ mm$ are very close. In case of the slender sections when $t = 5\ mm$ the measured normalized ultimate strength (σ_{ult}/f_y) equal to 0.43 and 0.92 for unstiffened and stiffened short columns, respectively. The ultimate strength curve for stiffened sections higher than unstiffened sections for all KL_e/r values as shown in Figure 31. According to this study, the stiffeners greatly affect the ultimate strength of slender sections in the long columns.

Table 12: The dimensions and FE results of the stiffened sections with one stiffener, where the ratio $(B/t) = 12.5$

No.	Specimen label	B/t	$\frac{KL_e}{r}$	$\frac{\sigma_{ult}}{f_y}$	Buckling mode
1	SS-20-3000	12.5	33.1	1.00	Plastic
2	SS-20-4000	12.5	44.1	0.84	Global
3	SS-20-5000	12.5	55.1	0.67	Global
4	SS-20-6000	12.5	66.2	0.52	Global
5	SS-20-7000	12.5	77.2	0.39	Global
6	SS-20-8000	12.5	88.2	0.31	Global
7	SS-20-9000	12.5	99.2	0.25	Global

Table 13: The dimensions and FE results of the unstiffened sections, where the ratio $(B/t) = 12.5$

No.	Specimen label	$\boldsymbol{B/t}$	$\boldsymbol{\frac{KL_e}{r}}$	$\boldsymbol{\frac{\sigma_{ult}}{f_y}}$	Buckling mode
1	US-20-2750	12.5	29.2	1.00	Plastic
2	US-20-3000	12.5	31.8	0.95	Global
3	US-20-4000	12.5	42.4	0.86	Global
4	US-20-5000	12.5	53	0.73	Global
5	US-20-6000	12.5	63.7	0.56	Global
6	US-20-7000	12.5	74.3	0.43	Global
7	US-20-8000	12.5	84.9	0.34	Global

Table 14: The dimensions and FE results of the unstiffened sections, where the ratio $(B/t) = 50$

No.	Specimen label	$\boldsymbol{B/t}$	$\boldsymbol{\frac{KL_e}{r}}$	$\boldsymbol{\frac{\sigma_{ult}}{f_y}}$	Buckling mode
1	US-5-3000	50	30	0.43	Local
2	US-5-4000	50	40	0.42	L+G
3	US-5-5000	50	50	0.41	L+G
4	US-5-6000	50	60	0.39	L+G
5	US-5-7000	50	70	0.37	L+G
6	US-5-8000	50	80	0.33	L+G
7	US-5-9000	50	90	0.29	Global

Table 15: The dimensions and FE results of the stiffened sections with one stiffener, where the ratio $(B/t) = 50$

No.	Specimen label	$\boldsymbol{B/t}$	$\boldsymbol{\frac{KL_e}{r}}$	$\boldsymbol{\frac{\sigma_{ult}}{f_y}}$	Buckling mode
1	SS-5-1000	50	10.3	0.92	Local
2	SS-5-2000	50	20.6	0.87	Local
3	SS-5-3000	50	30.9	0.84	Local
4	SS-5-4000	50	41.2	0.75	L+G
5	SS-5-5000	50	51.5	0.67	L+G
6	SS-5-6000	50	61.8	0.57	Global
7	SS-5-7000	50	72.1	0.45	Global
8	SS-5-8000	50	82.4	0.35	Global

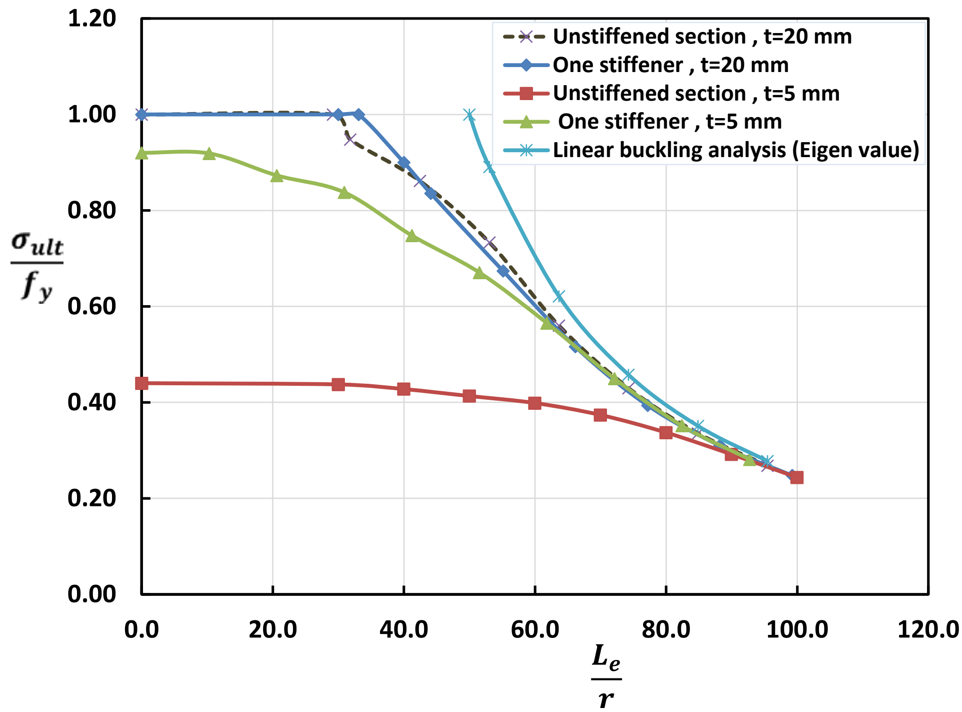


Figure 31: Comparison of the current FE results for the unstiffened and stiffened columns, where the tube thickness $t = 20mm$ and $t = 5mm$

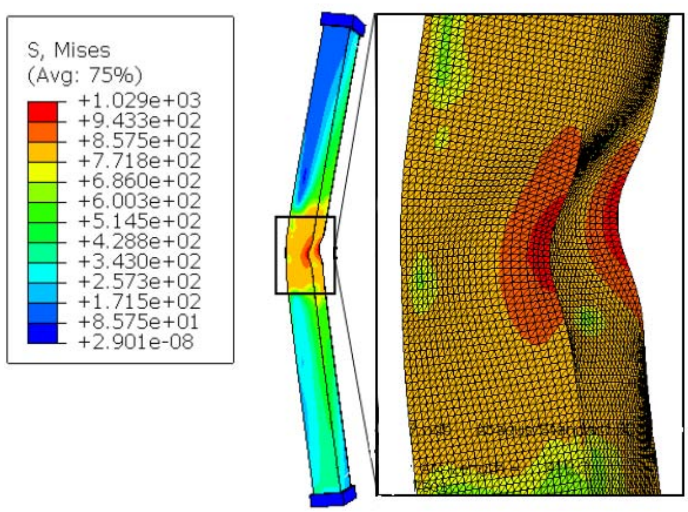


Figure 32: The buckling mode for the (US-5-4000) specimen

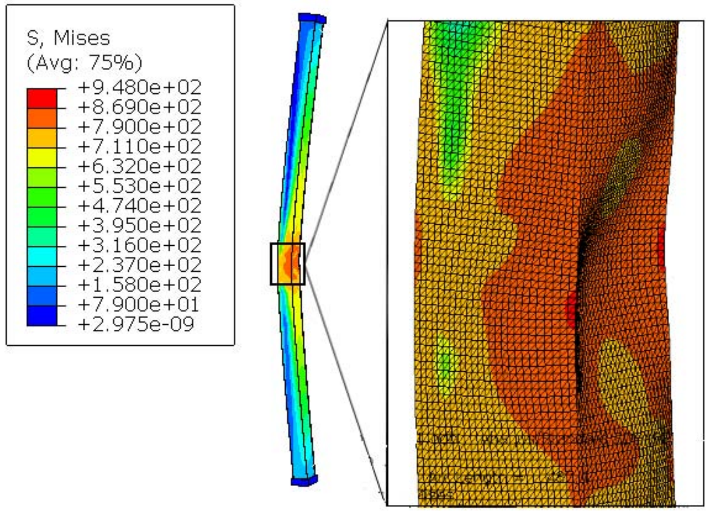


Figure 33: The buckling mode for the (US-5-7000) specimen

V. Development of Novel Analytical Equations

As a major result of the conducted analysis, novel equations to calculate the steel tube ultimate strength with either one or two stiffeners was presented. The proposed equations were deduced from the parametric study using data regression analysis. The strength ratio σ_{ult}/f_y, for hollow square sections stiffened with one stiffener can be calculated using Eq. (19). The α_y and α_{hs} are strength reduction factors according to the yield strength and stiffeners length, respectively. The values of α_y and α_{hs} are determined from the parametric study, as shown in Figure 29 and Figure 26.

$$\frac{\sigma_{ult}}{f_y} = \frac{7672}{779}\left(\frac{B}{t}\right)^{-0.62} + \alpha_{hs} + \alpha_y \tag{19}$$

Where; $\sigma_{ult}/f_y \leq 1$.

