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SCHOOL OF CIVIL, ENVIRONMENTAL AND LAND
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Master of Science in Structural Engineering

SEISMIC ASSESSMENT AND STRENGTHENING OF AN EXISTING MULTI-STORIED RC BUILDING – A CASE STUDY

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Certificate

This is to certify that the thesis entitled, "*SEISMIC ASSESMENT AND STRENGTHENING OF AN EXISTING MULTI-STORIED RC BUILDING – A CASE STUDY*" and submitted by KEERTHYVASSAN SITHANANDAM Enrollment No. 915210 in fulfillment of the requirements of Graduate Thesis embodies work done by him under my supervision.

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Finally, I dedicate this thesis to my parents, and I would like to express my gratitude to my friends and family who always supported me to make this work possible

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Abstract

Master of Science

SEISMIC ASSESSMENT AND STRENGTHENING OF AN EXISTING MULTI-STORIED RC BUILDING – A CASE STUDY

by KEERTHYVASSAN SITHANANDAM

Multi-storeyed structures are gaining wide approval nowadays. Due to the increasing need for high-rise structures in urban areas, the construction of many high-rise structures is in progress and hundreds of them will take place in the future. But the most significant aspect in this whole scenario is the safety and sustainability of these structures against natural disasters such as an earthquake. An earthquake is a sudden movement of the earth's surface, that might be happening since the beginning of the earth. An earthquake has caused a considerable amount of loss in infrastructure, which is a major concern for engineers. In the high-risk seismic regions, significant changes in the practice of seismic design have been made. Additionally, changes in the codes and new codes were prepared in developed countries with the provision of lateral loads.

The scope of this thesis work is to analyze the seismic performance of an existing G+4 building in the region of Puducherry Union Territory located in the Southern part of India which was damaged by an Earthquake in 2001. Based on the analysis due to seismic loads, the building is retrofitted. Additional elements like shear walls are added to strengthen the structure and column jacketing is performed to increase the capacity of the columns. The analyzed structure is symmetrical, G+4, Ordinary RC moment-resting frame (OMRF). Modeling of this building is done using ETABS software. The Lateral seismic force of the RC frame is carried out using the linear static method as per IS 1893(part1): 2002. Thus, the structure needs to have appropriate Earthquake resisting elements to safely resist large lateral forces that are enforced on the building during earthquakes. The results of the performance and the analysis of the models are then graphically represented and in tabular form which is compared for determining the better performance of the structure against lateral stiffness.

Section 1

1.1 Introduction

This report illustrates the strengthening of a 23years old five-storied reinforced cement concrete building. This residential building is comprised of 24 flats. The ground floor is fully dedicated to parking without any infill walls. On all other floors, brick masonry is used as infill/partition walls. The building was not designed to take seismic actions. Due to an earthquake in 2001 of 5.6magnitude, the structure has experienced mild distress. The building was not occupied and left alone for decades. Due to the recent development and population growth, people have shown interest which created the need to strengthen/rehabilitate the building for seismic compliance and fit for residential use.

The first part of the report illustrates the impact of the latest natural hazard that occurred in 2001 (earthquake), geotechnical information of the location, building system, its soil condition, and the description of the structural system and its seismic behavior. Also, general information regarding the building is given in a detailed manner such as the building's plan, damages that occurred due to earthquake, soil report of this site.

The second part defines the retrofitting process and techniques that are possible, and a very economical retrofitting technique is chosen. Also defining the Gravity load, Live load, seismic load and wind load, and all the other required loading combinations to emphasize the structure close to the reality.

The third part defines the analytical modeling of the structure on the structural analysis software ETABS 2018, performing the linear static analysis and getting their analysis results with other models. Particular emphasis is placed on the analytical development of the models in ETABS 2018, specifically on the constraints, links, meshing, and the critical zone to make the model close to reality and comparisons have been made concerning other models.

In the end, the final comments are made after obtaining the analysis results of each model. The retrofitting procedure along with site photos are given in a detailed manner. Also, a basic comparison of IS 1893(Part1):2016 and EN 1998-1:2004 is made. The analysis is carried out under the code defined for the seismic design in India i.e., Criteria for Earthquake-resistant Design of Structures – IS 1983 (Part 1): 2016 along with the standard code of Plain and Reinforced Concrete - IS 456: 2000.

1.2 Geological and Structural Setup

The epicenter of the earthquake falls well within intracratonic terrain, away from the Indian plate boundary and so a link between the earthquake and the plate boundary does not seem to hold well. What is of interest is the analysis of the geological and the structural setup of the coastal tract of Tamil Nadu and Pondicherry and the adjoining continental shelf area. Geological mapping, aerial photo interpretation, and subsurface data culled out from drilling carried out in the Cauvery basin during exploration for oil, are relevant to the analysis. Tamil Nadu is by and large covered by Precambrian crystalline rocks and patches of Gondwana, Late Jurassic, Cretaceous, Tertiary, and Quaternary sediments are traced along the east coast, extending from south of Chennai, through Pondicherry to near the southern tip of the Peninsula. This fault appears to have been affected by E-W faults, giving rise to sinistral strike-slip movements. The significance of the east coast faults in the formation of sedimentary basins in the coastal tract and the adjacent offshore area to the east has been amply brought out based on subsurface data provided by deep drilling for oil in the Cauvery basin. Due to the activation of the Precambrian crystalline basement, extensive strike-slip faulting occurred extending into the offshore area. Thus, it is evident that the fault in the coastal region has its origin in global tectonic processes related to the rifting and fragmentation of Gondwanaland.

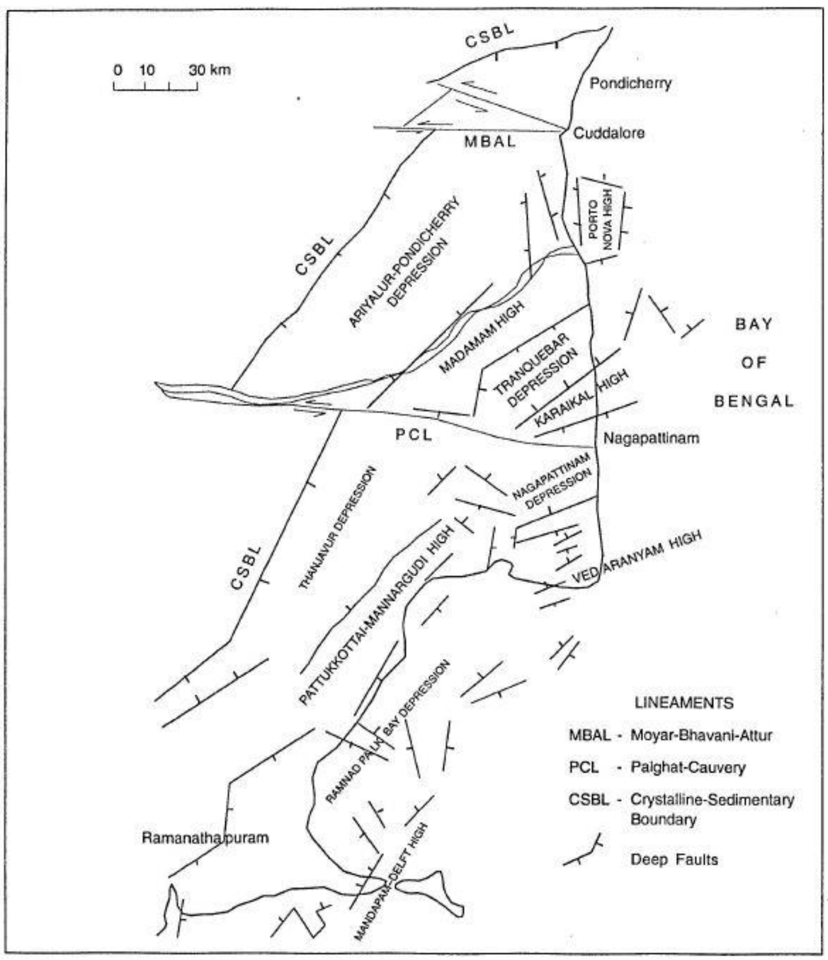

Figure.1. Fault systems of parts of coastal sedimentary belt, Tamil Nadu (after ONGC, 1993)

Reasonably, the accumulation of a heavy burden of sediments in the ridges and depressions throughout millions of years has inevitably led to crustal instability, resulting in vertical movement along faults. Such movement accounting for neotectonics activity in the coastal region may well be the root cause for the earth's tremors of September 2001. The other historically recorded earthquakes in the coastal region may also be the outcome of the periodical release of strain by fault movement. Slices of the crust at the continental edge of India bounded by NE-SW to NNE-SSW faults came into being. Vertical movement along the faults was imposed by stupendous sedimentation, giving rise to ridges and depressions. The faults continue to be active, accounting for earth tremors and the definition of a thermal signature along the coast. There is a view that if the epicenter of the earthquake of 2001 had been located on land and not in the offshore area, there would have been greater damage to structures.

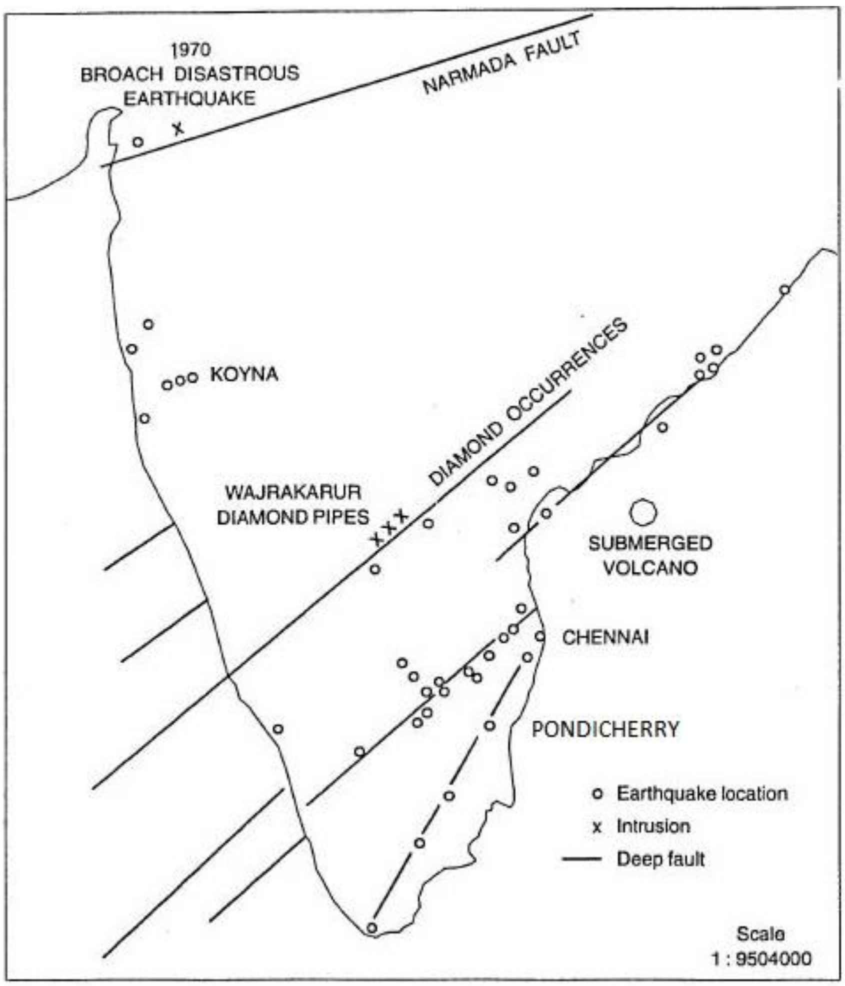

Figure.2. Earthquake locations in Peninsular India

1.3 Objectives

The main goal of the thesis is to design a real existing apartment building for lateral loads using present IS 875 codes for the application of gravity loads, Live load, wind load, IS 1893(Part1): 2016 for seismic analysis and IS 15988: 2013 to strengthen the existing R.C.C building (Retrofitting) in-order to increase the durability of the building.

1.4 Scope and Limitations

The scope of this thesis work limits the use of ETABS to design, analyze and assess an existing structure. The theme is to evaluate the performance of the structure in the presence of seismic loads and applying retrofitting techniques. The techniques considered for retrofitting in details employing software are:

1. Proposal of new shear wall panels in between existing columns.
2. Proposal of Jacketing (R.C.C column jacketing).

The above technique is chosen for an economical reason performed on-site as per the client's requirement.

The building is analyzed for zone 2 and IS 1893(part1): 2016 code is used for seismic evaluations with the aid of computer software.

1.5 Methodology

The structure will be studied in detail using ETABS (Extended three-dimensional analysis of building system) software which is universally accepted software for the analysis of high-rise buildings. The lateral load will be applied to these structures using ETABS. Those building which is deficient in resisting lateral loads will be retrofitted by suitable techniques.

G + 4 Existing Apartment Building is considered for seismic study in this project. The building software model is first designed for gravity loads considering the actual existing building designed condition. The building is then analyzed for lateral loads to study the earthquake impacts. For Seismic analysis, the building is put in zone 2 as per IS 1983(part1): 2016 for the analysis. The members which are deficit in shear, flexure, and biaxial moment; member level and structural level techniques are applied for retrofitting to have a structurally safe building.

Section 2

2.1 General Data

The Vikrant Complex Stilt + 4 story building was constructed roughly 23 years back, left unfinished and unoccupied due to an earthquake in 2001 of 5.5 magnitude. In the absence of architectural and structural drawings, the complete physical measurement of the building was taken along with the photos to ascertain the current condition of the structure.

General Data			
S.No.	**Description**	**Information**	**Notes**
(1)	Use of the building	Residential Building	
(2)	Number of stories above ground level (The including story is to be added later if any)	Five stories	
(3)	**Type of Structure** • Load-bearing walls. • R.C.C. frame • R.C.C. frame & shear walls • Steel frame	RCC Framed Structure	
(4)	**Soil data** • Type of soil • Design safe bearing capacity	Clay soil	IS:1893 CI:6.3.5.2 IS:1904
(5)	**Dead loads (unit weight adopted)** • Earth • Water • Brick masonry • Plain Cement Concrete • Reinforced Cement Concrete • Floor finish • Other fill materials • Piazza floor fill and landscape	16 kN/m^3 10 kN/m^3 19 kN/m^3 24 kN/m^3 25 kN/m^3 20 kN/m^3 20 kN/m^3 NOT USED	IS:875-Part 1
(6)	**Imposed (Live) loads** • Floor load • Roof load	2 kN/m^2 1.5 kN/m^2	IS:875-Part 2
(7)	**Cyclone/Wind** • **Speed**	50 m/s	IS:875-Part 3
(8)	**Seismic Zone**	ZONE – II	IS:1893-1 (2016)

(9)	**Importance Factor**	1.2	IS:1893-1 (2016) Table 6
(10)	**Seismic Zone Factor (Z)**	0.10	IS:1893-1 (2016) Table 2
(11)	**Response reduction factor**	3 (Ordinary Moment Resistant Frame)	IS:1893-1 (2016) Table 7
(12)	**Type of Structure** • Regular frames • Regular frames with shear wall • Irregular frames • Irregular frames with shear wall • Soft story	Regular Frames	IS:1893 CI.7.1
(13)	Number of basements	Nil	
(14)	Number of floors including stilt floor	Five stories	
(15)	Horizontal floor system	Beam and Slabs	
(16)	**Foundations** • Type of Foundation	Pile Foundation	
(17)	Grades of concrete used in different parts of the building	M20	
(18)	Method of analysis used.	P delta Analysis	
(19)	Computer software used	ETABS 2018	
(20)	**Clear minimum cover** provided in • Footing • Column • Beams • Slabs • Walls	60mm 40mm 25mm 20mm 20mm	

Table.1. General Data

2.2 Building Model

Figure.3. Building Perspective view

The structure that is taken under study is a reinforced concrete structure. It consists of 4 stories each having a height of 10 ft. Basement height is 12 ft and the OHWT height is 8 ft above the top roof level. It is 62′ × 113′ plot. Its covered area is 6500 sq-ft. The overall height of the structure is 60 feet. It is a residential building located on East Coast Road (ECR) of Pondicherry. Architectural drawings were drawn by taking actual measurements from the site. There are 12 balconies on each floor. The building is consisting of two blocks joined by a corridor. There are a total of 6 apartments on each floor.

The present condition of the structure:

- Spalling of concrete cover
- Cracks parallel to the reinforcement
- Spalling at edges
- Swelling of concrete
- Internal cracking and reduction in the area of steel reinforcement.

Beams at stilt floor:

- Spalling at edges
- Cracks due to insufficient cover

Lintels, Sunshade, Balcony, and Slab in all Floors:

- Slabs are intact. In balcony and sunshade corrosion of steel occurs at edges due to improper cover to the reinforcements. Hair cracks are found in the top terrace slabs.

Condition of Partition walls on all Floors and at Terrace:

- Cracks were found in the partition walls and mostly in the top floor area.

2.3 Present Building's condition

2.3.1 Columns

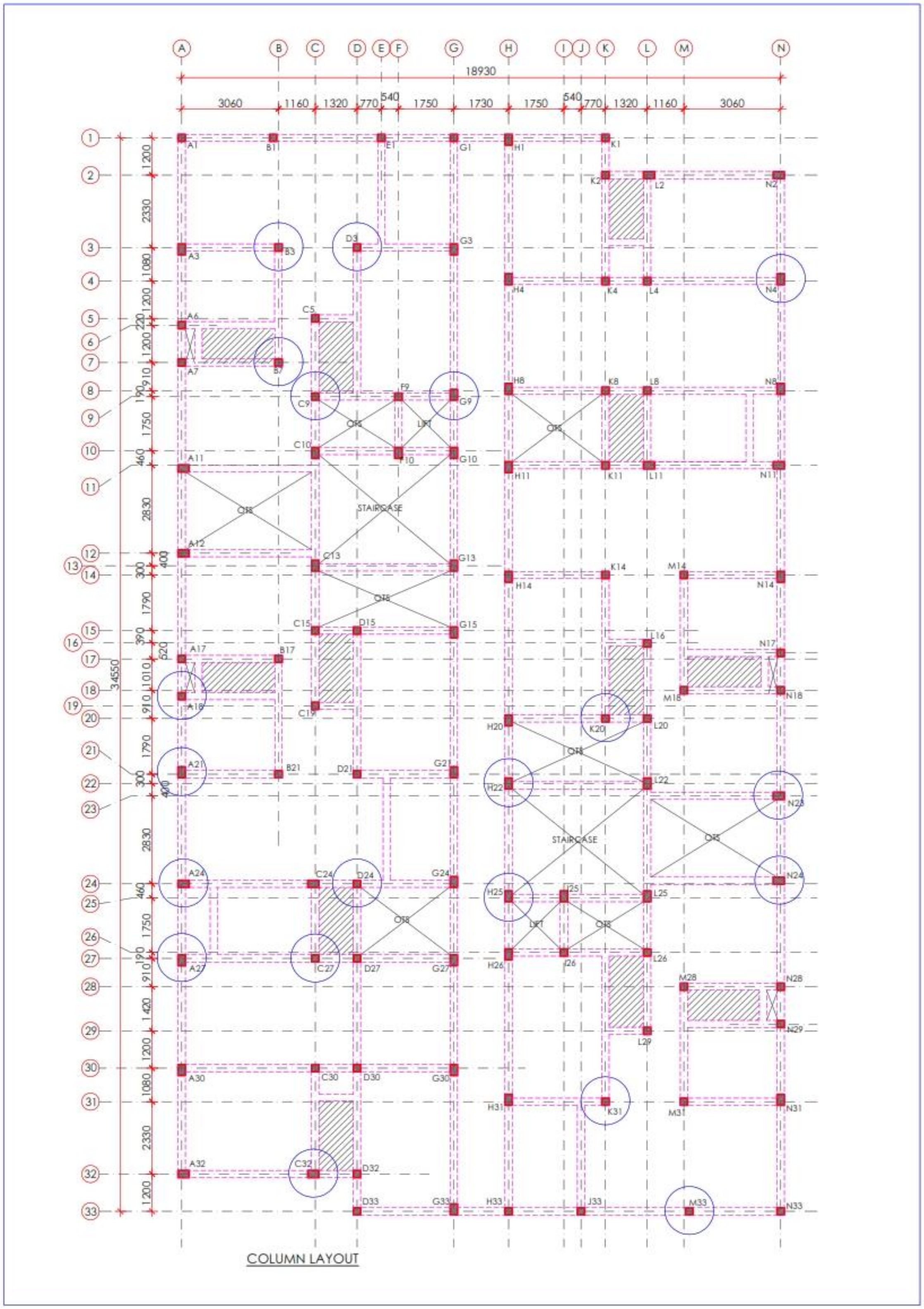

Figure.4. Column Layout of the building

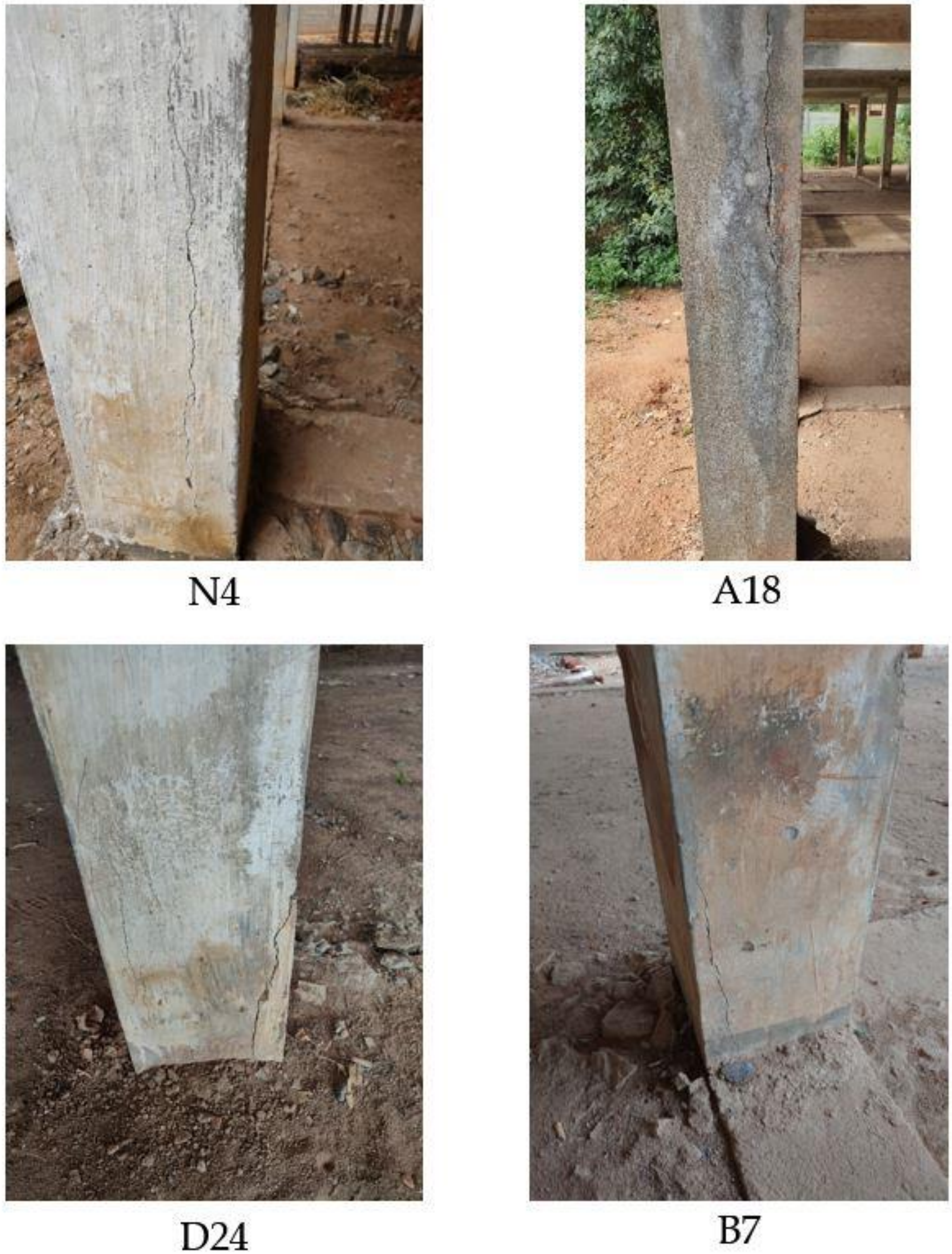

Figure.5. Cracks due to insufficient cover

Figure.6. Spalling of concrete due to overload

Figure.7. Spalling of concrete due to overload and insufficient cover

K20

G9

K31

Figure.8. Spalling of concrete due to overload

Figure.9. Swelling of concrete

2.3.2 Beams

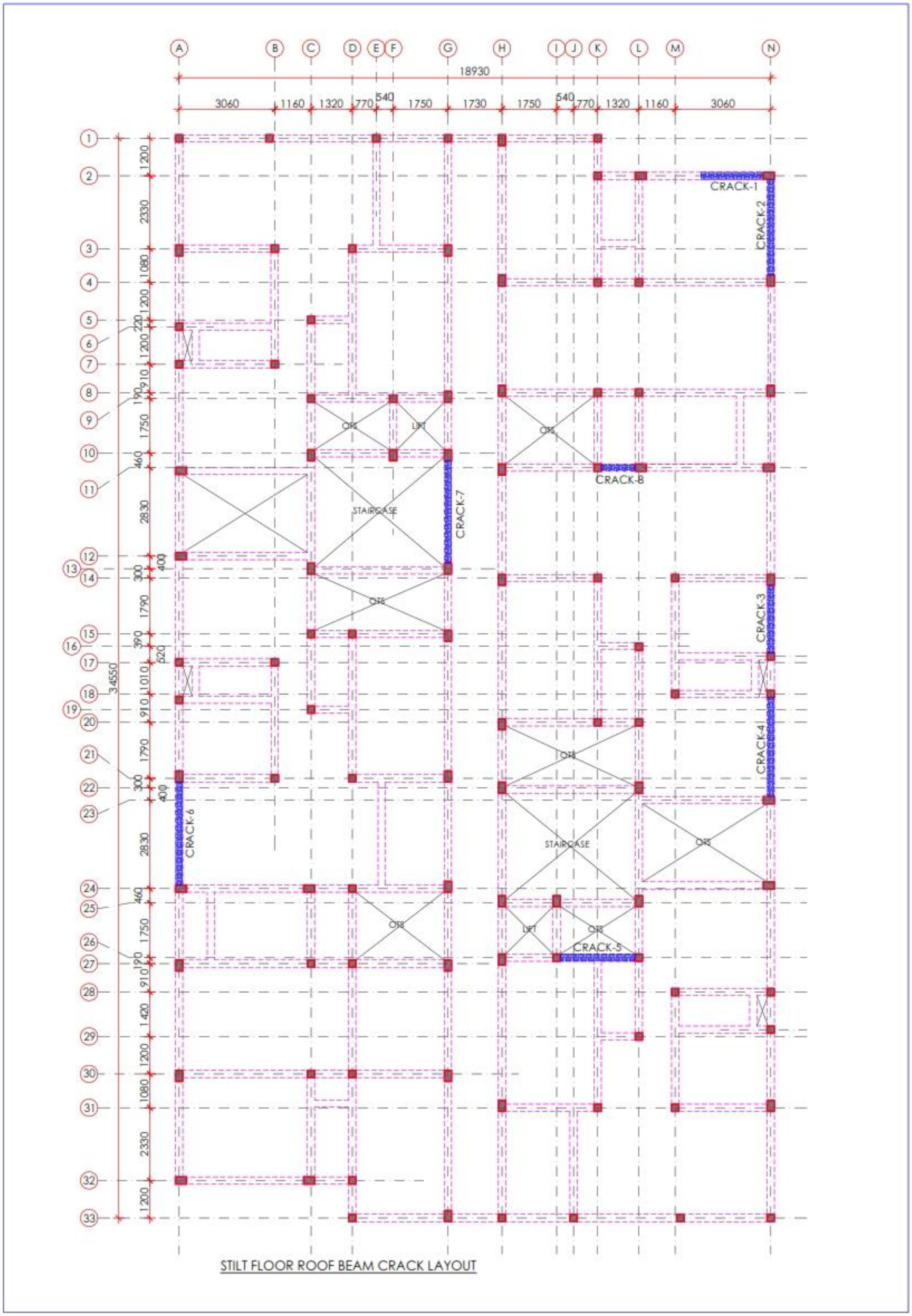

Figure.10. Stilt floor roof beam crack layout

Grid L2 N2

Grid N2 N4

Grid N14 N16

Figure.11. Cracks due to overload

Grid N18 N23

Grid I27 L27

Grid A21 A24

Figure.12. Cracks due to overload

Grid A21 A24

Grid G10 G11

COLUMN AND BEAM JUNCTION CRACK

Figure.13. Cracks due to insufficient cover

2.3.3 Balcony Slabs

Balcony Slab
Crack

Figure.14. Rusting of reinforcement due to insufficient cover

2.3.4 Balcony Brick wall

Figure.15. Cracks in the brick wall due to deflection of the slab

2.3.5 Thermal Cracks on wall

Figure.16. Cracks on the brick wall due to change in climatic conditions

2.3.6 Terrace

Figure.17. Grass and tree growth on the terrace

2.4 Soil Investigation

This investigation work was done for the multi-storied apartment building at Pondicherry to find the allowable safe bearing capacity of the soil. Two numbers of 150mm diameter bore holes were made by manually operated auger and shell boring method. Standard Penetration Test (SPT) was done according to IS 2131-1987 at regular intervals and the observed N values are given in the bore log. The refusal strata with N value of more than 50 was met at 18.7m and 15m in bore holes 1 and 2 respectively. After conforming to the strength and continuity of hard strata, the bore holes 1 and 2 were terminated at 21.2m and 20m respectively. The observation of ground water level was made during boring operations and recorded in the respective bore hole logs.

After performing the field test, it can be seen that the top soil at the site is soft to medium stiff sandy clay layer present up to about 1.1m to 1.3m depth from the existing ground level. Below the top soil, loose, medium, dense and very dense sand layers are present up to the termination depths of the bore holes. A compressible soft clay layer with many decayed wood pieces is present at 4m depth. The ground water level was observed at 1.5m from the existing ground level. The bore log along with the soil profile is attached below in the table.

Based on visual soil examination and field test results, it can be seen that the subsoil is very poor in strength and compressible clay with decayed wood pieces at shallow depth which may be exposed to pressure influence. Considering the recommendation according to the test report, Bored cast-in-situ piles are provided. Considering friction/adhesion and end bearing, the pile carrying capacity has calculated for 17.5m from existing ground level and are given below for various diameter of the piles.

Average length of the pile (m)	Diameter of Pile (mm)	Safe load in compression (t)
17.5	400 450 500 550 600	58 65 74 82 91

Table.2. Pile carrying capacity.