The reduction factors can be calculated as follows:

$$\alpha_y = 0.36 - 0.36\sqrt{\frac{f_y}{779}} \tag{20}$$

$$\alpha_{hs} = \left(-106.92\left(\frac{h_s}{B}\right)^2 + 35.95\frac{h_s}{B} - 2.88\right)\left(\frac{B}{t}\right)^{-0.472} \tag{21}$$

Furthermore, the strength ratio, σ_{ult}/f_y, for hollow steel sections stiffened with two stiffeners can be calculated using Eq. (22). Where β_y and β_{hs} are strength reduction factors according to the yield strength and stiffeners length, respectively. The value of β_y and β_{hs} are determined from the parametric study, as shown in Figure 30 and Figure 27.

$$\frac{\sigma_{ult}}{f_y} = \left(\frac{909}{779} \times e^{-\frac{4B}{1000t}}\right) + \beta_{hs} + \beta_y \tag{22}$$

Where $\sigma_{ult}/f_y \leq 1$

The reduction factors can be calculated as follows:

$$\beta_y = \sqrt{\frac{f_y}{779}}\left(0.13 - 0.0027\frac{B}{t}\right) + 0.0027\frac{B}{t} - 0.16 \tag{23}$$

If $\frac{B}{t} < 53 \beta_{hs}$ can be calculated as follows

$$\beta_{hs} = \left(-0.11\left(\frac{h_s}{B}\right)^2 + 0.04\frac{h_s}{B} - 0.004\right)\left(\frac{B}{t}\right)^{1.25} \tag{24}$$

And when $\frac{B}{t} \geq 53$

$$\beta_{hs} = \left(-23\left(\frac{h_s}{B}\right)^2 + 8\frac{h_s}{B} - 0.75\right)e^{-\frac{4B}{1000t}} \tag{25}$$

VI. Conclusions

This research aims to predict the behavior of hollow steel columns under monotonic loads and determine the effect of the main parameters on ultimate strength capacity. based on the study of verification, A parametric investigation was carried out to create three-dimensional finite element models that simulate the stiffened and unstiffened hollow steel columns under axial compression loads. These models focused on both the local and global buckling and were divided into two cases. Case 1, study effect of the local buckling on the ultimate strength and behavior for stiffened and unstiffened hollow steel short columns. Case 2, study the stiffeners' effect on the steel tube ultimate strength for long columns. The non-linear finite element (FE) analysis is used in the study to understand the effect of main structural parameters such as KL_e/r, stiffener length, the ratio of width-to-thickness B/t, and the yield stress on the hollow steel column performance. The conclusions that can be drawn are as follows:

1. The simulation of the behavior of hollow square columns using (FE) analysis can be done with about $(1:3)\%$ grade of accuracy. in addition to this, the (FE) analysis can reduce cost and time when compared with experimental work. The idealized elastic-plastic material model of the steel tube and the actual material models, as well as the actual initial imperfections and manufacturing errors in the real connections employed in experimental studies, were the main causes of the insignificant variations between the FEA results and experimental testing.
2. The study was conducted on the effect of the stiffeners length and proposed a novel equation to calculate the optimal stiffeners length in case of stiffened sections with one stiffener (SS) and stiffened sections with two stiffeners (DS) for short columns.
3. When increasing the width-to-thickness ratio (h_s/t) of stiffeners about the optimum stiffener length, the value of σ_{ult}/f_y decreases due to local buckling of the stiffener.
4. The current FE model produces good predictions of the steel box columns ultimate strength compared with the analytical methods. For the unstiffened steel tube columns, the average variation in the ultimate strength depending on the results from the present FE models and the effective width method by Uy[24] is about 4%. Furthermore, the average variation in the ultimate strength obtained from present FE models and the modified (DSM) is about 6%. While for stiffened columns, the average variation is around 6% between current FE models and the effective width method by Norsok. Thus, it can be concluded that the proposed method can accurately predict the ultimate load capacity of short columns.
5. As a major result of the conducted analysis, a novel equation to calculate the ultimate strength of box steel sections with one and two stiffeners was presented.
6. The presence of the stiffeners remarkably increases the ultimate strength of slender sections in the long columns. But on the other hand, it has no effect on the ultimate strength of compact sections.
7. The unstiffened columns with the ratio of width to thickness $B/t = 50$ and KL_e/r from 30 to 80 collapsed as a consequence of the combination of global and local buckling (G and L). In addition, these columns collapsed according to the global buckling when $KL_e/r > 80$. For stiffened sections with one stiffener, when the columns with $B/t = 50$ and $KL_e/r < 30$ collapsed by the local buckling only (L). In addition, these columns collapsed as a consequence of the combination of global and local buckling (G and L) when the $30 < KL_e/r < 51$.

References Références Referencias

1. L. Susanti, A. Kasai, and Y. Miyamoto, "Ultimate strength of box section steel bridge compression members in comparison with specifications," *Case Stud. Struct. Eng.,* vol. 2, no. 1, pp. 16–23, 2014, doi: 10.1016/j.csse.2014.07.001.
2. Z. Tao, L. H. Han, and Z. Bin Wang, "Experimental behaviour of stiffened concrete-filled thin-walled hollow steel structural (HSS) stub columns," *J. Constr. Steel Res.,* vol. 61, no. 7, pp. 962–983, Jul. 2005, doi: 10.1016/j.jcsr.2004.12.003.
3. M. A. Dabaon, M. H. El-Boghdadi, and M. F. Hassanein, "A comparative experimental study between stiffened and unstiffened stainless steel hollow tubular stub columns," *Thin-Walled Struct.,* vol. 47, no. 1, pp. 73–81, Jan. 2009, doi: 10.1016/j.tws.2008.05.008.
4. B. Somodi and B. Kövesdi, "Residual stress measurements on welded square box sections using steel grades of S235–S960," *Thin-Walled Struct.,* vol. 123, no. July 2016, pp. 142–154, 2018, doi: 10.1016/j.tws.2017.11.028.
5. M. Khan, B. Uy, Z. Tao, and F. Mashiri, "Concentrically loaded slender square hollow and composite columns incorporating high strength

properties," *Eng. Struct.,* vol. 131, pp. 69–89, 2017, doi: 10.1016/j.engstruct.2016.10.015.
6. F. Javidan, A. Heidarpour, X. L. Zhao, and J. Minkkinen, "Performance of innovative fabricated long hollow columns under axial compression," *J. Constr. Steel Res.,* vol. 106, pp. 99–109, 2015, doi: 10.1016/j.jcsr.2014.12.013.
7. K. M. El-Sayed, A. S. Debaiky, N. N. Khalil, and I. M. El-Shenawy, "Improving buckling resistance of hollow structural steel columns strengthened with polymer-mortar," *Thin-Walled Struct.,* vol. 137, no. November 2018, pp. 515–526, 2019, doi: 10.1016/j.tws.2018.12.029.
8. B. Zheng, G. Shu, F. Xie, and Q. Jiang, "Design of cold-rolled stainless steel rectangular hollow section columns," *J. Constr. Steel Res.,* vol. 170, p. 106072, 2020, doi: 10.1016/j.jcsr.2020.106072.
9. M. Anbarasu and M. Ashraf, "Interaction of local-flexural buckling for cold-formed lean duplex stainless steel hollow columns," *Thin-Walled Struct.,* vol. 112, no. December 2016, pp. 20–30, 2017, doi: 10.1016/j.tws.2016.12.006.
10. M. Nassirnia, A. Heidarpour, X. L. Zhao, and J. Minkkinen, "Innovative hollow columns comprising corrugated plates and ultra high-strength steel tubes," *Thin-Walled Struct.,* vol. 101, pp. 14–25, 2016, doi: 10.1016/j.tws.2015.12.020.
11. M. Longshithung Patton and K. Darunkumar Singh, "Buckling of fixed-ended lean duplex stainless steel hollow columns of square, L-, T-, and +-shaped sections under pure axial compression - A finite element study," *Thin-Walled Struct.,* vol. 63, pp. 106–116, 2013, doi: 10.1016/j.tws.2012.09.003.
12. N. Schillo and M. Feldmann, "Interaction of local and global buckling of box sections made of high strength steel," *Thin-Walled Struct.,* vol. 128, no. March, pp. 126–140, 2018, doi: 10.1016/j.tws.2017.07.009.
13. L. Pavlovčič, B. Froschmeier, U. Kuhlmann, and D. Beg, "Finite element simulation of slender thin-walled box columns by implementing real initial conditions," *Adv. Eng. Softw.,* vol. 44, no. 1, pp. 63–74, 2012, doi: 10.1016/j.advengsoft.2011.05.036.
14. E. Ellobody, "Buckling analysis of high strength stainless steel stiffened and unstiffened slender hollow section columns," *J. Constr. Steel Res.,* vol. 63, no. 2, pp. 145–155, 2007, doi: 10.1016/j.jcsr.2006.04.007.
15. S. J. Hilo, S. M. Sabih, M. M. Faris, and A. W. Al-Zand, "Numerical Investigation on the Axial Load Behaviour of Polygonal Steel Tube Columns," *Int. Rev. Civ. Eng.,* vol. 13, no. 5, pp. 397–408, 2022, doi: 10.15866/irece.v13i5.20548.
16. T. G. Singh and K. D. Singh, "Design of perforated cold-formed steel hollow stub columns using direct strength method," *Thin-Walled Struct.,* vol. 168, no. July, p. 108265, 2021, doi: 10.1016/j.tws.2021.108265.
17. H. Ban, G. Shi, Y. Shi, and Y. Wang, "Residual stress of 460 MPa high strength steel welded box section: Experimental investigation and modeling," *Thin-Walled Struct.,* vol. 64, pp. 73–82, 2013, doi: 10.1016/j.tws.2012.12.007.
18. X. Cao, Y. Xu, M. Wang, G. Zhao, L. Gu, and Z. Kong, "Experimental study on the residual stresses of 800 MPa high strength steel welded box sections," *J. Constr. Steel Res.,* vol. 148, pp. 720–727, 2018, doi: 10.1016/j.jcsr.2018.06.019.
19. J. R. Association, "Specifications for highway bridges, Part V," *Earthq. Resist. Des.,* vol. 228, no. September, 1996.
20. A. I. of S. Construction, "Specification for Structural Steel Buildings," pp. 1–612, 2010.
21. N. Standard, "National Standard of the People's Republic of China Notice on Ministry of Housing and Urban-Rural Development," 2003.
22. L. Guo, S. Zhang, W. J. Kim, and G. Ranzi, "Behavior of square hollow steel tubes and steel tubes filled with concrete," *Thin-Walled Struct.,* vol. 45, no. 12, pp. 961–973, Dec. 2007, doi: 10.1016/j.tws.2007.07.009.
23. Z. Tao, Z. Bin Wang, and Q. Yu, "Finite element modelling of concrete-filled steel stub columns under axial compression," *J. Constr. Steel Res.,* vol. 89, pp. 121–131, 2013, doi: 10.1016/j.jcsr.2013.07.001.
24. B. Uy, "Local and post-local buckling of concrete filled steel welded box columns," *J. Constr. Steel Res.,* vol. 47, no. 1–2, pp. 47–72, 1998, doi: 10.1016/S0143-974X(98)80102-8.
25. American Iron and Steel Institute, "AISI S100: North American Specification for the Design of Cold-Formed Steel Structural Members (with commentaries)," p. 505, 2016.
26. H. Fang and T. M. Chan, "Axial compressive strength of welded S460 steel columns at elevated temperatures," *Thin-Walled Struct.,* vol. 129, no. March, pp. 213–224, 2018, doi: 10.1016/j.tws.2018.04.006.
27. Norsok-Standard, "Norsok Standard M-001," no. Rev.4, 2004.
28. von Karman T, Sechler EE, Donnel LH. Strength of thin plates in compression. Trans ASME 1932;54:53.
29. Winter G. Strength of thin steel compression flanges. Reprint No. 32. Ithaca, NY, USA: Cornell University Engineering Experimental Station, 1947.
30. A. I. of S. Construction "Specification for Structural Steel Buildings" Q., vol. 37, no. 2, pp. 169–170, 2017, doi: 10.1080/10462937.2017.1349256.
31. ABAQUS. Standard user's manual, version 2017. Providence, RI (USA): Dassault Systems Corp.; 2017.

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Seismic Behaviour of Tall Structures with RC Shear Walls and Columns Configuration by ETABS (2021)

By Bimlendu K Gautam & Abhay K Jha

Abstract- Shear wall System Commonly used in the Tall Structures to resist/Sustain the Lateral forces Exerted due to Winds, Earthquakes, Due to Shear Wall's high in-Plane Stiffness and Simultaneously has Capacity to take Gravity Loads, Inclusion of Shear Wall has become very inevitable in Tall Structures to resist Lateral forces. It is important & necessary to Find the Structural Configuration is effectively Safe or not. Hence In this article, The Structural analysis is conducted on Basement+G+31 Tall Building of Total Height of 108m in order to determine the Base Shear, Maximum Storey Displacement, Maximum Storey Drifts, Storey Shears, Overturning Moments and Axial Forces over the Critical Load Combination. For this Purpose, different zones are selected to investigate the effect of Lateral Forces, If Building is Either on Shear Wall Configuration or on Column Configuration. A detailed study on behaviour of both columns and RC Shear Wall is conducted with eight model made on CSI ETABS (2021) Software in the present study.

Keywords: RC shear wall, base shear, max. storey drift, max. storey displacement, storey shear, response spectrum method.

GJRE-E Classification: FOR Code: 0905

SEISMICBEHAVIOUROFTALLSTRUCTURESWITHRCSHEARWALLSANDCOLUMNSCONFIGURATIONBYETABS2021

Strictly as per the compliance and regulations of:

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Bimlendu K Gautam [α] & Abhay K Jha [σ]

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Keywords: RC shear wall, base shear, max. storey drift, max. storey displacement, storey shear, response spectrum method.

I. Introduction

Shear walls are essential structural components that effectively withstand both gravity and lateral loads exerted on buildings. Their primary function is to provide lateral stiffness to buildings, thereby effectively resisting seismic forces that may arise from an earthquake. They provide lateral support for buildings. Shear walls are generality important in tall/high-rise buildings subjected to wind, seismic and other lateral forces. They are constructed from the foundation to the top story. Shear walls resist shear forces and uplift forces. Shear walls transfer horizontal forces to other components in the load path. They should be located on each level of the structure. Shear walls can have openings for windows and doors. The size and location of Shear Wall affects the seismic response. Owing to their numerous benefits to structural design, shear walls have become increasingly popular in building construction. However, their placement is crucial and requires careful evaluation. Ideally, in a floor layout, shear walls should be positioned as close as possible to the center of mass to prevent any additional moments that may arise otherwise. Therefore, it is imperative to utilize the appropriate number of shear walls with the appropriate cross-sectional area.

This study investigates the story Response parameters in all seismic zones using Shear Wall and Columns in RC framed structures. G+31 buildings are considered in different seismic seismic of India. Finite element software ETAB v 21 is used for analysis.

II. Objective

To analyse/Investigate the Seismic Behavior of the B+G+31 building of 108m height on Shear Wall and Column Configuration by Etabs software and find various parameter such as Max. Story Displacement, peak story shear, base shear, axial forces, Overturning Moment and story drift, in all seismic zones using Linear Dynamic Method on FEM based software as per IS 1893 (Part-I): 2016.

III. Methodology

In general Structures are analysed in Software for finding more frequent results for multiple iterations, Therefore, A building is analysed in Etabs Software Which is FEM Based and Having good UI. Linear Dynamic Method (Response Spectrum) used for analysis on multiple modes (Shapes).

A General Outline of the method is used as below:

Selected a Real geometry of almost Square Shape and Done the Analytical modelling on Etabs, followed through the assignments of defined x-sections, Loads and their Combinations, Diaphragm, Support

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Conditions at base. And Lastly Analysed the structure on Selected Modes and Load Combinations.

a) Present Work Description

Taking a B+G+31 story Tall building, modelled and Analysed in ETABS 2021. Analysis Done on both option either building will be analysed on columns or on Shear Wall. So, in this Study, comparison of Parameters Like Max. Story Displacement, Max. Story drift, Story Shear, Base Shear, Overturning Moment, Axial Force is done on the both of the Structural System.