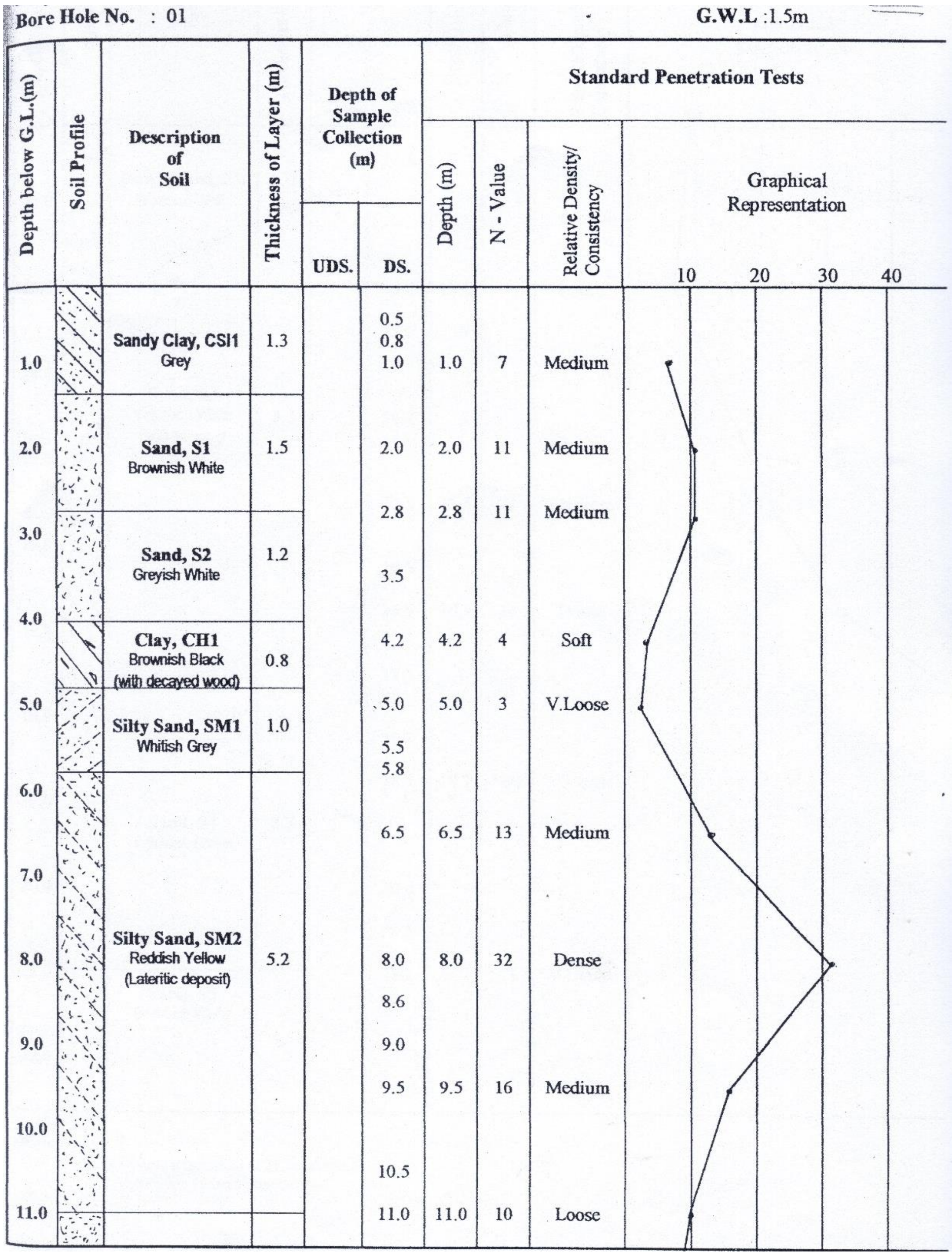

Figure.18. Bore hole Log1.

Conti.....

Depth below G.L.(m)	Soil Profile	Description Of Soil	Thickness of Layer (m)	Depth of Sample Collection (m) UDS.	Depth of Sample Collection (m) DS.	Standard Penetration Tests Depth (m)	N - Value	Relative Density/ Consistency
		Gravelly Sand, SG1 Brownish White	2.0		11.6			
12.0								
13.0		Sand, S3 Yellowish White (with traces of Gravel)	5.3		13.0	13.0	7	Loose
					13.6			
14.0					14.2			
15.0					15.5	15.5	22	Medium
16.0					16.5			
					16.9	16.9	34	Dense
17.0					17.5			
18.0								
		Sand, S4 Yellowish Brown	2.7		18.3			
					18.7	18.7	*60	V.Dense
19.0								
20.0					20.0			
					20.5			
21.0		Sand, S5 Brownish White			21.2	21.2	63	V.Dense
22.0								

Graphical Representation: 10, 20, 30, 40

Note:

1. Bore hole terminated at 21.2m depth.
2. * Values for 15.0cm penetration.

Figure.19. Bore hole Log (cont.)

2.5 Seismic Retrofitting

Seismic Retrofitting requires to enhance the existing structure to resist seismic activity, ground motion, or soil failure due to earthquakes. Retrofitting techniques are applied when there is a risk to the structure by some catastrophe. The damage of the structure due to an earthquake is the internal force generated by the weight of the structure. In order to have a seismic resistance design, quite a few factors are associated such as torsion, ductility, and so on. Several new technologies are quickly becoming more dominant in the seismic design of building structures is most preferred. Retrofitting structures that are deficient to earthquake in order to reach an adequate level of performance is a highly considered in the current framework. As a result, a seismically inadequate structure can be achieved by either minimizing the load effect input to existing structures or strengthening their strength, stiffness, and/or ductility. The capacity of the reinforced concrete structure has to be increased in the Retrofitting techniques.

2.5.1 Background

The seismic measures are used to calculate forces that earthquakes enforce on buildings. Ground shaking (pushing back and forth, sideways, up, and down) generates internal forces within buildings called the Inertial Force thus causing seismic damage.

$$\text{Inertial Force} = \text{Mass (M)} \times \text{Acceleration (A)}$$

The inertial force is directly proportional to the mass (weight of the building). A conventional benefit in seismic design is the Lightweight construction with less mass. Mass is directly proportional to lateral forces and thereby greater mass produces greater lateral forces thus increasing the possibility of columns being displaced, and/or buckling under vertical load (P delta Effect).

2.6 Retrofitting Techniques

In general, two alternative approaches are conceptually adopted in practise for seismic retrofitting,

1. The first approach focuses on the reduction of induced earthquake forces (modifying the demand). In this damping devices or the base isolation is generally used to the structure.

2. While the second approach focuses on strengthening the structure to resist induced earthquake forces (modifying the capacity). The capacity of the structure is enhanced by intervening a particular element or by modifying the loads path within the structure.

2.6.1 Structure System-Level Rehabilitation

Global strengthening of structure is commonly used to reduce lateral drift, decrease ductility requirement, and enhance the lateral resistance of existing structures. Such rehabilitations for RCC buildings include addition of infill walls, steel braces, post-tensioned cables, steel plate shear walls, and base isolators. Implementation of a structured system-level rehabilitation techniques are commonly used methods which are described below. There is no unique solution, and several different retrofit schemes can be designed to provide effective seismic resistance. Inter-story lateral drifts and lateral displacements must be controlled to have a satisfactory response of the overall structure. Also, a new member added must ensure a significant increase in the load capacity and stiffness of the structure. Structure System-Level Rehabilitation Include the following Techniques.

- Supplementary Energy Dissipation
- Addition of RC Shear Walls
- Use of Steel Bracing
- Ferrocement

2.6.1.1 Seismic Isolation and Energy Dissipation Systems

Seismic isolation and energy dissipation systems involve the use of special specific devices to alter or monitor the dynamic behaviour of buildings. The technologies used in these structural schemes can be broadly categorized as passive, active, or hybrid control systems. Other guidelines and design provisions for base isolation systems are provided in FEMA 302. Related guidance for energy dissipation systems is provided in FEMA 273. The definitions of the passive, active, and hybrid control system are,

Passive Control Systems

A significant part of incoming earthquake energy is dissipated by means of a specialised devices or unique connection details that deform and yield during an earthquake. Since the yielding and deformation are focused on the device, there is a reduction of damages to other components of the building. Passive systems are activated by the earthquake motion and do not require any additional energy source to function. The examples of a passive control systems are Seismic isolation and passive energy dissipation. Most of these devices can also be utilised as energy dissipation devices at the base of a structure as part of an isolation system or in tandem with braced frames or walls.

(a) Seismic isolation systems: The purpose of this system is to dissociate the structure of the building from damaging the components due to earthquake motion, i.e., these systems prevent the superstructure of the building from absorbing the seismic shock propagation. The whole superstructure is supported on distinctive isolation devices called isolators that uncouple the ground motion. Some isolators are also designed to add significant damping. The isolation devices yield and displaces, and the superstructure acts as a rigid body.

(b) Passive energy dissipation systems: The purpose of this system is to substantially reduce response of the structure to earthquake movements by providing additional damping. This involves the addition of viscous damping through the use of viscoelastic dampers, hydraulic devices, or the hysteretic damping is added through friction-slip devices, metallic yielding devices, or shape-memory alloy devices. With the help of these systems, the building is able to dissipate a greater portion of the seismic energy through inelastic deformations or friction that are focused on the energy dissipation devices thus protecting from damaging other structural elements.

Active Control Systems

Active Control systems provide earthquake resistance on a structure by imposing forces that counter-balance the earthquake-induced forces. Active Control systems need an energy source and computer-control devices to operate particular braces or dampers that are located all over the building. Active systems are more complicated than passive systems since they depend on motion sensors, computer control, feedback mechanisms, and moving components that may require repair or maintenance. In addition, these systems need an emergency power supply to ensure that they will function during a major earthquake and any immediate impact.

2.6.1.2 Hybrid Control Systems

Hybrid control systems merge features of both passive and active control systems. In general, they have reduced energy demands, enhanced reliability, and less expensive when compared to fully active systems. In the future, these systems may include variable friction dampers, variable viscous dampers, and semi-active isolation bearings. It is important to note that the passive energy dissipation systems discussed above are new technologies when applied to civil engineering structures but are used in mechanical engineering for many years. There are many situations where dampers, springs, torsion bars, or elastomeric bearings have been used to control vibration or change the dynamic behaviour of mechanical systems. Several examples include automotive shock absorbers, spring mounts that provide vertical vibration isolation for mechanical equipment, and hydraulic damping devices that utilize fluid flow through a vent to provide shock isolation for military hardware. Many of these devices have been used for decades and have performed well in situations where they are subjected to millions of cycles of loading and many more required for seismic resistance.

2.6.1.3 Addition of RC Structural Walls

One of the most traditional structure system-level rehabilitation methods is to add structural walls in order to strengthen existing structures. Addition of shear walls are effective in controlling global lateral drifts and reduces damage in frame members. The shear wall panels can be prefabricated and assembled on-site to save time, cost, and ensure quality. The addition of new shear walls results in improved seismic performance by having a bracing effect on the frame, however, its side effect on the existing structure and its relatively intrusive and disrupt construction style are disadvantages. The infilling process tends to stiffen the existing structure such that there is an increase in base shear. Along with the addition of the weight, in turn, the gravity load effect gives more pressure to the existing foundation. Thus, addition of new shear wall to an existing structure requires a new foundation through which the load can be distributed thus reducing the load on existing foundation.

2.6.1.4 Use of Steel Bracing

RC frames involving Steel bracing reduce drift demands. Implementation of Bracing can either be inside the frame or on the periphery of the building like RC walls. Post-tensioning can also be applied to bracing elements. Also, steel bracing provides more appropriate solutions in aesthetics for many applications. Steel bracings can be installed on the external facades but its application inside a building with a small opening is not easy. The design of steel elements must be made in conformity with the details specified in steel standards and codes. For the connection between the existing structure and steel members, the anchor design principles must be followed properly. Installing lateral supports at story levels helps to prevent lateral buckling.

2.6.1.5 Ferrocement

Ferro-cement is a homogeneous thin wall type composite section consisting of wire mesh and hydraulic cement mortar, having a total thickness ranging between 12 to 30 mm. The hydraulic cement mortar is reinforced with a minimum of two layers of uninterrupted and comparatively small diameter orthogonally woven wire mesh separated by 4–6 mm dip galvanized spacer wires. The cement mortar is combined or mixed with plasticizers and polymers. The MS wire mesh is mechanically connected to the surface by U-shaped nails fixed with a suitable epoxy bonding system. The mesh is made up of hot-dip galvanized Mild steel wire or using various metallic materials. To make sure proper compaction of wire mesh in mortar, Orbital vibrators are used for compacting the Ferro-cement layers. This repair technique provides a protected membrane for the rehabilitation of damaged RCC structures which behaves as a protective layer against environmental factors. It also acts as a waterproofing layer over reinforced concrete shell structures and RCC slabs as it provides an impermeable thin membrane thus preventing seepage and water leakage. Ferro-cement has no noticeable advantages over any other type of reinforced concrete either in direct tension or flexure, but it has a high level of control over cracking provided by appropriate spacing and specific surface area of the wire reinforcing mesh.

2.7 Rehabilitation

Rehabilitation means restoration of the building’s basic elements of construction involving the occurrence of distress, removal of damaged elements, selection of an appropriate element, alteration or strengthening of damaged structural elements to extend the structure’s life, and is generally considered to be less significant than renovation. Repair work of damaged roofs, exterior walls, windows, etc. are typically included. Rehabilitation of structure mainly aims in increasing the level of quality of building systems.

2.7.1 Member-Level Rehabilitation or Element-based strengthening

Element-based strengthening approach is the modification of deficient elements to increase ductility so that the deficient elements will reach their limit states in a ductile manner when subjected to design events. This local level rehabilitation approach is cost-effective when compared to structure system-level rehabilitation only for those components that are needed to effectively improve the seismic capacity of the existing structure. These rehabilitation approaches include the addition of concrete, steel, composite material (FRP) jackets, or pretension tendons/wires in confining RC columns, beams, and joints. This would involve jacketing the columns, beams, and joint regions to improve shear strength and flexural strength, and confinement of concrete. Member Level Rehabilitation can be done by several methods. Some of them are as follows,

- Column Jacketing
- External Reinforcement in the form of Steel Plate Bonding and External-Bond (FRP Composites)
- Steel plate bonding

2.7.1.1 Column Jacketing

Columns are crucial components in any structure system and their performance during an earthquake can control the overall consequence of the structure. Shear failure of these older RC columns usually occurs at modest deformations and is accompanied by a sharp decrease in lateral load resistance.. Moreover, the column’s shear strength tends to decrease more rapidly than its flexural strength with the lateral load. Column failures have caused the most substantial failures of RC structures. So, column retrofitting is often important to the seismic behaviour of a structure. To prevent column failure during earthquakes, columns should be the strongest components in the entire structure. The column’s response in a structure is controlled by its combined axial, flexural, and shear load. Therefore, jacketing of columns may be used to enhance the column’s shear strength and flexural strength so that they are not damaged. The details of the four-sided RC jacketing of an existing column may be provided as follows.

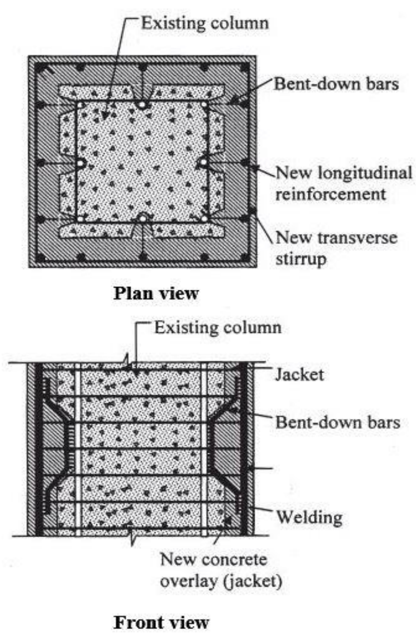

Figure.20. Column Jacketing

2.7.1.2 External Reinforcement in the form of FRP or Steel

Strengthening of concrete structures using reinforcements bonded externally is usually done using either steel plates or CFRP laminates. Each material has its specific benefits and drawbacks. Steel plates are in use for many years due to their simplicity in managing and their effectiveness for strengthening. The properties and behaviour of the steel adhesive-concrete combination are well known. Steel plates are efficient to be used as bending reinforcement. The high-level tensile strength and stiffness increase its bending capacity and reduce deformations. Steel plates can also be used as external shear reinforcement. However, skilled laborers are required, and it is quite expensive.

CFRP sheets and laminates are good under tension and have adequate stiffness, but they are not compatible under every strengthening situation. For bending of sheets, the stresses in the CFRP laminates are kept small to prevent the yielding of internal steel reinforcement. Thus, the high-strength CFRP sheets are not used efficiently, except if the laminates are pre-stressed. Prestressing, on the other hand, increases the cost and reduces the ease of application, both of which have an effect on the cost of this procedure. Besides pre-stressing, the required increased bearing capacity is achieved by adding a significant number of CFRP sheets or a thick laminate, thus increasing the material and labour costs. CFRP sheets are not very effective in limiting the deflections. Since the cross-sectional area per sheet is small, the inertia moment slightly increases and thus reduction in deformation is negligible. In these cases, a better alternative are steel plates. On contrary, CFRP sheets are used for shear strengthening than steel plates. Carbon fibres bonded orthogonally at both sides of a beam are good in reducing shear forces. Even complex geometries are done using CFRP sheets as it is very easy. Labour costs for CFRP are much lower than externally bonded steel stirrups.

2.7.1.3 Steel Plate Bonding

Plate bonding is an economical, adaptable, and innovative technique for rehabilitation, renovating concrete structures by mechanically connecting MS plated by bolting and gluing to their surfaces with epoxy. The strength, ductility, stiffness, and stability of the reinforced concrete elements can be considerably increased by Plate bonding and can be used effectively for seismic retrofitting. The behaviour of the composite system mainly depends upon the bond between concrete and plate. Thick plates can initiate horizontal cracks and separation of plate and thus it has to be used properly. Also, with large width, there is a risk of a defect in epoxy, and the slip between the concrete and reinforcing element becomes greater. The width-thickness ratio of the plate is less than 50:1 due to increasing stresses near the ends of the plates which leads to premature failure and this requiring Anchor plates. This technique is impossible where the member shows any indication of reinforcement corrosion.

Section 3

3.1 Computer application in the civil & structural engineering industry

The introduction of software used in the civil & structural engineering industry has greatly reduced the complexities of different aspects in the analysis and design of projects, as well as reducing the amount of time necessary to complete the designs. Concurrently, this leads to greater savings and reductions in costs. More complex projects that were almost impossible to work out several years ago are now easily solved with the use of computers. Presently, much structural analysis and design software applications are present in the market. Even though they are expensive, their use has become prevalent amongst most structural engineers and engineering firms.

The finite-Element method of analysis plays a major role in most of these applications. This method simplifies computations in a broad range of problems including heat transfer, seepage, the flow of fluids, and electrical & magnetic potential. In the finite-element method, a continuum is idealized by assembling finite elements having specific nodes.

Displacement and stiffness methods are used in the analysis of a structure by the finite-element method. A large number of degrees of freedom are commonly involved in the finite-element approach and thus it is essential with the use of a computer.

The systematic sequences is made used by computerized computations executed in a computer program at an high processing speeds. Some common Structural Analysis & Design Software available in the market:

- **<u>STADD Pro:</u>**

  Comprehensive structural software that addresses all aspects of structural engineering- model development, analysis, design, visualization, and verification.

- **<u>SAP 2000:</u>**

  SAP is general-purpose civil engineering software standard for the analysis and design of any type of structural system. From basic to advance systems ranging from 2D to 3D made of simple or complex geometry, may be modelled, analyzed, designed, and enhanced using a practical object-based modelling environment that streamlines the engineering process.

- **<u>Midas Gen:</u>**

  Midas Gen supports engineers to readily perform structural analysis and design for standard and complicated structures. **Midas Gen** uses a diverse range of finite element analysis functions and also modern theories of structural analysis to render accurately and to obtain practical results.

- **<u>ETABS:</u>**

  Offers a sophisticated 3-D analysis and design for multi-story building structures.

3.1.1 ETABS

The pioneering and progressive new ETABS 2018 software is one of the best-integrated software packages for the structural analysis and design of buildings. Over 40 years of consistent research and development, this latest ETABS offers matchless 3D object-based modeling and visualization tools with fast linear and nonlinear analytical power, sophisticated and comprehensive design capabilities for a wide range of materials, and perceptive graphic displays, reports, and graphic drawings that allow users to understand analysis and design results easily and quickly.

From the start of the design concept with the production of graphic drawings, ETABS 2018 integrates every aspect of the process involved in engineering design. The creation of models is now easier and intuitive drawing commands allow to rapidly generate floor and elevation framing. AutoCAD drawings can be directly converted into ETABS models or can be used as templates in which ETABS objects can be pasted. Extremely large and complicated models are rapidly analyzed and support non-linear modeling techniques such as construction sequencing and time effects with the help of an advanced SAP Fire 64-bit solver. (e.g., creep and shrinkage).

Design of concrete frames and steel (with automatic optimization), composite beams, composite columns, steel joists, and concrete and masonry shear walls, the capacity check for steel connections and base plates can be performed. Models may be rendered in a realistic manner, and all results can be shown directly on the structural model. Complete and customizable reports are available for all analysis and design output, and graphic construction drawings of framing plans, elevations, schedules, details, and cross-sections can be generated for concrete and steel structures.

ETABS offers advanced analysis and design for steel, concrete masonry multistorey building structures. Its analysis is based upon direct stiffness formulation and finite element techniques. The input, output, and numerical solution techniques of ETABS are a great advantage of the distinctive physical and numerical features associated with building-type structures. A complete group of window graphical tools and functions are included with the base package, including a modeler and a post-processor for viewing all results including forces diagrams and shapes. The basic concept is that only one model consisting of the floor systems and the vertical and lateral-framing system to analyze and design the whole building is created. Everything that are essential is created into one multipurpose analysis and design system with one user interface. There are no external modules to be maintained and no issues about data transfer between modules. The effects on one part of the model changes in another part that are instantaneous and automatic.

3.2 Analysis and Design Procedure Using ETABS Software

3.2.1 Code Book Consideration:

- IS 456 : 2002 - For general consideration.
- IS: 875-1 (1897) - For Dead load
- IS 875-2 (1897) - For Live load.
- IS 875 (Part 3) - For Wind load.
- IS 1893 (Part 1) : 2016 - For seismic design.

3.2.2 Model 1

Following steps are performed before analysis for gravity loads,

Step - 1: Creation of Grid points & Generation of basic structure:

After getting opened with ETABS, select a new model and a window appears where the grid dimensions and story dimensions of the structure are entered. Here itself the 3D structure is generated.

Step - 2: Defining material property:

First define the material property by selecting Define menu→Material properties. Add new material for structural elements (beams, columns, slabs) by giving the specified details in defining.

Step - 3: Assigning the property:

After defining the property, assign the structural properties for beams, columns, and slab. The meshing of the slab is also done.

Step - 4: Assigning of Supports:

By keeping the selection at the base of the structure and selecting all the columns, assign supports by going to assign menu→ joint\frame→Restraints (supports)→ Pinned.

Step - 5: Defining loads:

In ETABS all the load considerations are first defined and then assigned.

Step - 6: Assigning Dead load:

Dead loads are calculated as per **IS: 875-1 (1987)** for external walls, parapet walls including the self-weight of the structure.

Step - 7: Assigning Live loads:

Live loads are calculated as per **IS: 875-2 (1987)**.

Step - 10: Assigning load combinations:

After assigning all the loads, the load combinations are given i.e., 1.5(DL+LL)

Step - 11: Analysis:

After the completion of all the above steps, the analysis must be performed and checked for errors.

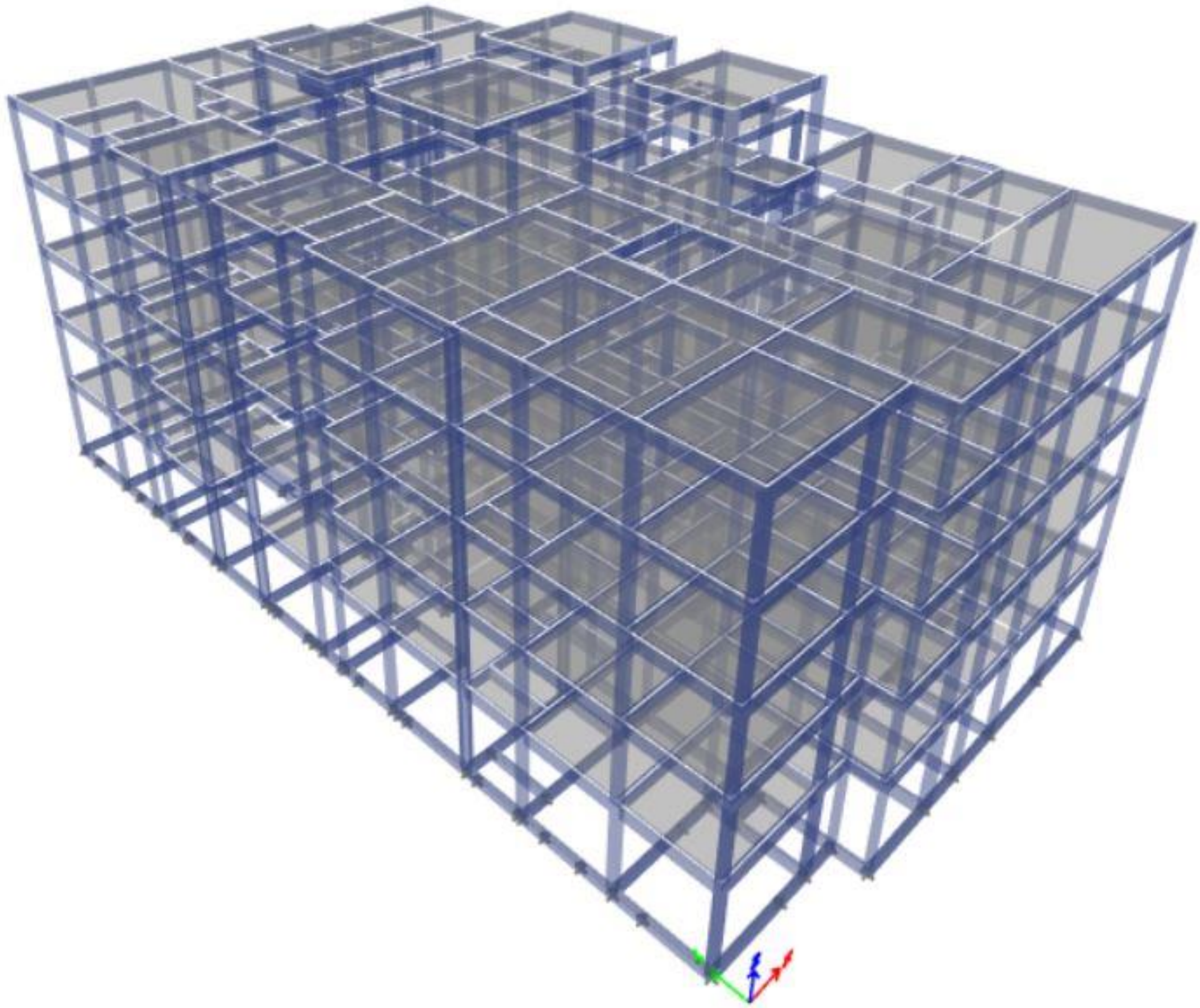

Figure.21. A 3-D view of the model

No Architectural and Structural drawings were provided during the rehabilitation of this structure. Measurements were taken physically, and the drawing was prepared by Engineers. Since many data were unknown, physical investigations happened on-site and then the model was created and analyzed. So, model 1 is the general analysis of this existing building. Here, column and beam reinforcements were manually inputted in the ETABS software, and then the members were checked according to the existing data. Thus, the actual strength of the structure was obtained in this model and the details are given in a further table.

3.2.2.1 Load Calculation

LIVE LOAD	
Floor Load	2kN/m^2
Terrace	1.5kN/m^2
Balcony Load	2kN/m^2
Roof Balcony Load	1.5kN/m^2
DEAD LOAD	
Floor Slab Load	
Self-Weight (0.15x25)	3.75kN/m^2
Floor Finish	1kN/m^2
Total	4.75kN/m^2
Sunken Slab Load	
Self-Weight (0.15x25)	3.75kN/m^2
Filling (0.23x20)	4.6kN/m^2
Total	8.35kN/m^2
Roof Slab Load	
Self-Weight (0.15x25)	3.75kN/m^2
Weathering Course & Tiles (0.15x20)	3kN/m^2
Total	6.75kN/m^2
Brickwork Load – Ground Floor	
Grade Beam (0.22x0.23x19.2)	1kN/m
Stair Wall (2.67x0.23x19.2)	11.80kN/m
Brickwork Load – Other Floors	
Outer Wall (2.67x0.23x19.2)	11.80kN/m
Stair Wall (2.67x0.12x19.2)	6kN/m
Balcony Parapet Wall (1x0.12x19.2)	2.3kN/m
Parapet _ OTS (1x0.23x19.2)	4.5kN/m
Parapet _All around (1x0.12x19.2)	2.3kN/m
Headroom Wall (2.32x0.23x19.2)	10.3kN/m
Lift Wall (0.82x0.23x19.2)	3.7kN/m
Headroom Parapet Wall (0.45x0.23x19.2)	2kN/m
Tank RCC Wall (1.40x0.23x25)	8.1kN/m

Table.3. Load Calculation

3.3 Analysis Inputs

3.3.1 Story Data

Story	Height m	Elevation m	Master Story	Similar To	Splice Story	Splice Height m	Story Color
Head Room	1.8	18.45	No	None	No	0	
Lift Head space	1.2	16.65	No	None	No	0	
Story4	3	15.45	No	None	No	0	
Story3	3	12.45	No	None	No	0	
Story2	3	9.45	No	None	No	0	
Story1	3	6.45	No	None	No	0	
Ground Floor	3.45	3.45	Yes	None	No	0	
Base		0					

Table.4. Story Height Data

3.3.2 Load Cases

Load	Type	Self Weight Multiplier
Dead	Dead	0
Live	Live	0
Masonry	Super Dead	0
SelfWeight	Dead	1

Table.5. Static Load Cases

3.3.3 Load Combinations

Define Combination of Load Case/Combo Results

Load Name	Scale Factor
Dead	1.5
Live	1.5
Masonry	1.5
SelfWeight	1.5

Table.6. Load Combinations

3.4 Analysis Results

VERIFICATION CRITERIA: As per IS 456:2000, Clause 26.5.3.1,
The cross-sectional area of longitudinal reinforcement shall not be less than 0.8 percent nor more than 6% of the column's gross cross-sectional area.
NOTE - The use of 6% reinforcement may cause issues in the placement and compacting of concrete; therefore, a low percentage is recommended. Where bars from lower columns must be lapped with those in the column in concern, the percentage of steel used **shall not exceed 4%.**

So, the column forces and moments are taken from the software and the percentage of reinforcement is calculated for each column and the corresponding results have been obtained.

- For Column 230mm x 230mm, the existing reinforcement is 4nos. of #20mm diameter rebar and the percentage of steel is 2.34%.
- For columns 230mm x 350mm, the existing reinforcement is 4nos. of #20mm diameter rebar and 2nos. of #16mm diameter rebar with the percentage of steel 2.34%.

Thus, the columns within this limit are safe and columns exceeding this limit must be changed according to the existing structure.
For simplicity, the output results of the Ground Floor's column forces, moments, Area of steel provided and required amount in percentage and its results are presented below.

Label	Size	Loc	Load Comb	P (kN)	M2 (kNm)	M3 (kNm)	AsMin (mm^2)	As required (mm^2)	% of long reinf required (%)	% of existing reinf provided (%)	Result
C1	23x23	0	1.5(DL+LL)	-519	4.22	-2.72	423	1467	2.77	2.34	Fail
C1	23x23	1535	1.5(DL+LL)	-516	-1.97	0.80	423	1349	2.55	2.34	Fail
C1	23x23	3070	1.5(DL+LL)	-513	-8.15	4.31	423	1620	3.06	2.34	Fail
C2	23x23	0	1.5(DL+LL)	-596	4.83	3.44	423	1585	3.00	2.34	Fail
C2	23x23	1535	1.5(DL+LL)	-593	-2.24	-1.15	423	1455	2.75	2.34	Fail
C2	23x23	3070	1.5(DL+LL)	-590	-9.31	-5.74	423	1867	3.53	2.34	Fail
C3	23x23	0	1.5(DL+LL)	-667	5.08	1.53	423	4781	9.04	2.34	Change Section
C3	23x23	1535	1.5(DL+LL)	-664	-2.64	-0.32	423	4630	8.75	2.34	Change Section
C3	23x23	3070	1.5(DL+LL)	-661	-10.35	-2.16	423	4985	9.42	2.34	Change Section
C4	23x23	0	1.5(DL+LL)	-474	2.74	0.88	423	2100	3.97	2.34	Fail
C4	23x23	1535	1.5(DL+LL)	-471	-1.42	-0.11	423	2027	3.83	2.34	Fail
C4	23x23	3070	1.5(DL+LL)	-468	-5.58	-1.09	423	2189	4.14	2.34	Change Section
C5	23x23	0	1.5(DL+LL)	-221	0.13	3.35	423	423	0.80	2.34	OK
C5	23x23	1535	1.5(DL+LL)	-218	-0.03	-0.84	423	423	0.80	2.34	OK
C5	23x23	3070	1.5(DL+LL)	-215	-0.20	-5.04	423	423	0.80	2.34	OK
C6	23x23	0	1.5(DL+LL)	-430	2.56	0.06	423	788	1.49	2.34	OK
C6	23x23	1535	1.5(DL+LL)	-427	-1.08	-0.04	423	706	1.33	2.34	OK
C6	23x23	3070	1.5(DL+LL)	-424	-4.72	-0.14	423	866	1.64	2.34	OK
C7	23x23	0	1.5(DL+LL)	-636	7.77	-3.98	423	3335	6.30	2.34	Change Section
C7	23x23	1535	1.5(DL+LL)	-633	-4.49	1.85	423	3122	5.90	2.34	Change Section
C7	23x23	3070	1.5(DL+LL)	-630	-16.75	7.68	423	3817	7.22	2.34	Change Section
C8	23x23	0	1.5(DL+LL)	-612	-3.49	2.23	423	1471	2.78	2.34	Fail
C8	23x23	1535	1.5(DL+LL)	-609	1.59	-0.56	423	1362	2.57	2.34	Fail
C8	23x23	3070	1.5(DL+LL)	-606	6.66	-3.36	423	1607	3.04	2.34	Fail
C9	23x23	0	1.5(DL+LL)	-803	-3.54	-4.13	423	3962	7.49	2.34	Change Section
C9	23x23	1535	1.5(DL+LL)	-800	1.60	1.40	423	3855	7.29	2.34	Change Section