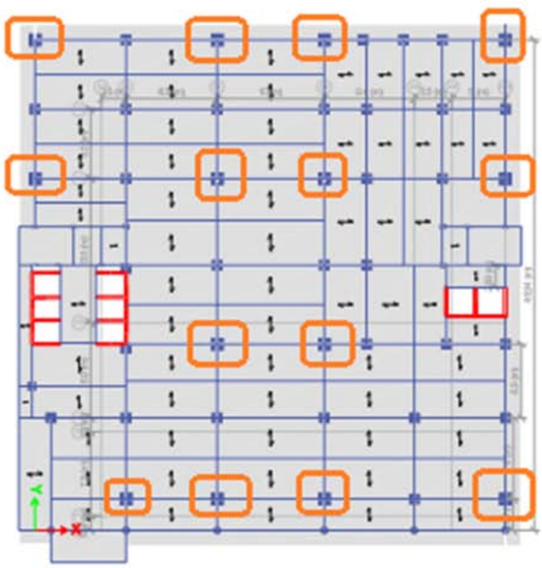


Figure 1: Plan With Column

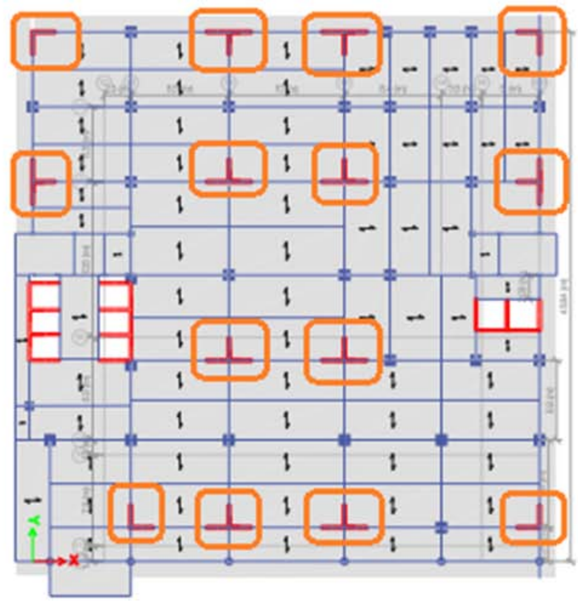


Figure 2: Plan With Shear Wall

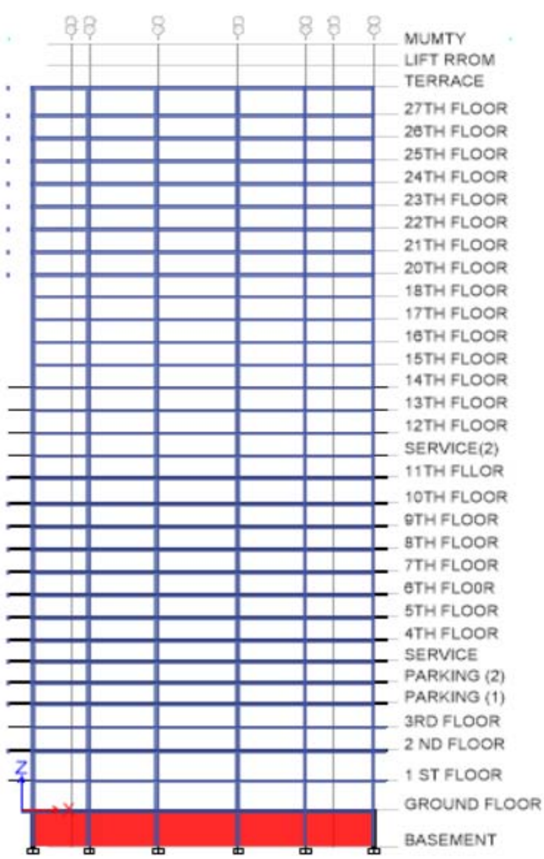


Figure 3: Elevation With Column

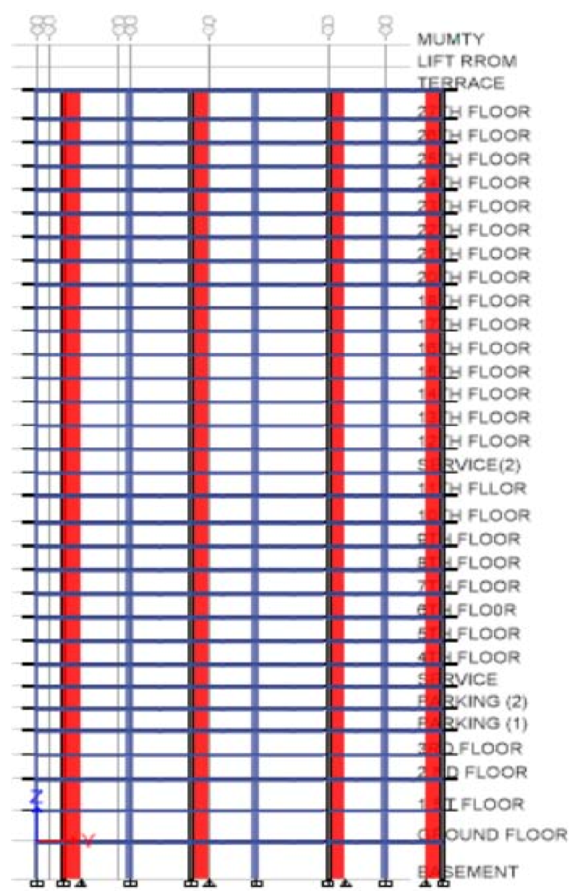


Figure 4: Elevation With Shear Wall

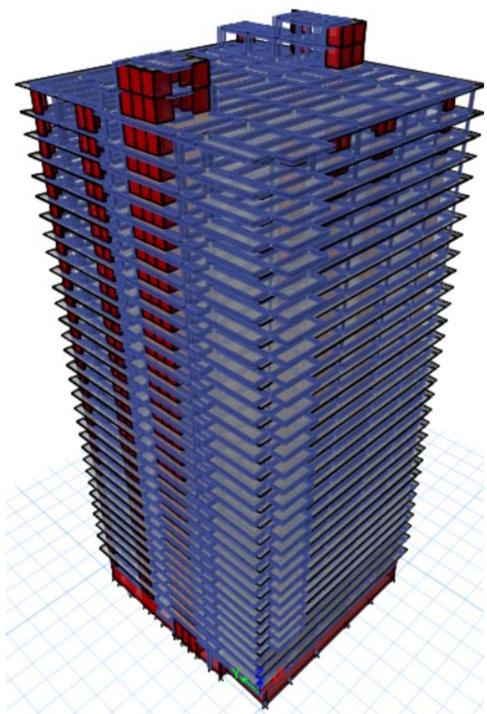


Figure 5: Bird Eye View (Extruded) With Column

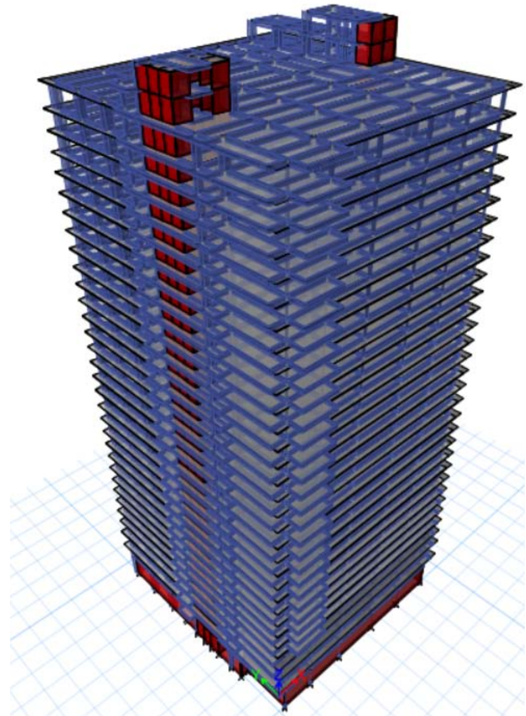


Figure 6: Bird Eye View (Extruded) With Shear Wall

b) *Specification of the Model*

Following data used for analysis of as above mentioned RC frame building model.

Table 1: Building Specification

SPECIFICATION	DATA
Model	B+G+31
Plan Size	43mx44m
Total Building Height	108m
Floor to Floor Height	(5.2x1)+(4.2x2)+(3.35x2)+(3.0x3)+(3.2x6)+3.6+(3.2x16)+3.9+(3x2)
No. of bays along, X-direction	5
No. of bays along, Y-direction	6
Column size	1200x1200,1000x1000, 600 dia.
Beam size	200x500, 300x500,300x600,400x600
Slab Thickness	150mm
Shear wall Thickness	400thk., 300thk.(For Lift only)
Inner Wall Thickness	230mm AAC Block (Density- 1000kg/m3)
Outer wall	230mm AAC Block (Density- 1000kg/m3)

Table 2: Material Property

SPECIFICATION	DATA
Grade of Concrete	For Column/Shear Wall- M40
	For Slabs/ Beams -M30
Grade of Steel	Fe500
Density of Brick	1000Kg/m3
Unit weight of RCC	2500kg/m3

Table 3: Seismic Parameters

SPECIFICATION	DATA
Seismic Zone	Zone II, III, IV & Zone V
Zone Factor corresponding to seismic zone	0.1,0.16 ,0.24,0.36 (as per table 2 of IS:1893(Part-1-2016)
Importance Factor	1.2 (as per table 6 of IS:1893(Part-1-2016)
Response Reduction Factor	3 (as per table 7 of IS:1893(Part-1)-2016)
Type of frame	Ordinary RC moment resisting frame (as per Table-7; IS 1893:2016)
Damping Ratio	5%
Soil Type	Medium Soil (Type II)

c) *Load Calculations*

1. *Dead load* (Table 2 as per IS 875(part1):1987)

➢ *On floor slabs:*

Self-weight => 0.150 * 25 =3.725 KN/m^2
Partition wall (assumed) = 6.4 KN/m
Floor finish (assumed) = 1.5 KN/m^2
DL on floors => 3.725 + 1.5 = 5.25 KN/m^2
(As per clause 7.3.1, table 8 of IS1893 (part 1): 2016, for imposed uniformly distributed floor loads of 3KN/m^2 or below, the % age of imposed load is 25%.)
Total DL on the floor => 5.25 + (50/100) x4 = 7.25 KN/m^2

➢ *On roof slabs:*

Self-weight => 0.150 * 25 =3.725 KN/m^2
Floor finish (assumed) = 1.5 KN/m^2
DL on floors => 3.725 + 1.5 = 5.25 KN/m^2
(As per clause 7.3.2 of IS 1893 (part 1): 2016, for calculating the design seismic force of the structure, the superimposed load on top roof need not to be considered.)
Total DL on roof =5.25 KN/m^2

2. *Live load* (Table 1 as per IS 875(part 2):1987)

Live load on floors = 4 KN/m^2
Live load on roof = 4 KN/m^2

3. *Seismic Calculations (Linear Dynamic Method)*

Response Spectrum Analysis: Qik =Ak ωik Pk Wi

Where, Qik is Design lateral force at the floor I in mode k.
Ak is the Design horizontal acceleration spectrum value for the mode k of vibration.
ωik is Mode Shape coeff. at a Floor I in mode k.
Pk Modal Participation factor of the mode k.
Wi Seismic weight of the floor i.

User will provide Ak and Wi. In these Ak can be provided by specifying Seismic parameter configuration. Wi can be provided by specifying self-weight contribution in X, Y, Z direction with factor 1 and dead load and appropriate live load in all three directions. Response Spectrum Method **53** of analysis shall be performed using the Design Spectrum-

ETABS utilizes following procedure to generate the lateral seismic loads:

- User provides the value of Z I as factors for input spectrum. 2 R
- Program calculates time period for the first 12 modes or as specified by the user.
- Program calculates S_a/g for each and every mode in respect of time period & damping.
- The program calculates design horizontal acceleration spectrum A_k for different modes.
- The program also calculates mode participation factor for different modes.
- The Peak lateral seismic force at every floor in each mode is calculated.
- All the response values for each mode are calculated.

The peak response values are combined as per method (ABS or SRSS or CSM or CQC or TEN) as defined by the user to find the final results for modes.

- The Design Base shear VB (Calculated from the Response Spectrum Method) is compared with the base shear Vb (Calculated by empirical formula for fundamental time period).
- If VB is less than Vb, all of the values (Response) are multiplied by Vb/VB as per clause 7.8.2 (IS1893:2016).

Calculation of Time Period

$Ta=0.09h/\sqrt{d}$
Where h = 108m
d = 44
Ta=1.4661 sec
As per IS Code 1893 (part-1) – 2016.

The Design Horizontal Seismic Coeff.(Cl. 6.4.2/ IS1983:2016)

Ah= {(Z/2)*(Sa/g)}/(I/R)
I=1.2, R=3, Sa/g= 1.36/Ta
Case I (Zone II, Z=0.1) Ah=0.115
Case II (Zone III, Z=0.16) Ah=0.184
Case III (Zone IV, Z=0.24) Ah=0.276
Case IV (Zone V, Z=0.36) Ah=0.414

The Design Seismic Acceleration Spectral Value (Cl. 6.4.6/ IS1983:2016)

Av= {(.667*Z/2)*2.5}/(R/I)
I=1.2, R=3
Case I (Zone II, Z=0.1) Av=0.0670
Case II (Zone III, Z=0.16) Av=0.1072
Case III (Zone IV, Z=0.24) Av=0.161
Case IV (Zone V, Z=0.36) Av=0.24

d) Load Combinations

Load combinations that are to be used for Limit state Design (LSM) of reinforced concrete structure are listed below.1.5(DL+LL)

1. 1.2(DL+LL+EQX)
2. 1.2(DL+LL+EQ-X)
3. 1.2(DL+LL+EQZ)
4. 1.2(DL+LL+EQ-Z)
5. 1.5(DL+EQX)
6. 1.5(DL-EQX)
7. 1.5(DL+EQZ)
8. 1.5(DL-EQZ)
9. 0.9DL+1.5EQX
10. 0.9DL-1.5EQX
11. 0.9DL+1.5EQZ
12. 0.9DL-1.5EQZ

IV. Result and Discussion

Results are extract and study about the Parameters like Maximum Story Displacements, drifts, story shear, Overturning moments, base shear and axial forces. By these results, These Story Response parameters will be discussed which affect the tall structures.

Table 4: Model Cases

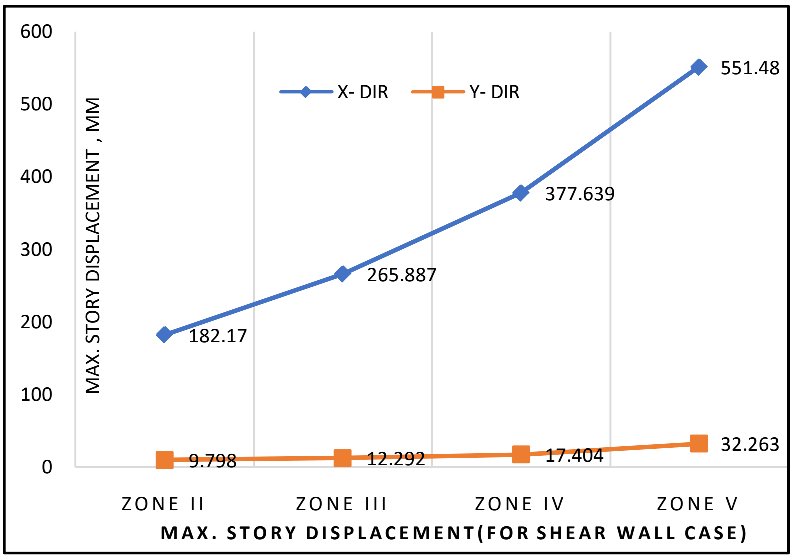
4.1.1.	Case I- Shear Wall & Seismic Zone II
4.1.2.	Case II- Shear Wall & Seismic Zone III
4.1.3.	Case III- Shear Wall & Seismic Zone IV
4.1.4.	Case IV- Shear Wall & Seismic Zone V
4.1.5.	Case V- Column & Seismic Zone II
4.1.6.	Case VI- Column & Seismic Zone III
4.1.7.	Case VII- Shear Wall & Seismic Zone IV
4.1.8.	Case VIII- column & Seismic Zone V

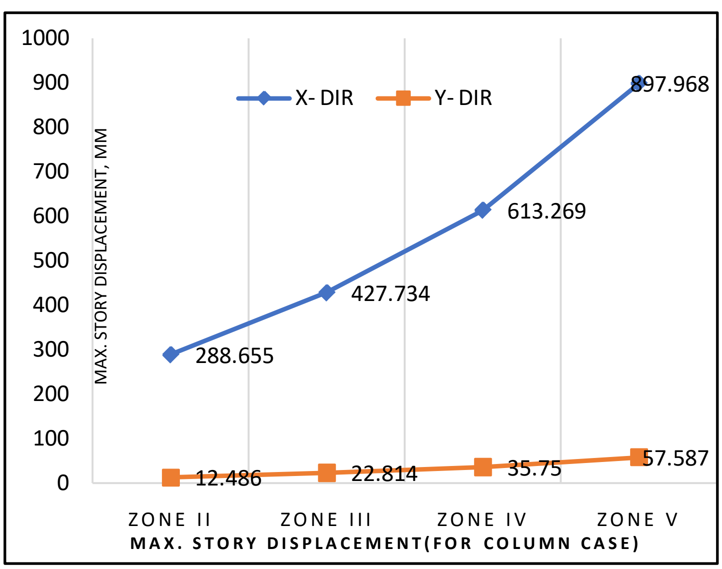
a) Story Response - Maximum Story Displacement

Maximum Story Displacement Defined as Displacement occurred at each story level, generally high rise/multi-storey/tall Buildings, has maximum storey displacements at top floors, as height increases story displacements increases. Following are the Result extractions from model done in Etabs 2021, for the story response- Max. Story displacement. This Parameter is being analyzed for Critical Load Combination is 1.5DL-1.5 Eqx.