C9	23x23	3070	1.5(DL+LL)	-797	6.74	6.94	423	4079	7.71	2.34	Change Section
C10	23x23	0	1.5(DL+LL)	-524	1.78	2.09	423	2260	4.27	2.34	Change Section
C10	23x23	1535	1.5(DL+LL)	-521	-0.55	-0.57	423	2199	4.16	2.34	Change Section
C10	23x23	3070	1.5(DL+LL)	-518	-2.87	-3.23	423	2278	4.31	2.34	Change Section
C11	23x23	0	1.5(DL+LL)	-705	1.50	-3.37	423	3176	6.00	2.34	Change Section
C11	23x23	1535	1.5(DL+LL)	-702	-0.43	1.63	423	3119	5.90	2.34	Change Section
C11	23x23	3070	1.5(DL+LL)	-699	-2.36	6.62	423	3184	6.02	2.34	Change Section
C12	23x23	0	1.5(DL+LL)	-566	-1.98	1.94	423	2495	4.72	2.34	Change Section
C12	23x23	1535	1.5(DL+LL)	-563	0.43	-0.56	423	2373	4.49	2.34	Change Section
C12	23x23	3070	1.5(DL+LL)	-560	2.85	-3.06	423	2512	4.75	2.34	Change Section
C13	23x23	0	1.5(DL+LL)	-757	5.24	3.49	423	2232	4.22	2.34	Change Section
C13	23x23	1535	1.5(DL+LL)	-754	-2.72	-1.05	423	2079	3.93	2.34	Fail
C13	23x23	3070	1.5(DL+LL)	-751	-10.69	-5.59	423	2558	4.84	2.34	Change Section
C15	23x23	0	1.5(DL+LL)	-503	-0.63	-5.58	423	2492	4.71	2.34	Change Section
C15	23x23	1535	1.5(DL+LL)	-500	0.42	2.02	423	2263	4.28	2.34	Change Section
C15	23x23	3070	1.5(DL+LL)	-497	1.47	9.63	423	2701	5.11	2.34	Change Section
C16	23x23	0	1.5(DL+LL)	-596	2.55	-3.77	423	1416	2.68	2.34	Fail
C16	23x23	1535	1.5(DL+LL)	-593	-0.93	1.33	423	1288	2.43	2.34	Fail
C16	23x23	3070	1.5(DL+LL)	-590	-4.42	6.42	423	1526	2.88	2.34	Fail
C17	23x23	0	1.5(DL+LL)	-625	-5.22	3.47	423	1648	3.12	2.34	Fail
C17	23x23	1535	1.5(DL+LL)	-622	2.47	-1.25	423	1487	2.81	2.34	Fail
C17	23x23	3070	1.5(DL+LL)	-619	10.16	-5.97	423	1954	3.69	2.34	Fail
C18	23x23	0	1.5(DL+LL)	-609	-2.43	-4.02	423	1466	2.77	2.34	Fail
C18	23x23	1535	1.5(DL+LL)	-606	1.02	1.29	423	1338	2.53	2.34	Fail
C18	23x23	3070	1.5(DL+LL)	-603	4.47	6.60	423	1568	2.96	2.34	Fail
C22	23x23	0	1.5(DL+LL)	-503	1.08	-5.48	423	2241	4.24	2.34	Change Section
C22	23x23	1535	1.5(DL+LL)	-500	-0.36	2.12	423	2093	3.96	2.34	Fail
C22	23x23	3070	1.5(DL+LL)	-497	-1.80	9.71	423	2397	4.53	2.34	Change Section
C24	23x23	0	1.5(DL+LL)	-592	4.55	-3.04	423	1557	2.94	2.34	Fail
C24	23x23	1535	1.5(DL+LL)	-589	-2.11	0.92	423	1431	2.71	2.34	Fail
C24	23x23	3070	1.5(DL+LL)	-586	-8.78	4.88	423	1808	3.42	2.34	Fail
C25	23x23	0	1.5(DL+LL)	-528	1.26	6.90	423	2479	4.69	2.34	Change Section
C25	23x23	1535	1.5(DL+LL)	-525	-0.37	-3.41	423	2255	4.26	2.34	Change Section
C25	23x23	3070	1.5(DL+LL)	-522	-1.99	-13.71	423	2837	5.36	2.34	Change Section
C26	23x23	0	1.5(DL+LL)	-616	-5.11	-3.21	423	1608	3.04	2.34	Fail
C26	23x23	1535	1.5(DL+LL)	-613	2.42	1.30	423	1466	2.77	2.34	Fail
C26	23x23	3070	1.5(DL+LL)	-610	9.94	5.81	423	1914	3.62	2.34	Fail
C27	23x23	0	1.5(DL+LL)	-597	2.50	3.50	423	2802	5.30	2.34	Change Section
C27	23x23	1535	1.5(DL+LL)	-594	-0.95	-1.42	423	2674	5.05	2.34	Change Section
C27	23x23	3070	1.5(DL+LL)	-591	-4.40	-6.34	423	2909	5.50	2.34	Change Section
C28	23x23	0	1.5(DL+LL)	-617	4.94	-3.70	423	1738	3.29	2.34	Fail
C28	23x23	1535	1.5(DL+LL)	-614	-2.63	1.31	423	1561	2.95	2.34	Fail
C28	23x23	3070	1.5(DL+LL)	-611	-10.20	6.32	423	2038	3.85	2.34	Fail
C29	23x23	0	1.5(DL+LL)	-600	-3.08	3.75	423	2876	5.44	2.34	Change Section
C29	23x23	1535	1.5(DL+LL)	-597	0.84	-1.48	423	2746	5.19	2.34	Change Section
C29	23x23	3070	1.5(DL+LL)	-594	4.75	-6.70	423	2981	5.64	2.34	Change Section
C30	23x23	0	1.5(DL+LL)	-600	-5.14	-3.15	423	1680	3.18	2.34	Fail
C30	23x23	1535	1.5(DL+LL)	-597	2.29	0.70	423	1504	2.84	2.34	Fail

C30	23x23	3070	1.5(DL+LL)	-594	9.73	4.55	423	1952	3.69	2.34	Fail
C31	23x23	0	1.5(DL+LL)	-507	-4.69	2.30	423	2049	3.87	2.34	Fail
C31	23x23	1535	1.5(DL+LL)	-504	1.33	-0.63	423	1853	3.50	2.34	Fail
C31	23x23	3070	1.5(DL+LL)	-501	7.35	-3.56	423	2161	4.09	2.34	Change Section
C34	23x23	0	1.5(DL+LL)	-654	-5.53	-1.57	423	3391	6.41	2.34	Change Section
C34	23x23	1535	1.5(DL+LL)	-651	1.04	0.21	423	3135	5.93	2.34	Change Section
C34	23x23	3070	1.5(DL+LL)	-648	7.61	1.99	423	3495	6.61	2.34	Change Section
C35	23x23	0	1.5(DL+LL)	-477	-4.04	-1.07	423	1252	2.37	2.34	Fail
C35	23x23	1535	1.5(DL+LL)	-474	1.11	0.09	423	1074	2.03	2.34	OK
C35	23x23	3070	1.5(DL+LL)	-471	6.25	1.25	423	1358	2.57	2.34	Fail
C36	23x23	0	1.5(DL+LL)	-266	-0.36	-3.44	423	423	0.80	2.34	OK
C36	23x23	1535	1.5(DL+LL)	-263	0.08	0.78	423	423	0.80	2.34	OK
C36	23x23	3070	1.5(DL+LL)	-259	0.52	5.01	423	459	0.87	2.34	OK
C37	23x23	0	1.5(DL+LL)	-425	-2.16	-0.18	423	1652	3.12	2.34	Fail
C37	23x23	1535	1.5(DL+LL)	-422	0.72	0.08	423	1585	3.00	2.34	Fail
C37	23x23	3070	1.5(DL+LL)	-419	3.60	0.35	423	1718	3.25	2.34	Fail
C38	23x23	0	1.5(DL+LL)	-721	-0.89	-2.50	423	1667	3.15	2.34	Fail
C38	23x23	1535	1.5(DL+LL)	-718	-0.14	0.59	423	1595	3.02	2.34	Fail
C38	23x23	3070	1.5(DL+LL)	-715	0.62	3.68	423	1682	3.18	2.34	Fail
C39	23x23	0	1.5(DL+LL)	-763	2.77	2.67	423	2007	3.79	2.34	Fail
C39	23x23	1535	1.5(DL+LL)	-760	-1.34	-1.48	423	1965	3.71	2.34	Fail
C39	23x23	3070	1.5(DL+LL)	-757	-5.45	-5.62	423	2123	4.01	2.34	Change Section
C42	23x23	0	1.5(DL+LL)	-595	1.12	-2.94	423	2642	4.99	2.34	Change Section
C42	23x23	1535	1.5(DL+LL)	-592	-0.23	1.02	423	2537	4.80	2.34	Change Section
C42	23x23	3070	1.5(DL+LL)	-588	-1.58	4.98	423	2743	5.19	2.34	Change Section
C43	23x23	0	1.5(DL+LL)	-788	-5.22	-4.68	423	2314	4.37	2.34	Change Section
C43	23x23	1535	1.5(DL+LL)	-785	2.65	1.92	423	2171	4.10	2.34	Change Section
C43	23x23	3070	1.5(DL+LL)	-782	10.53	8.52	423	2683	5.07	2.34	Change Section
C44	23x23	0	1.5(DL+LL)	-582	-4.86	2.99	423	1580	2.99	2.34	Fail
C44	23x23	1535	1.5(DL+LL)	-579	2.21	-1.22	423	1449	2.74	2.34	Fail
C44	23x23	3070	1.5(DL+LL)	-576	9.29	-5.43	423	1851	3.50	2.34	Fail
C46	23x23	0	1.5(DL+LL)	-520	-1.35	-7.08	423	2433	4.60	2.34	Change Section
C46	23x23	1535	1.5(DL+LL)	-517	0.29	3.37	423	2218	4.19	2.34	Change Section
C46	23x23	3070	1.5(DL+LL)	-513	1.94	13.82	423	2796	5.29	2.34	Change Section
C47	23x23	0	1.5(DL+LL)	-622	5.15	3.23	423	1780	3.36	2.34	Fail
C47	23x23	1535	1.5(DL+LL)	-619	-2.53	-1.30	423	1571	2.97	2.34	Fail
C47	23x23	3070	1.5(DL+LL)	-616	-10.22	-5.84	423	2061	3.90	2.34	Fail
C48	23x23	0	1.5(DL+LL)	-484	0.34	-0.80	423	826	1.56	2.34	OK
C48	23x23	1535	1.5(DL+LL)	-481	-0.14	0.13	423	810	1.53	2.34	OK
C48	23x23	3070	1.5(DL+LL)	-478	-0.62	1.06	423	819	1.55	2.34	OK
C49	23x23	0	1.5(DL+LL)	-639	5.62	-2.24	423	3156	5.97	2.34	Change Section
C49	23x23	1535	1.5(DL+LL)	-636	-2.82	0.41	423	3027	5.72	2.34	Change Section
C49	23x23	3070	1.5(DL+LL)	-633	-11.25	3.07	423	3449	6.52	2.34	Change Section
C52	23x35	0	1.5(DL+LL)	-716	9.62	-1.49	644	3442	4.28	2.34	Change Section
C52	23x35	1500	1.5(DL+LL)	-711	-3.58	0.43	644	3317	4.12	2.34	Change Section
C52	23x35	3000	1.5(DL+LL)	-707	-16.78	2.36	644	3577	4.44	2.34	Change Section
C54	23x35	0	1.5(DL+LL)	-952	0.37	7.95	644	4505	5.60	2.34	Change Section
C54	23x35	1535	1.5(DL+LL)	-948	-1.08	-3.22	644	4349	5.40	2.34	Change Section

C54	23x35	3070	1.5(DL+LL)	-943	-2.54	-14.40	644	4773	5.93	2.34	Change Section
C55	23x35	0	1.5(DL+LL)	-671	-8.33	4.03	644	3698	4.59	2.34	Change Section
C55	23x35	1535	1.5(DL+LL)	-666	5.25	-1.25	644	3542	4.40	2.34	Change Section
C55	23x35	3070	1.5(DL+LL)	-662	18.83	-6.54	644	4011	4.98	2.34	Change Section
C56	23x35	0	1.5(DL+LL)	-834	6.01	4.24	644	3011	3.74	2.34	Fail
C56	23x35	1535	1.5(DL+LL)	-830	-3.29	-2.40	644	2872	3.57	2.34	Fail
C56	23x35	3070	1.5(DL+LL)	-825	-12.60	-9.04	644	3253	4.04	2.34	Change Section
C57	23x35	0	1.5(DL+LL)	-832	-4.14	7.62	644	3327	4.13	2.34	Change Section
C57	23x35	1535	1.5(DL+LL)	-827	2.20	-3.98	644	3215	3.99	2.34	Fail
C57	23x35	3070	1.5(DL+LL)	-823	8.55	-15.58	644	3712	4.61	2.34	Change Section
C58	23x35	0	1.5(DL+LL)	-919	-8.49	2.77	644	5355	6.65	2.34	Change Section
C58	23x35	1535	1.5(DL+LL)	-915	6.65	-1.42	644	5263	6.54	2.34	Change Section
C58	23x35	3070	1.5(DL+LL)	-910	21.79	-5.60	644	5734	7.12	2.34	Change Section
C65	23x35	0	1.5(DL+LL)	-768	12.44	-4.85	644	3441	4.27	2.34	Change Section
C65	23x35	1535	1.5(DL+LL)	-764	2.17	1.85	644	3055	3.80	2.34	Fail
C65	23x35	3070	1.5(DL+LL)	-759	-8.10	8.56	644	3262	4.05	2.34	Change Section
C67	23x35	0	1.5(DL+LL)	-725	-2.57	3.24	644	2019	2.51	2.34	Fail
C67	23x35	1535	1.5(DL+LL)	-720	0.83	-1.99	644	1975	2.45	2.34	Fail
C67	23x35	3070	1.5(DL+LL)	-715	4.23	-7.22	644	2006	2.49	2.34	Fail
C72	23x35	0	1.5(DL+LL)	-672	6.76	-2.65	644	1229	1.53	2.34	OK
C72	23x35	1500	1.5(DL+LL)	-668	-1.96	-1.14	644	1083	1.35	2.34	OK
C72	23x35	3000	1.5(DL+LL)	-663	-10.69	0.38	644	1296	1.61	2.34	OK
C73	23x35	0	1.5(DL+LL)	-636	-5.23	-0.96	644	2994	3.72	2.34	Fail
C73	23x35	1535	1.5(DL+LL)	-631	-1.84	1.08	644	2897	3.60	2.34	Fail
C73	23x35	3070	1.5(DL+LL)	-627	1.55	3.13	644	2862	3.56	2.34	Fail
C63	23x35	0	1.5(DL+LL)	-912	-1.71	-6.63	644	2288	2.84	2.34	Fail
C63	23x35	1535	1.5(DL+LL)	-907	0.99	3.23	644	2267	2.82	2.34	Fail
C63	23x35	3070	1.5(DL+LL)	-903	3.69	13.08	644	2348	2.92	2.34	Fail
C77	23x35	0	1.5(DL+LL)	-800	4.94	-7.75	644	1936	2.40	2.34	Fail
C77	23x35	1535	1.5(DL+LL)	-795	-2.33	4.08	644	1894	2.35	2.34	Fail
C77	23x35	3070	1.5(DL+LL)	-790	-9.61	15.90	644	2042	2.54	2.34	Fail
C80	23x35	0	1.5(DL+LL)	-852	2.56	-4.35	644	1874	2.33	2.34	OK
C80	23x35	1535	1.5(DL+LL)	-847	-1.39	1.46	644	1847	2.29	2.34	OK
C80	23x35	3070	1.5(DL+LL)	-843	-5.34	7.27	644	1847	2.29	2.34	OK
C82	23x23	0	1.5(DL+LL)	-490	-1.19	-1.37	423	1998	3.78	2.34	Fail
C82	23x23	1535	1.5(DL+LL)	-487	3.49	0.30	423	2088	3.95	2.34	Fail
C82	23x23	3070	1.5(DL+LL)	-484	8.16	1.97	423	2258	4.27	2.34	Change Section
C84	23x35	0	1.5(DL+LL)	-841	-3.14	3.39	644	6864	8.53	2.34	Change Section
C84	23x35	1535	1.5(DL+LL)	-837	1.12	-1.64	644	6746	8.38	2.34	Change Section
C84	23x35	3070	1.5(DL+LL)	-832	5.38	-6.68	644	6852	8.51	2.34	Change Section
C89	23x23	0	1.5(DL+LL)	-480	-0.43	0.61	423	763	1.44	2.34	OK
C89	23x23	1535	1.5(DL+LL)	-477	0.21	-0.18	423	737	1.39	2.34	OK
C89	23x23	3070	1.5(DL+LL)	-474	0.84	-0.96	423	758	1.43	2.34	OK
C90	23x23	0	1.5(DL+LL)	-640	-6.10	2.00	423	1648	3.12	2.34	Fail
C90	23x23	1535	1.5(DL+LL)	-637	2.70	-0.45	423	1454	2.75	2.34	Fail
C90	23x23	3070	1.5(DL+LL)	-634	11.49	-2.91	423	1976	3.74	2.34	Fail
C91	23x35	0	1.5(DL+LL)	-1,022	1.90	5.00	644	3028	3.76	2.34	Fail
C91	23x35	1535	1.5(DL+LL)	-1,017	-4.36	-1.78	644	3048	3.79	2.34	Fail