Table 5: Summary of Max. Storey Displacments

SUMMARY OF MAX. DISPLACEMENT				
CRITICAL CASE 1.5 DL-1.5EQX				
	ON SHEAR WALL		ON COLUMN	
	X- DIR	Y- DIR	X- DIR	Y- DIR
ZONE II	182.17	9.798	288.655	12.486
ZONE III	265.887	12.292	427.734	22.814
ZONE IV	377.639	17.404	613.269	35.75
ZONE V	551.48	32.263	897.968	57.587





b) Max. Story Drift

Story Response - Maximum Story Drift Story Drift is defined as relative (Inter-storey) displacement between the stories. Higher Drift Causes the horizontal displacement of the story/building in the case of lateral forces application like earthquake and winds. Building sway laterally in case of higher drift occurred.

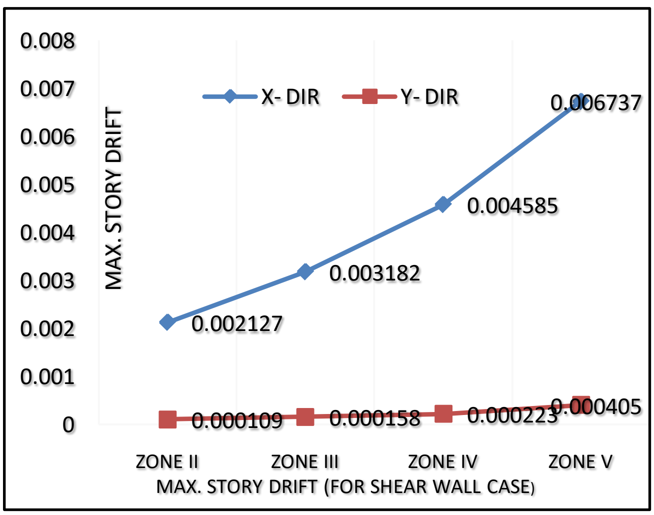
Total drift of th i floor $= \Delta i$ Inter-storey drift of i floor $(\delta)\ i = \Delta\ i - \Delta\ (i-1)$

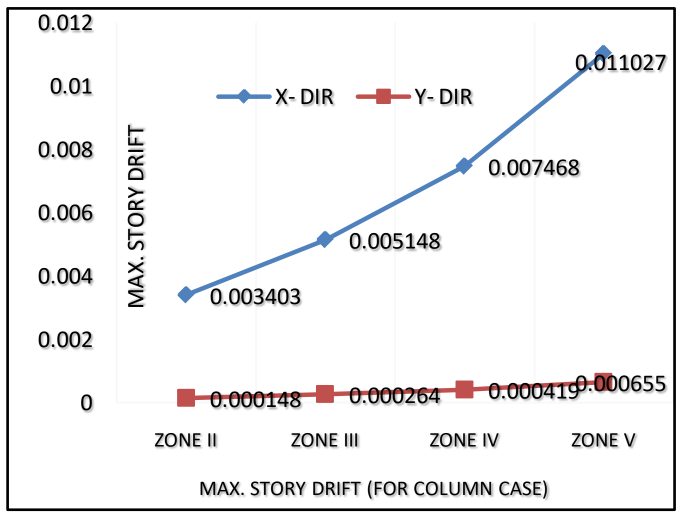
Drift Index Drift Index = deflection/height

Following are the Result extractions from model we did in Etabs 2021, for the story response- Max. Story Drift. Followings are the tables and their graphs in eight cases, are formed for the analysis for critical case 1.5DL-1.5Eqx.

Table 6: Summary of Max. Storey Drifts

SUMMARY OF MAX. DRIFT				
CRITICAL CASE 1.5 DL-1.5EQX				
	ON SHEAR WALL		ON COLUMN	
	X- DIR	Y- DIR	X- DIR	Y- DIR
ZONE II	0.002127	0.000109	0.003403	0.000148
ZONE III	0.003182	0.000158	0.005148	0.000264
ZONE IV	0.004585	0.000223	0.007468	0.000419
ZONE V	0.006737	0.000405	0.011027	0.000655





c) Story Shear

Story Response – Story Shear Defined as the Forces acting on each story of the building due to lateral forces like wind and earthquakes.

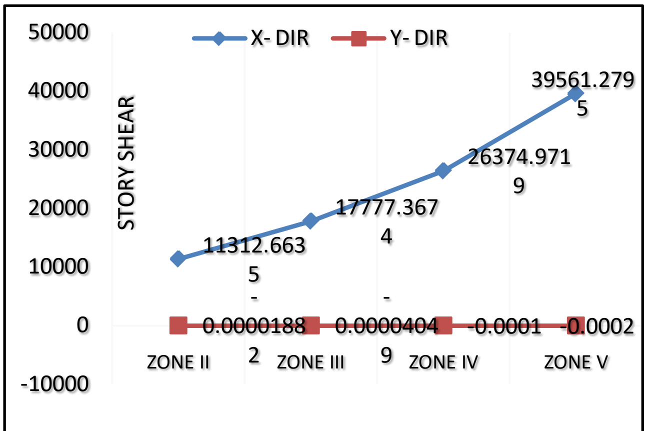
Building having lesser stiffness have lesser story shear on each level of building and vice versa.

Following are the Result extractions from model we did in Etabs 2021, for the story response-Story Shear.

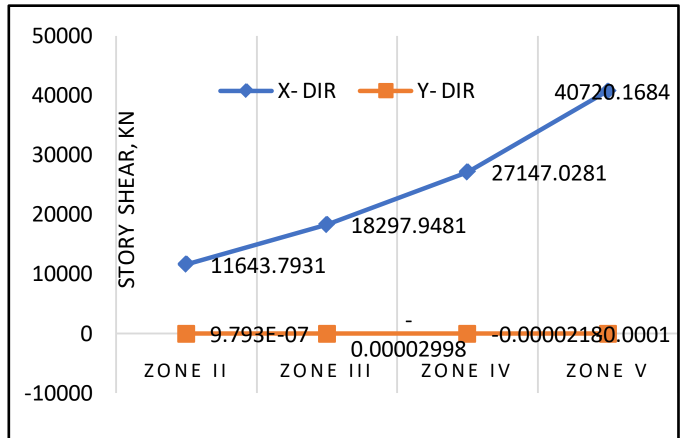
Followings are the tables and their graphs in eight cases, are formed for the analysis for critical case 1.5DL-1.5Eqx.

Table 7: Summary of Max. Storey Shear

SUMMARY OF STORY SHEAR				
CRITICAL CASE 1.5 DL-1.5EQX				
	ON SHEAR WALL		ON COLUMN	
	X- DIR	Y- DIR	X- DIR	Y- DIR
ZONE II	11643.7931	9.793E-07	11312.6635	-0.00001882
ZONE III	18297.9481	-0.00002998	17777.3674	-0.00004049
ZONE IV	27147.0281	-0.0000218	26374.9719	-0.0001
ZONE V	40720.1684	-0.0001	39561.2795	-0.0002



MAX. STORY SHEAR (FOR COLUMN CASE)



MAX. STORY DRIFT (FOR SHEAR WALL CASE)

d) Overturning Moment

Story Response - Maximum Overturning Moments

Overturning moment defined as the Total moment of building with developed through Lateral forces applications.

Overturning moment in x- direction = Seismic Force in X-Dir x Height of building from N.G.L

Overturning moment in Y- direction = Seismic Force in Y-Dir x Height of building from N.G.L

Following are the Result extractions from model we did in Etabs 2021, for the story response- Max. Overturning Moment.

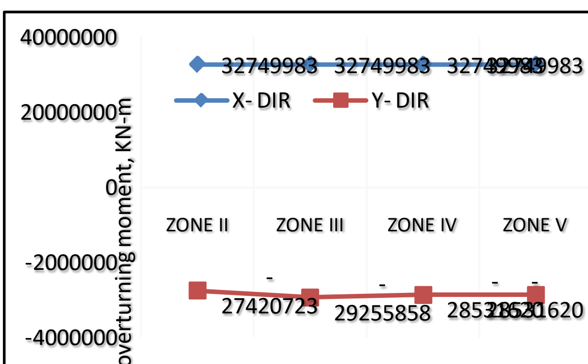
This is nothing but the torsion generated over the building due to lateral forces.

Basically, this is the moment that turns building with the central axis due to forces causes due to lateral forces at each of the story.

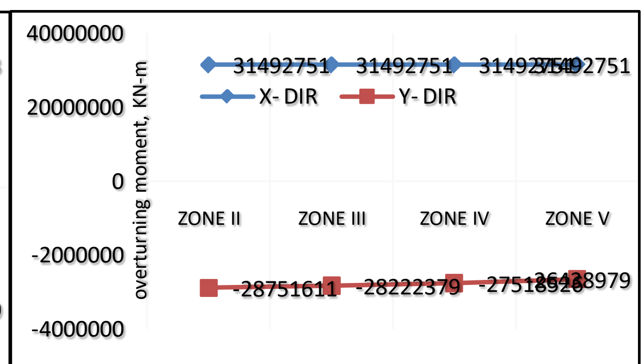
Torsional rigidity can be seen if overturning moments are lesser in below cases.

Followings are the tables and their graphs in eight cases, are formed for the analysis for critical case 1.5DL-1.5Eqx.

Table 8: Summary of Overturning Moment



Overturning Moment (FOR SHEAR WALL CASE)



Overturning moment (FOR COLUMN CASE)

e) Base Shear

Base Shear is defined as Total Force act at foundation level or lowest level of building due Seismic Building Weight.

Base Shear = Seismic Weight of the Building x Design Horizontal Coeff.(A_h)

$$V_B = A_h \times W$$

$$Ah = \frac{Z}{2}\,\frac{I}{R}\,\frac{Sa}{g}$$

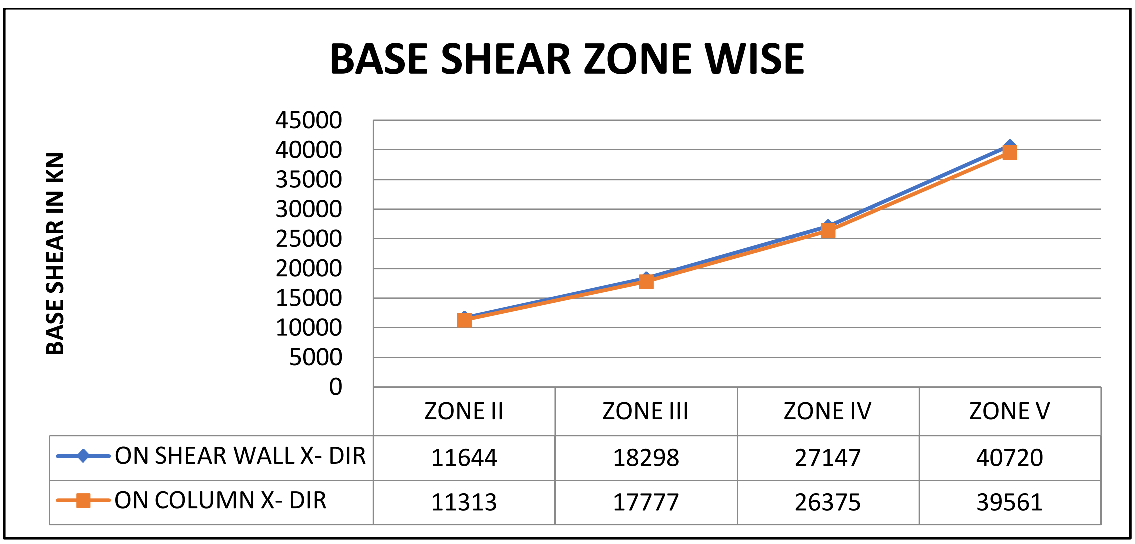
Where,

A_h is the outline flat seismic coefficient, which relies upon the seismic zone factor (Z), response reduction factor (R), importance factor (I), and the normal reaction speeding up coefficients (S_a/g). S_a/g thus establishment relies upon the idea of soil (shake, medium or delicate soil site), characteristic span and damping of the structure. Followings are the tables and their graphs in eight cases, are formed for the analysis for critical case 1.5DL-1.5Eqx.

Table 9: Summary of Base Shear

Max. Base Shear in Shear Wall Case	Shear Wall Zone II	Shear Wall Zone III	Shear Wall Zone IV	Shear Wall Zone V
Critical Case	KN	KN	KN	KN
1.5DL-1.5EQ+X	11644	18298	27147	40720

Max. Base Shear in Column Case	Column Zone II	Column Zone III	Column Zone IV	Column Zone V
Critical Case	KN	KN	KN	KN
1.5DL-1.5EQ+X	11313	17777	26375	39561

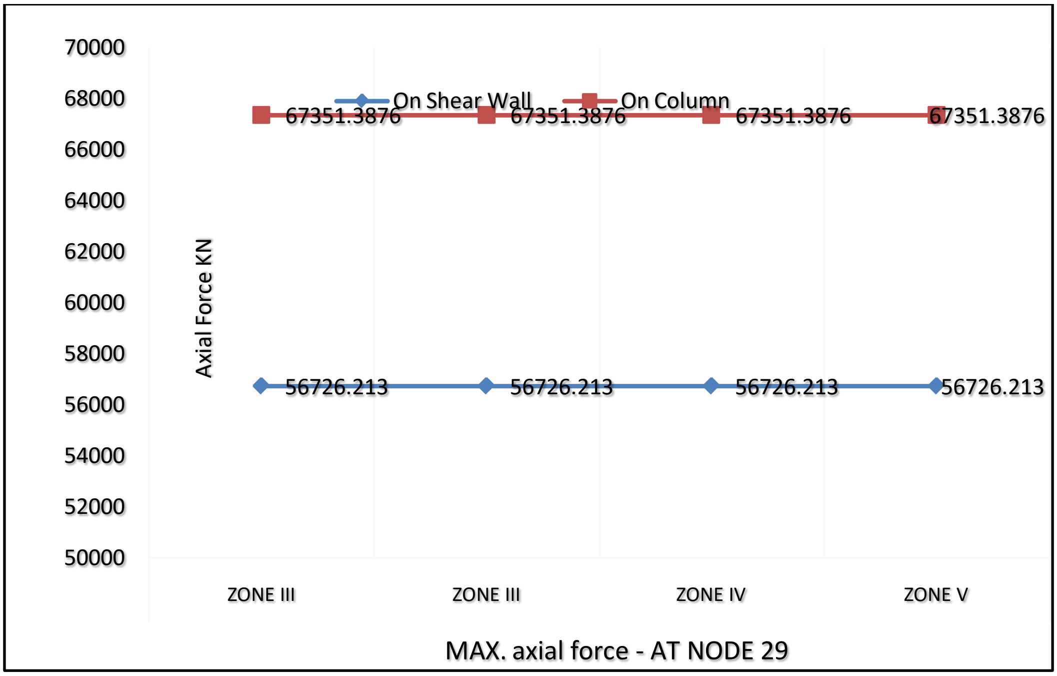


f) Max. Axial Force

Followings are the tables and their graphs in eight cases, are formed for the analysis for critical case 1.5DL+1.5LL. At node no 29 in critical case, max. Individual axial force is found in all eight cases.