C91	23x35	3070	1.5(DL+LL)	-1,013	-10.62	-8.57	644	3213	3.99	2.34	Fail
C92	23x35	0	1.5(DL+LL)	-1,043	-4.86	3.79	644	2586	3.21	2.34	Fail
C92	23x35	1500	1.5(DL+LL)	-1,038	1.37	-2.15	644	2541	3.16	2.34	Fail
C92	23x35	3000	1.5(DL+LL)	-1,034	7.59	-8.09	644	2656	3.30	2.34	Fail
C93	23x35	0	1.5(DL+LL)	-897	7.58	3.08	644	2287	2.84	2.34	Fail
C93	23x35	1500	1.5(DL+LL)	-893	-2.28	-0.97	644	2175	2.70	2.34	Fail
C93	23x35	3000	1.5(DL+LL)	-888	-12.13	-5.01	644	2370	2.94	2.34	Fail
C94	23x35	0	1.5(DL+LL)	-774	-3.31	4.67	644	3144	3.91	2.34	Fail
C94	23x35	1535	1.5(DL+LL)	-770	1.45	-1.93	644	3056	3.80	2.34	Fail
C94	23x35	3070	1.5(DL+LL)	-765	6.21	-8.53	644	3222	4.00	2.34	Change Section
C95	23x35	0	1.5(DL+LL)	-775	7.55	-1.07	644	1875	2.33	2.34	OK
C95	23x35	1535	1.5(DL+LL)	-770	-4.82	0.68	644	1762	2.19	2.34	OK
C95	23x35	3070	1.5(DL+LL)	-766	-17.19	2.42	644	2109	2.62	2.34	Fail
C96	23x35	0	1.5(DL+LL)	-748	-16.28	-1.73	644	2490	3.09	2.34	Fail
C96	23x35	1535	1.5(DL+LL)	-743	9.92	-1.09	644	2235	2.78	2.34	Fail
C96	23x35	3070	1.5(DL+LL)	-739	36.12	-0.46	644	3290	4.09	2.34	Change Section
C97	23x35	0	1.5(DL+LL)	-638	3.21	3.09	644	1843	2.29	2.34	OK
C97	23x35	1535	1.5(DL+LL)	-633	-1.60	0.88	644	1738	2.16	2.34	OK
C97	23x35	3070	1.5(DL+LL)	-628	-6.41	-1.34	644	1955	2.43	2.34	Fail
C64	23x23	0	1.5(DL+LL)	-701	-5.29	2.36	423	5741	10.85	2.34	Change Section
C64	23x23	1535	1.5(DL+LL)	-698	2.84	-1.30	423	5644	10.67	2.34	Change Section
C64	23x23	3070	1.5(DL+LL)	-695	10.96	-4.96	423	5882	11.12	2.34	Change Section
C104	23x35	0	1.5(DL+LL)	-938	-3.06	-0.35	644	3276	4.07	2.34	Change Section
C104	23x35	1725	1.5(DL+LL)	-933	0.72	0.21	644	3158	3.92	2.34	Fail
C104	23x35	3450	1.5(DL+LL)	-928	4.50	0.78	644	3295	4.09	2.34	Change Section
C107	23x23	0	1.5(DL+LL)	-644	1.55	-2.58	423	2815	5.32	2.34	Change Section
C107	23x23	1535	1.5(DL+LL)	-641	-0.34	0.50	423	2739	5.18	2.34	Change Section
C107	23x23	3070	1.5(DL+LL)	-638	-2.23	3.59	423	2819	5.33	2.34	Change Section
C108	23x23	0	1.5(DL+LL)	-718	-1.53	3.61	423	1749	3.31	2.34	Fail
C108	23x23	1535	1.5(DL+LL)	-714	0.33	-1.42	423	1663	3.14	2.34	Fail
C108	23x23	3070	1.5(DL+LL)	-711	2.19	-6.46	423	1923	3.64	2.34	Fail
C112	23x35	0	1.5(DL+LL)	-1,034	-5.10	-5.07	644	3092	3.84	2.34	Fail
C112	23x35	1535	1.5(DL+LL)	-1,030	3.23	1.75	644	3047	3.79	2.34	Fail
C112	23x35	3070	1.5(DL+LL)	-1,025	11.55	8.58	644	3222	4.00	2.34	Change Section
C40	23x23	0	1.5(DL+LL)	-625	-0.01	0.05	423	2854	5.40	2.34	Change Section
C40	23x23	1535	1.5(DL+LL)	-622	-0.06	0.08	423	2841	5.37	2.34	Change Section
C40	23x23	3070	1.5(DL+LL)	-619	-0.11	0.11	423	2828	5.35	2.34	Change Section
C41	23x35	0	1.5(DL+LL)	-752	-10.83	2.76	644	5973	7.42	2.34	Change Section
C41	23x35	1535	1.5(DL+LL)	-747	5.63	-1.92	644	5784	7.19	2.34	Change Section
C41	23x35	3070	1.5(DL+LL)	-743	22.10	-6.60	644	6213	7.72	2.34	Change Section
C53	23x35	0	1.5(DL+LL)	-773	-10.96	-3.84	644	6137	7.62	2.34	Change Section
C53	23x35	1535	1.5(DL+LL)	-768	5.62	1.84	644	5954	7.40	2.34	Change Section
C53	23x35	3070	1.5(DL+LL)	-764	22.19	7.52	644	6367	7.91	2.34	Change Section
C60	23x23	0	1.5(DL+LL)	-489	0.49	5.74	423	3364	6.36	2.34	Change Section
C60	23x23	1535	1.5(DL+LL)	-486	-0.34	-2.27	423	3329	6.29	2.34	Change Section
C60	23x23	3070	1.5(DL+LL)	-483	-1.17	-10.28	423	3387	6.40	2.34	Change Section
C61	23x35	0	1.5(DL+LL)	-827	2.26	3.36	644	3021	3.75	2.34	Fail
C61	23x35	1535	1.5(DL+LL)	-823	-1.41	-1.14	644	2958	3.67	2.34	Fail

C61	23x35	3070	1.5(DL+LL)	-818	-5.08	-5.64	644	3115	3.87	2.34	Fail
C62	23x23	0	1.5(DL+LL)	-601	-0.01	-0.29	423	1182	2.23	2.34	OK
C62	23x23	1535	1.5(DL+LL)	-597	0.00	-0.11	423	1165	2.20	2.34	OK
C62	23x23	3070	1.5(DL+LL)	-594	0.02	0.07	423	1151	2.18	2.34	OK
C68	23x35	0	1.5(DL+LL)	-890	-5.98	0.58	644	2053	2.55	2.34	Fail
C68	23x35	1535	1.5(DL+LL)	-885	3.04	-0.51	644	1983	2.46	2.34	Fail
C68	23x35	3070	1.5(DL+LL)	-881	12.06	-1.60	644	2196	2.73	2.34	Fail
C69	23x35	0	1.5(DL+LL)	-972	5.29	-2.43	644	3239	4.02	2.34	Change Section
C69	23x35	1535	1.5(DL+LL)	-968	-4.10	0.61	644	3178	3.95	2.34	Fail
C69	23x35	3070	1.5(DL+LL)	-963	-13.49	3.64	644	3485	4.33	2.34	Change Section
C70	23x35	0	1.5(DL+LL)	-722	-9.91	1.22	644	3476	4.32	2.34	Change Section
C70	23x35	1500	1.5(DL+LL)	-718	3.44	-0.53	644	3344	4.15	2.34	Change Section
C70	23x35	3000	1.5(DL+LL)	-713	16.79	-2.27	644	3623	4.50	2.34	Change Section
C71	23x35	0	1.5(DL+LL)	-932	4.63	3.13	644	2212	2.75	2.34	Fail
C71	23x35	1500	1.5(DL+LL)	-928	-1.50	-1.24	644	2158	2.68	2.34	Fail
C71	23x35	3000	1.5(DL+LL)	-923	-7.62	-5.61	644	2265	2.81	2.34	Fail
C83	23x35	0	1.5(DL+LL)	-710	2.54	3.19	644	1524	1.89	2.34	OK
C83	23x35	1535	1.5(DL+LL)	-705	-0.96	-1.29	644	1474	1.83	2.34	OK
C83	23x35	3070	1.5(DL+LL)	-701	-4.46	-5.76	644	1538	1.91	2.34	OK
C110	23x35	0	1.5(DL+LL)	-865	-9.41	12.78	644	4105	5.10	2.34	Change Section
C110	23x35	1500	1.5(DL+LL)	-861	2.55	-5.18	644	3929	4.88	2.34	Change Section
C110	23x35	3000	1.5(DL+LL)	-856	14.50	-23.13	644	4555	5.66	2.34	Change Section
C115	23x35	0	1.5(DL+LL)	-1,000	5.67	3.91	644	2397	2.98	2.34	Fail
C115	23x35	1500	1.5(DL+LL)	-996	-1.02	-1.74	644	2357	2.93	2.34	Fail
C115	23x35	3000	1.5(DL+LL)	-991	-7.71	-7.39	644	2428	3.02	2.34	Fail
C116	23x23	0	1.5(DL+LL)	-881	17.84	-15.03	423	6337	11.98	2.34	Change Section
C116	23x23	1535	1.5(DL+LL)	-878	-10.87	7.87	423	6146	11.62	2.34	Change Section
C116	23x23	3070	1.5(DL+LL)	-875	-39.58	30.78	423	6989	13.21	2.34	Change Section
C118	23x35	0	1.5(DL+LL)	-784	-3.44	-4.02	644	1648	2.05	2.34	OK
C118	23x35	1535	1.5(DL+LL)	-779	3.66	1.91	644	1626	2.02	2.34	OK
C118	23x35	3070	1.5(DL+LL)	-775	10.76	7.84	644	1692	2.10	2.34	OK
C119	23x35	0	1.5(DL+LL)	-844	-5.88	2.36	644	2735	3.40	2.34	Fail
C119	23x35	1535	1.5(DL+LL)	-840	4.05	-0.73	644	2604	3.23	2.34	Fail
C119	23x35	3070	1.5(DL+LL)	-835	13.97	-3.82	644	3102	3.85	2.34	Fail
C120	23x35	0	1.5(DL+LL)	-622	6.95	-3.02	644	1504	1.87	2.34	OK
C120	23x35	1535	1.5(DL+LL)	-617	-4.99	1.37	644	1433	1.78	2.34	OK
C120	23x35	3070	1.5(DL+LL)	-613	-16.93	5.76	644	1907	2.37	2.34	Fail
C121	23x35	0	1.5(DL+LL)	-879	8.58	-3.82	644	2681	3.33	2.34	Fail
C121	23x35	1535	1.5(DL+LL)	-874	-6.69	1.38	644	2554	3.17	2.34	Fail
C121	23x35	3070	1.5(DL+LL)	-869	-21.97	6.57	644	3245	4.03	2.34	Change Section
C122	23x35	0	1.5(DL+LL)	-780	11.02	3.82	644	3493	4.34	2.34	Change Section
C122	23x35	1535	1.5(DL+LL)	-776	-5.48	-1.82	644	3281	4.08	2.34	Change Section
C122	23x35	3070	1.5(DL+LL)	-771	-21.99	-7.45	644	3954	4.91	2.34	Change Section
C123	23x35	0	1.5(DL+LL)	-767	10.93	-3.00	644	3440	4.27	2.34	Change Section
C123	23x35	1535	1.5(DL+LL)	-762	-5.46	1.84	644	3225	4.01	2.34	Change Section
C123	23x35	3070	1.5(DL+LL)	-757	-21.85	6.68	644	3866	4.80	2.34	Change Section
C124	23x35	0	1.5(DL+LL)	-864	-2.74	-3.83	644	2009	2.50	2.34	Fail
C124	23x35	1535	1.5(DL+LL)	-860	1.60	1.54	644	1977	2.46	2.34	Fail

C124	23x35	3070	1.5(DL+LL)	-855	5.94	6.90	644	2030	2.52	2.34	Fail
C125	23x35	0	1.5(DL+LL)	-581	-14.10	-3.00	644	2063	2.56	2.34	Fail
C125	23x35	1535	1.5(DL+LL)	-576	-2.45	-1.15	644	1515	1.88	2.34	OK
C125	23x35	3070	1.5(DL+LL)	-571	9.19	0.70	644	1838	2.28	2.34	OK
C126	23x35	0	1.5(DL+LL)	-508	5.28	1.47	644	644	0.80	2.34	OK
C126	23x35	1535	1.5(DL+LL)	-503	1.25	1.01	644	644	0.80	2.34	OK
C126	23x35	3070	1.5(DL+LL)	-498	-2.78	0.56	644	644	0.80	2.34	OK
C127	23x23	0	1.5(DL+LL)	-493	-1.96	7.78	423	2428	4.59	2.34	Change Section
C127	23x23	1535	1.5(DL+LL)	-490	0.45	-4.10	423	2222	4.20	2.34	Change Section
C127	23x23	3070	1.5(DL+LL)	-487	2.86	-15.97	423	2849	5.39	2.34	Change Section
C128	23x35	0	1.5(DL+LL)	-1,027	4.00	-3.59	644	2509	3.12	2.34	Fail
C128	23x35	1500	1.5(DL+LL)	-1,023	-1.53	1.33	644	2459	3.05	2.34	Fail
C128	23x35	3000	1.5(DL+LL)	-1,018	-7.05	6.25	644	2604	3.23	2.34	Fail
C129	23x35	0	1.5(DL+LL)	-897	-5.75	-3.25	644	2129	2.64	2.34	Fail
C129	23x35	1500	1.5(DL+LL)	-892	2.96	0.90	644	2058	2.56	2.34	Fail
C129	23x35	3000	1.5(DL+LL)	-888	11.67	5.05	644	2261	2.81	2.34	Fail
C132	23x35	0	1.5(DL+LL)	-717	2.34	-3.25	644	2829	3.51	2.34	Fail
C132	23x35	1535	1.5(DL+LL)	-712	-1.06	1.24	644	2740	3.40	2.34	Fail
C132	23x35	3070	1.5(DL+LL)	-708	-4.47	5.73	644	2881	3.58	2.34	Fail
C133	23x35	0	1.5(DL+LL)	-699	-2.93	-3.28	644	2763	3.43	2.34	Fail
C133	23x35	1535	1.5(DL+LL)	-694	0.88	1.24	644	2630	3.27	2.34	Fail
C133	23x35	3070	1.5(DL+LL)	-690	4.69	5.76	644	2798	3.48	2.34	Fail
C134	23x35	0	1.5(DL+LL)	-924	-4.93	-2.92	644	2396	2.98	2.34	Fail
C134	23x35	1500	1.5(DL+LL)	-920	1.39	1.31	644	2339	2.91	2.34	Fail
C134	23x35	3000	1.5(DL+LL)	-915	7.71	5.54	644	2453	3.05	2.34	Fail
C14	23x23	0	1.5(DL+LL)	-543	0.51	0.03	423	2764	5.22	2.34	Change Section
C14	23x23	1535	1.5(DL+LL)	-540	-0.37	-1.92	423	2747	5.19	2.34	Change Section
C14	23x23	3070	1.5(DL+LL)	-537	-1.25	-3.87	423	2841	5.37	2.34	Change Section

Table.7. Analysis Result output of Ground floor's column forces, moments & A_{st} % calculated (Model 1).

Thus, for all the stories, column forces, moments, Area of steel provided, and required amount in percentage are calculated and the final details of columns are provided below.

Level	**No. of Columns passed with provided reinforcement (OK)**	**No. of Columns exceeds provided reinforcement but within 4% (Fail)**	**Columns exceed 4% reinforcement (Fail and change section)**
Ground Floor	14	44	42
Storey1	71	25	4
Storey2	88	8	4
Storey3	95	2	3
Storey4	96	1	3
Headroom	22	NIL	NIL

Table.8. The final result of columns passed and failed (Model 1).

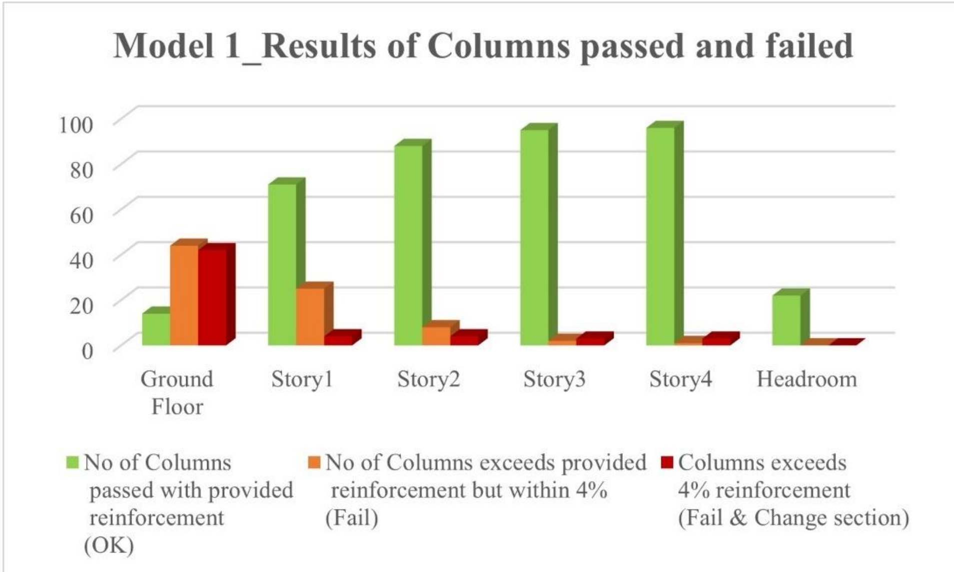

Figure.22. The final result of columns passed and failed (Model 1).

3.5 Seismic Analysis

The strengthening an existing structure widely depends on the seismic resistance of a building which gives way for appropriate rehabilitation scheme, an accurate conditioning of seismic performance of the structure. In this model, the strength of existing building for the given seismic zone is evaluated by adopting a practice to apply the earthquake load using Design Code IS 1893(Part 1) : 2016, whether the building is safe to bear the earthquake load for the required zone 'II' was determined. The earthquake requirements considered in this study is to primarily protect against major structural collapse and to limit damage or maintain the function of the building.

3.5.1 Basis of Design

The procedures and the limits for the design of structures can be determined by considering seismic zoning, site characteristics, occupancy, configure ration, structural system, and height in accordance with this section. Structures should be designed with enough strength to withstand the lateral displacements induced by the Ground Motion, considering the inelastic response of the structure and the essential redundancy, over strength and ductility of the lateral-force- resisting system.

3.5.2 Equivalent Static Method

First, for the whole building, the design base shear V_B shall be computed. Then, this V_B is distributed to the various floor levels at the corresponding centres of mass. Finally, using structural analysis and floor diaphragm action, this design seismic force at each floor level must be transferred to separate lateral load resisting elements. This method shall be applicable for regular buildings with height less than 15m in Seismic Zone II.

3.5.2.1 Design Base Shear

As per Clause 7.6.1, The design base shear V_B along any principal direction of a building shall be determined by,

$$\mathbf{V_B = A_h\ W}$$

where,

A_h = design horizontal acceleration coefficient value as per 6.4.2, using approximate fundamental natural period Ta as per 7.6.2 along the considered direction of shaking, and

W = seismic weight of the building as per 7.4.

3.5.2.2 Seismic Zone Map of India

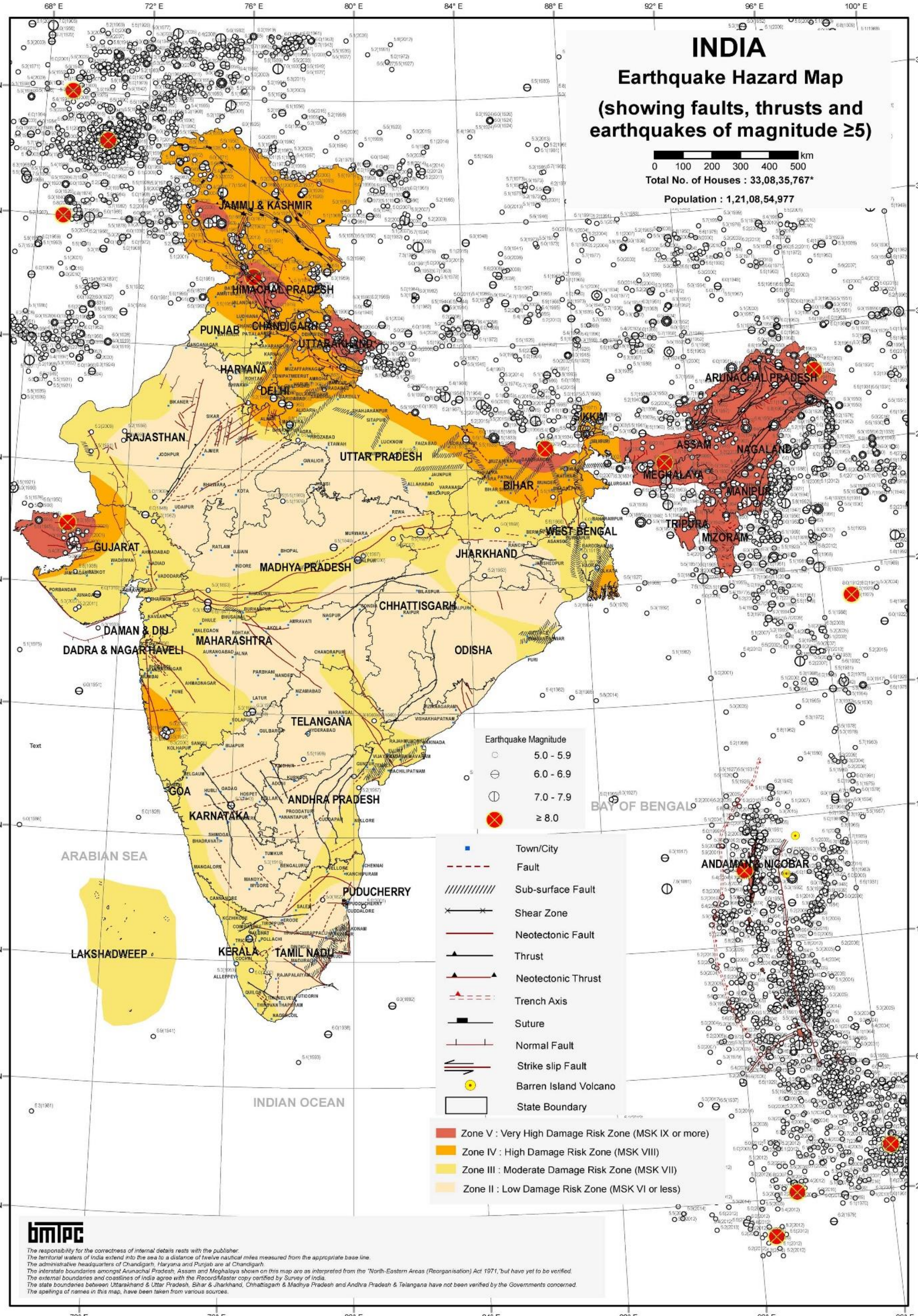

Figure.23. Seismic Zone Map of India.

3.5.2.3 Design Horizontal Seismic Coefficient

As per IS 1893 (Part 1): 2016, Clause 6.4.2, the design horizontal seismic coefficient A_h for a structure shall be determined by,

$$A_h = \frac{\frac{Z}{2} \cdot \frac{S_a}{g}}{\frac{R}{I}}$$

where,

Z = seismic zone factor
I = Importance factor depending upon the functional use of the structures, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance.
R = Response reduction factor, depending on the apparent seismic damage performance of the structure, characterized by ductile or brittle deformations.

S_a/g= Design acceleration coefficient for different soil types, normalized with peak ground acceleration, corresponding natural period T of structure (considering soil-structure interaction, if required)

3.5.2.4 Seismic Zone Factor

Seismic Zone Factor is given in IS 1893 (Part 1) : 2016, Clause 6.4.2.,

Table 3 Seismic Zone Factor *Z*
(*Clause* 6.4.2)

Seismic Zone Factor (1)	II (2)	III (3)	IV (4)	V (5)
Z	0.10	0.16	0.24	0.36

Table.9. Seismic Zone Factor, Z.

Here, in this study, Pondicherry (Puducherry) lies in zone II. Thus, the seismic zone factor, Z is 0.10.

3.5.2.5 Design Acceleration Coefficient for Different Soil Types

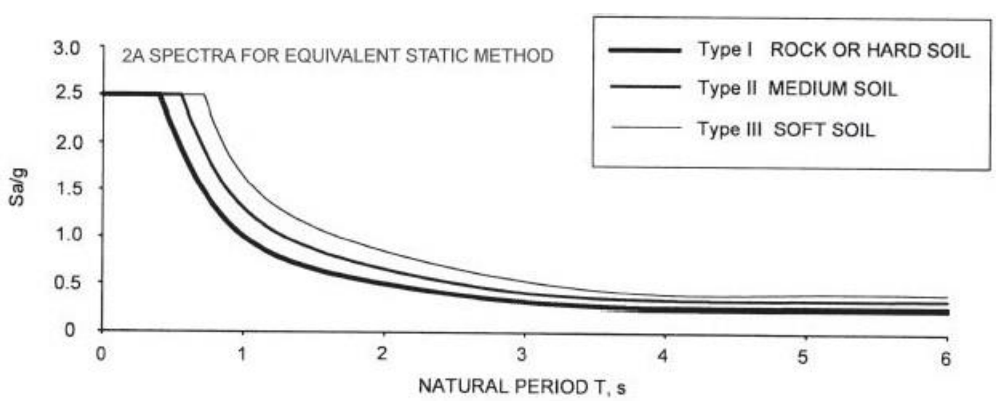

Figure.24. Design Acceleration Coefficient (S_a/g) corresponding to 5% Damping.

The approximate fundamental translation natural period T_a of oscillation, in second, shall be estimated by the following expression,

$$T_a = \frac{0.09h}{\sqrt{d}}$$

where,

h = height of building, in meter.

d = base dimension of the building at the plinth level along the considered direction of earthquake shaking, in meter.

After finding T_a, this value has to be located in S_a/g expression for design acceleration coefficient.

a) For use in equivalent static method [*see* Fig. 2(a)]:

$$\frac{S_a}{g} = \begin{cases} \text{For rocky or hard soil sites} & \begin{cases} 2.5 & 0 < T < 0.40\ \text{s} \\ \frac{1}{T} & 0.40\ \text{s} < T < 4.00\ \text{s} \\ 0.25 & T > 4.00\ \text{s} \end{cases} \\ \text{For medium stiff soil sites} & \begin{cases} 2.5 & 0 < T < 0.55\ \text{s} \\ \frac{1.36}{T} & 0.55\ \text{s} < T < 4.00\ \text{s} \\ 0.34 & T > 4.00\ \text{s} \end{cases} \\ \text{For soft soil sites} & \begin{cases} 2.5 & 0 < T < 0.67\ \text{s} \\ \frac{1.67}{T} & 0.67\ \text{s} < T < 4.00\ \text{s} \\ 0.42 & T > 4.00\ \text{s} \end{cases} \end{cases}$$

Figure.25. Design Acceleration Coefficient (S_a/g) expression.

In this study, the soil Type C is taken as the soil below the ground level is Clayey soil (Soft soils).

3.5.2.6 Response Reduction Factor

Response reduction factor, along with damping during extreme shaking and redundancy influences the non-linear behaviour of buildings during strong earthquake shaking and accounts for inherent system ductility, redundancy, and overstrength normally available in buildings, if designed as per IS standards. For design as per this standard, the value of R can be used for the design of buildings with lateral load resisting systems.

As per IS 1893 (Part 1): 2016, Clause 7.2.6, Response Reduction Factor R for Building Systems are given,

Sl No. (1)	Lateral Load Resisting System (2)	R (3)
i)	**Moment Frame Systems**	
	a) RC buildings with ordinary moment resisting frame (OMRF) (*see* Note 1)	3.0
	b) RC buildings with special moment resisting frame (SMRF)	5.0
	c) Steel buildings with ordinary moment resisting frame (OMRF) (*see* Note 1)	3.0
	d) Steel buildings with special moment resisting frame (SMRF)	5.0

Table.10. Response Reduction Factor (R) for Building Systems

In this study, RC building with ordinary moment-resisting frame (OMRF) with R-value 3 is considered.

3.5.2.7 Seismic Weight

The seismic weight of each floor is its full dead load plus the appropriate amount of imposed load. While computing the seismic weight of each floor, the weight of columns and walls in any storey shall be appropriately apportioned to the floors above and below the storey. Imposed load on roof need not be considered. As per Clause 7.3.1, the Percentage of Imposed Load to be considered in the calculation of Seismic Weight is given.

Sl No. (1)	Imposed Uniformity Distributed Floor Loads kN/m^2 (2)	Percentage of Imposed Load (3)
i)	Up to and including 3.0	25
ii)	Above 3.0	50

Table.11. Percentage of Imposed Load to be considered in Seismic Weight calculation

Imposed load values indicated in the above table for calculating design earthquake lateral forces are applicable to normal conditions. When loads during earthquakes are more accurately assessed, designers may alter imposed load values indicated above.

3.5.2.8 Vertical Distribution of base shear to different floor levels

According to IS 1893 (Part 1): 2016, Clause 7.6.3, the base shear V_B calculated shall be distributed along the height of the building as per the following expression:

$$Q_i = \left(\frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2} \right) V_B$$

where,

Q_i = design lateral force at floor i ;

W_i = seismic weight of floor i ;

h_i = height of floor I measured from base;

n = number of storeys in the building.

3.6 Analysis and Design Procedure Using ETABS Software

3.6.1 Model 2

From Model 1, wind load was defined using IS 875-3; seismic load and load combinations were defined using IS 1893(Part 1): 2016. In continuation from Model 1,

Step - 1: Assigning Wind loads:

Wind loads are assigned as per **IS: 875(Part 3)** by giving wind speed and wind angle in X, X1, Z & Z1 directions.

Step - 2: Assigning Seismic loads:

Seismic loads are defined and assigned as per **IS 1893 (Part 1):2016** by giving zone, soil type, Importance factor, and response reduction factor in X and Y directions.

Step - 3: Assigning load combinations:

After assigning all the loads, the load combinations are given as per **IS1893 (Part 1):2016.**

Step - 4: Analysis:

After the completion of all the above steps, the model was checked for errors, and analysis was performed.

3.6.2 Analysis Input

3.6.2.1 Definition of Earthquake load in ETABS

Definition of earthquake load cases is made from Menu → Define → Load Patterns. EQX represents earthquake load in X direction and EQY represents earthquake load in Y direction.