Table 9: Summary of Max. Axial Force

		On Shear Wall	On Column	% DIFFRENCE
MAX. FZ (AXIAL REACTION-KN)	ZONE III	56726.213	67351.3876	-19%
	ZONE III	56726.213	67351.3876	-19%
	ZONE IV	56726.213	67351.3876	-19%
	ZONE V	56726.213	67351.3876	-19%



g) Discussion on Results

1. Max. Storey Displacement- As the seismic zones increases, Maximum story displacement increases in both cases either Building Analyzed on shear wall or on columns, When Critical Load Combination found 1.5DL-1.5EQx, In Various Zones II, III, IV, V the max. Story displacement found 37%, 38%, 38%, 39% lesser Value in case of Building being analyzed on Shear wall respectively. Building's max. Story displacement is under allowable limit. As per IS 1893:2016).
2. Max. Storey Drift- As the seismic zones increases, Maximum story displacement increases in both cases either Building Analyzed on shear wall or on columns, When Critical Load Combination found 1.5DL-1.5EQx, In Various Zones II, III, IV, V the max. Story drift found 37%, 38%, 38%, 39% lesser Value in case of Building being analyzed on Shear wall respectively. Building's max. Story drift is under allowable limit. As per IS 1893:2016).
3. Story Shear- As the seismic zones increases, Story Shear increases in both cases either Building Analyzed on shear wall or on columns, When Critical Load Combination found 1.5DL-1.5EQx, In Various Zones II, III, IV, V the max. Story Shear found 3%, greater Value in each zone, Building being analyzed on Shear wall respectively. Story Shear Found Greatest in Value on Ground floor.
4. Story Overturning Moment- As the seismic zones increases, No Change in Story Overturning Moment in both cases either Building Analyzed on shear wall or on columns, When Critical Load Combination found 1.5DL-1.5EQx, In Various Zones II, III, IV, V the max. Story Overturning Moment found 4%, greater Value in each zone Building being analyzed on Shear wall respectively. Story Overturning Moment Found Greatest in Value on Ground floor.
5. Base Shear- As the seismic zones increases, Base Shear increases in both cases either Building Analyzed on shear wall or on columns, When Critical Load Combination found 1.5DL-1.5EQx, In Various Zones II, III, IV, V the max. Base Shear found 3%, greater Value in each zone, Building being analyzed on Shear wall respectively. Base Shear Found Greatest in Value on Basement Level.
6. Axial force/Reaction- As the seismic zones increases, No Change in Axial Force in both cases either Building Analyzed on shear wall or on columns, When Critical Load Combination found 1.5DL+1.5LL, In Various Zones II, III, IV, V the max. axial force found 19%, lesser Value in each zone Building being analyzed on Shear wall respectively. At Column/Node No. 29 max. axial force Found.

V. Conclusion/Summary and Findings

Based on the result obtained the following conclusions can be drawn by Etabs 2021.

1. Maximum Story Displacement found 38% average lesser if Building Analyses over Shear Wall in comparison of as on Column.
2. Maximum Storey Displacement Found at 108m lvl. For critical case 1.5DL-1.5Eqx
3. Max. Storey displacements is min. In Zone II (Shear Wall case) is 182.17mm and maximum in Zone V (Column Case) is 897.968mm. This Building is Safe Up to Zone IV for Shear Wall Case and Safe up to Zone III for Column Case. (Refer Table no. 4.10)
4. As Inter Max. storey Displacements or Max. Story Drifts relates with Storey Displacements, Max.

Storey Drift Found 38% average lesser if Building Analyses over Shear Wall in comparison of as on Column.

5. Maximum Storey Drift Found at 46.9 m lvl. In each of Model Case, For critical case 1.5DL-1.5Eqx
6. Max. Storey Drift is min. In Zone II (Shear Wall case) is .00212 and maximum in Zone V (Column Case) is 0.011027. This Building is Safe Up to Zone IV for Shear Wall Case and Safe up to Zone II for Column Case. (Refer Table no. 4.19)
7. Storey Shear Found 3% greater if Building Analyses over Shear Wall in comparison of as on Column, Which is Marginal.
8. Storey Shear Found Greatest in Value at Ground Floor 0.00 m Lvl. In each of Model Case, For critical case 1.5DL-1.5Eqx
9. Storey Shear is min. In Zone II (Column case) is 11312.6 kN and maximum in Zone V (Shear Wall Case) is 40720.17 kN. (Refer Table no. 4.28)
10. Storey Overturning moment Found 4% greater if Building Analyses over Shear Wall in comparison of as on Column, Which is Marginal.
11. Storey overturning moment Found Greatest in Value at Ground Floor 0.00 m Lvl. In each of Model Case, For critical case 1.5DL-1.5Eqx
12. Storey overturning moment is min. In Column case is 31492751 kN-m and maximum in Shear Wall Case is 32749983 kN-m. (Refer Table no. 4.37) for Each Seismic Zone.
13. Base Shear Found 3% greater if Building Analyses over Shear Wall in comparison of as on Column, which is Marginal.
14. Base Shear is min. in Zone II (Column case) is 11313 kN and maximum in Zone V (Shear Wall Case) is 40720 kN. (Refer Table no. 4.40), Which is Greatest in Value at foundation/Base Floor -5.2 m Lvl. In each of Model Case, For critical case 1.5DL-1.5Eqx.
15. Maximum Axial force/Reaction found 19% Lesser if Building Analyses over Shear Wall in comparison of as on Column, at Node/Column No. 29, for Critical Case 1.5DL+1.5LL. (Refer Table no. 4.41)
16. Hence, If all above conclusion taken in the Consideration, Shear wall performs/behaves better than Column comparatively in case of tall Structure. To provide better safety against Maximum Story displacement, Maximum Story Drift, Story Shear, Maximum Overturning Moment, Base shear and Axial Reaction shear wall Configuration is Recommended to use.
17. For deliver more safety in the building in All Seismic Zone, Parametric Properties of Shear Wall can be improved.

References Références Referencias

1. Anshuman S, Dipendu Bhunia, Bhavin Ramjiyani, Solution of Shear Wall Location in Multi-Storey Building International Journal of Civil & Structural Engineering, 2011, Volume 2, Issue 2, Online ISSN: 0976-4399.84
2. Bureau of Indian Standards: IS-1893, part 1 (2016), “Criteria for Earthquake Resistant Design of Structures: Part 1 General provisions and Buildings”, New Delhi, India.
3. Bureau of Indian Standards: IS-875, part 1 (2015), dead loads on buildings and Structures, New Delhi, India.
4. Bureau of Indian Standards: IS-875, part 2 (2015), live loads on buildings and Structures, New Delhi, India.
5. Bureau of Indian Standards: IS-875, part 3 (2015), Wind loads on buildings and Structures, New Delhi, India.
6. Bureau of Indian Standards: IS-456, (2000), Design of Reinforced Concrete, New Delhi, India.
7. H.-S. Kim, D.-G. Lee, Analysis of shear wall with openings using super elements, Engineering Structures, Volume 25, Issue 8, 2003, Pages 981-991, ISSN 0141-0296, https://doi.org/10.1016/S0141-0296(03)00041-5.
8. Hyun-Su Kim, Dong-Guen Lee, Chee Kyeong Kim, Efficient three-dimensional seismic analysis of a high-rise building structure with shear walls, Engineering Structures, Volume 27, Issue 6, 2005, Pages 963-976, ISSN 0141-0296, https://doi.org/10.1016/j.engstruct.2005.02.006.
9. Kushalkumar Yadav, R. L. Sharma (2023) Dynamic Analysis of Multi-Storey Building for Minimization of Lateral Displacement using Shear Wall, Journal of Xi’an Shiyou University, Natural Science Edition ISSN: 1673-064X, http://xisdxjxsu.asia VOLUME 19 ISSUE 01 JANUARY 2023.
10. M. S. Aainawala, Dr. P. S. Pajgade (2014), “Design of Multistoried R.C.C. Buildings with and without Shear Walls.” IJESRT
11. Niveditha M P, Sunil R (2018), “Seismic analysis of regular and irregular buildings with and without shear wall.” International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 07 July 2018.
12. Romy Mohan, C Prabha (2011), “Dynamic Analysis of RCC Buildings with Shear Wall.” International Journal of Earth Sciences and Engineering ISSN 0974-5904, Volume 04, No 06 SPL, pp 659-662 Pages 308-316, ISSN 0143-974X, https://doi.org/10.1016/j.jcsr.2011.09.016.
13. Semih S Tezcan, Cenk Alhan, Parametric analysis of irregular structures under seismic loading according to the new Turkish Earthquake Code, Engineering Structures, Volume 23, Issue 6, 2001, Pages 600-

609, ISSN 0141-0296, https://doi.org/10.1016/S0141-0296(00)00084-5.
14. Shaik Akhil Ahamad, K. V. Pratap, Dynamic analysis of G?+?20 multi storied building by using shear walls in various locations for different seismic zones by using Etabs, Materials Today: Proceedings, Volume 43, Part 2, 2021, Pages 1043-1048, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2020.08.014.88
15. Zahid, M., Miraz, M., Warsi, M.F.S., Pal, S. (2022). Seismic Analysis of Vertically Regular and Irregular Buildings with Shear Walls and RCC X-Bracing System. In: Gupta, A. K., Shukla, S. K., Azamathulla, H. (eds) Advances in Construction Materials and Sustainable Environment. Lecture Notes in Civil Engineering, vol 196. Springer, Singapore. https://doi.org/10.1007/978-981-16-6557-8_7989

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21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.
22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.
23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- o Explain the value (significance) of the study.
- o Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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