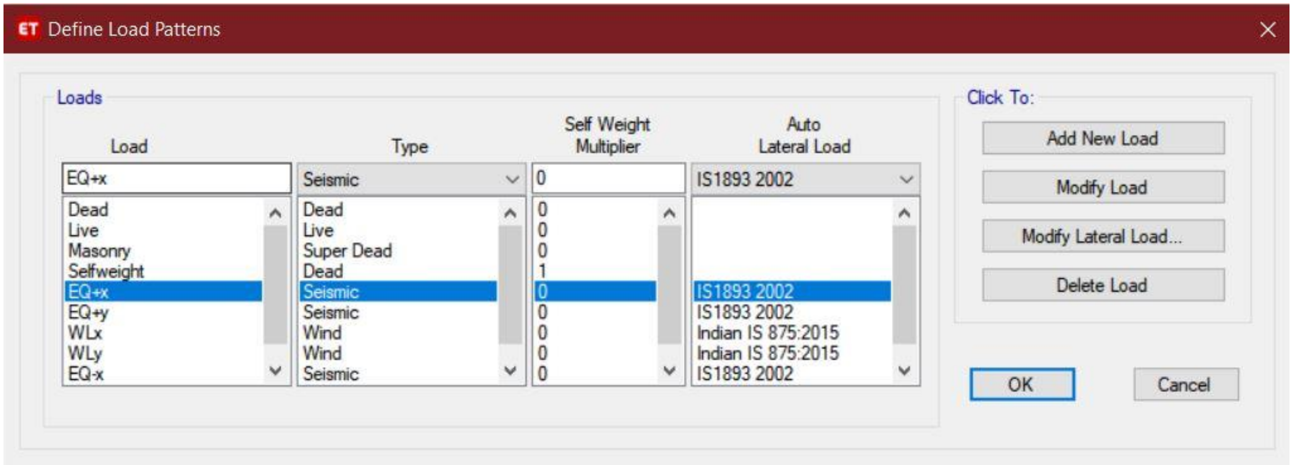

Figure.26. Definition of Earthquake Load Cases

Lateral loads are defined in load patterns with Direction and Eccentricity values. Time period, Story Range, Response Reduction Factor (R), Seismic zone factor (Z), Soil Type, and Importance factor (I). Values of these are taken as mentioned below.

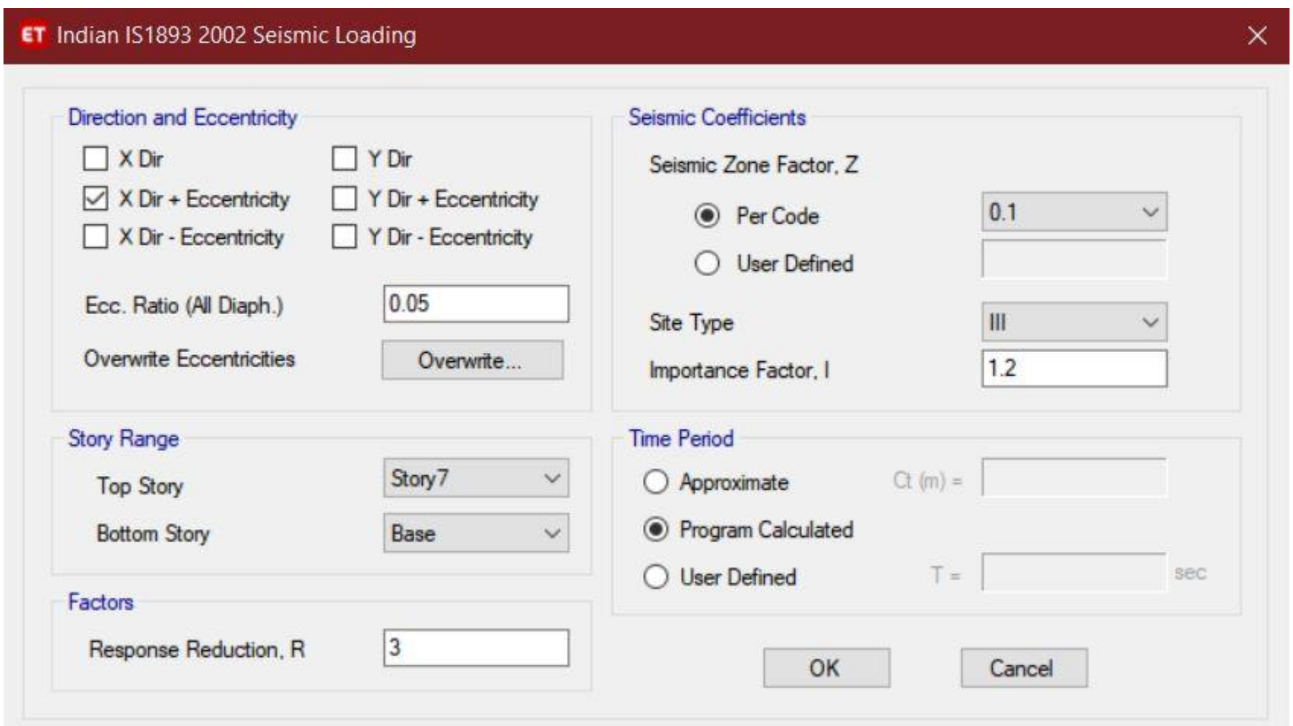

Figure.27. Definition of Seismic Loading

3.6.2.2 Load Combinations

As per IS 1893(Part 1): 2016, the following load combinations were used.

i. 1.2 (D.L + L.L + EQx)
ii. 1.2 (D.L + L.L - EQx)
iii. 1.2 (D.L + L.L + EQy)
iv. 1.2 (D.L + L.L – EQy)
v. 1.5 (D.L + EQx)
vi. 1.5 (D.L – EQx)
vii. 1.5 (D.L + EQy)
viii. 1.5 (D.L – EQy)
ix. 0.9 D.L + 1.5 EQx
x. 0.9 D.L – 1.5 EQx
xi. 0.9 D.L + 1.5 EQy
xii. 0.9 D.L – 1.5 EQy
xiii. 1.2 (D.L + L.L + WLx)
xiv. 1.2 (D.L + L.L - WLx)
xv. 1.2 (D.L + L.L + WLy)
xvi. 1.2 (D.L + L.L – WLy)

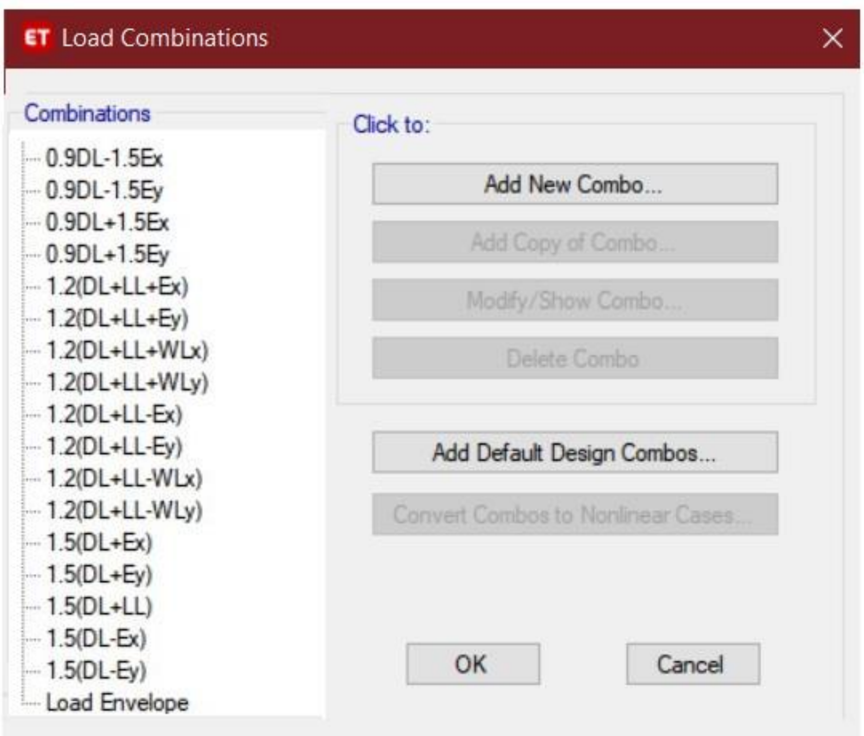

Figure.28. Definition of Load Combinations

3.6.3 Analysis Output

With the help of Model 1, seismic and wind load was defined along with the combinations and respective the output results of the Ground Floor's column forces, moments, Area of steel provided and required amount in percentage, and its results were obtained and are presented below.

Label	Size	Loc	Load Comb	P (kN)	M2 (kNm)	M3 (kNm)	AsMin (mm^2)	As required (mm^2)	% of long reinf required (%)	% of existing reinf provided (%)	Result
C1	23x23	0	1.2(DL+LL-WLy)	-478	3.18	-25.42	423	2363	4.47	2.34	Change Section
C1	23x23	1535	1.5(DL-Ey)	-524	-1.59	-1.01	423	1353	2.56	2.34	Fail
C1	23x23	3070	1.5(DL+Ey)	-522	-15.61	4.90	423	2197	4.15	2.34	Change Section
C2	23x23	0	1.2(DL+LL+WLy)	-566	4.14	29.01	423	2788	5.27	2.34	Change Section
C2	23x23	1535	1.5(DL+LL)	-593	-2.24	-1.15	423	1442	2.73	2.34	Fail
C2	23x23	3070	1.5(DL+Ey)	-523	-15.54	-3.77	423	2485	4.70	2.34	Change Section
C3	23x23	0	1.5(DL+LL)	-667	5.07	1.55	423	4798	9.07	2.34	Change Section
C3	23x23	1535	1.5(DL+LL)	-664	-2.64	-0.31	423	4624	8.74	2.34	Change Section
C3	23x23	3070	1.5(DL+LL)	-661	-10.35	-2.18	423	4984	9.42	2.34	Change Section
C4	23x23	0	1.2(DL+LL-WLy)	-420	2.19	-32.29	423	3148	5.95	2.34	Change Section
C4	23x23	1535	1.5(DL+LL)	-471	-1.42	-0.11	423	2029	3.84	2.34	Fail
C4	23x23	3070	1.2(DL+LL-WLy)	-415	-4.37	24.42	423	2819	5.33	2.34	Change Section
C5	23x23	0	1.5(DL+Ey)	-306	15.34	1.44	423	1164	2.20	2.34	OK
C5	23x23	1535	1.2(DL+LL-WLy)	-159	-0.30	-3.74	423	423	0.80	2.34	OK
C5	23x23	3070	1.5(DL+Ey)	-300	-10.76	-3.20	423	1537	2.91	2.34	Fail
C6	23x23	0	1.2(DL+LL-WLy)	-507	2.64	-32.64	423	2551	4.82	2.34	Change Section
C6	23x23	1535	1.2(DL+LL-WLy)	-504	-1.03	-4.56	423	1107	2.09	2.34	OK
C6	23x23	3070	1.5(DL-Ey)	-474	-3.93	11.42	423	2549	4.82	2.34	Change Section
C7	23x23	0	1.5(DL+LL)	-637	7.75	-3.85	423	3456	6.53	2.34	Change Section
C7	23x23	1535	1.5(DL+LL)	-634	-4.49	1.86	423	3120	5.90	2.34	Change Section
C7	23x23	3070	1.5(DL+LL)	-631	-16.73	7.56	423	3817	7.22	2.34	Change Section
C8	23x23	0	1.2(DL+LL-WLy)	-542	-2.90	-31.58	423	2693	5.09	2.34	Change Section
C8	23x23	1535	1.5(DL+LL)	-609	1.59	-0.58	423	1338	2.53	2.34	Fail
C8	23x23	3070	1.5(DL-Ey)	-543	6.31	10.37	423	2739	5.18	2.34	Change Section
C9	23x23	0	1.5(DL+LL)	-803	-3.55	-4.28	423	4077	7.71	2.34	Change Section
C9	23x23	1535	1.5(DL+LL)	-800	1.60	1.39	423	3829	7.24	2.34	Change Section
C9	23x23	3070	1.5(DL+LL)	-797	6.75	7.06	423	4087	7.73	2.34	Change Section
C10	23x23	0	1.2(DL+LL-WLx)	-468	1.61	-32.59	423	3452	6.53	2.34	Change Section
C10	23x23	1535	1.5(DL+Ey)	-530	1.49	-0.65	423	2263	4.28	2.34	Change Section
C10	23x23	3070	1.2(DL+LL-WLy)	-464	-2.54	23.13	423	2998	5.67	2.34	Change Section
C11	23x23	0	1.5(DL+LL)	-706	1.49	-3.58	423	3405	6.44	2.34	Change Section
C11	23x23	1535	1.5(DL+LL)	-703	-0.43	1.61	423	3110	5.88	2.34	Change Section
C11	23x23	3070	1.5(DL+LL)	-700	-2.35	6.81	423	3313	6.26	2.34	Change Section
C12	23x23	0	1.5(DL-Ex)	-582	-2.41	-18.63	423	3488	6.59	2.34	Change Section
C12	23x23	1535	1.2(DL+LL-WLy)	-564	0.32	-4.97	423	2579	4.88	2.34	Change Section
C12	23x23	3070	1.2(DL+LL-WLx)	-562	2.04	25.17	423	3191	6.03	2.34	Change Section
C13	23x23	0	1.2(DL+LL+WLy)	-653	2.55	28.62	423	3101	5.86	2.34	Change Section
C13	23x23	1535	1.5(DL+LL)	-752	-2.73	-1.06	423	2051	3.88	2.34	Fail
C13	23x23	3070	1.5(DL+Ey)	-662	-16.95	-4.05	423	2868	5.42	2.34	Change Section

C15	23x23	0	1.2(DL+LL-WLy)	-441	-0.68	-23.06	423	3011	5.69	2.34	Change Section
C15	23x23	1535	1.5(DL+LL)	-500	0.40	2.01	423	2260	4.27	2.34	Change Section
C15	23x23	3070	1.2(DL+LL-WLy)	-436	1.25	20.82	423	2894	5.47	2.34	Change Section
C16	23x23	0	1.2(DL+LL-WLy)	-537	1.88	-27.52	423	2428	4.59	2.34	Change Section
C16	23x23	1535	1.5(DL+LL)	-593	-0.94	1.33	423	1282	2.42	2.34	Fail
C16	23x23	3070	1.5(DL-Ey)	-577	-5.45	14.64	423	2906	5.49	2.34	Change Section
C17	23x23	0	1.2(DL+LL+WLy)	-590	-4.73	27.81	423	2751	5.20	2.34	Change Section
C17	23x23	1535	1.5(DL+LL)	-621	2.47	-1.25	423	1475	2.79	2.34	Fail
C17	23x23	3070	1.2(DL+LL+WLy)	-585	9.20	-23.05	423	2469	4.67	2.34	Change Section
C18	23x23	0	1.2(DL+LL-WLy)	-547	-2.09	-27.51	423	2473	4.67	2.34	Change Section
C18	23x23	1535	1.5(DL+Ey)	-603	3.05	0.99	423	1400	2.65	2.34	Fail
C18	23x23	3070	1.5(DL-Ey)	-604	2.79	15.67	423	2527	4.78	2.34	Change Section
C22	23x23	0	1.2(DL+LL-WLy)	-441	0.71	-21.73	423	2694	5.09	2.34	Change Section
C22	23x23	1535	1.5(DL+LL)	-501	-0.36	2.09	423	2087	3.95	2.34	Fail
C22	23x23	3070	1.5(DL-Ey)	-485	-3.15	15.50	423	2647	5.00	2.34	Change Section
C24	23x23	0	1.2(DL+LL-WLy)	-560	4.00	-27.62	423	2689	5.08	2.34	Change Section
C24	23x23	1535	1.5(DL+LL)	-588	-2.11	0.91	423	1415	2.67	2.34	Fail
C24	23x23	3070	1.5(DL+Ey)	-522	-15.79	4.52	423	2401	4.54	2.34	Change Section
C25	23x23	0	1.2(DL+LL+WLx)	-491	0.99	29.09	423	3384	6.40	2.34	Change Section
C25	23x23	1535	1.5(DL+LL)	-524	-0.37	-3.41	423	2249	4.25	2.34	Change Section
C25	23x23	3070	1.2(DL+LL+WLy)	-486	-1.71	-25.43	423	3163	5.98	2.34	Change Section
C26	23x23	0	1.2(DL+LL-WLy)	-582	-4.42	-25.41	423	2601	4.92	2.34	Change Section
C26	23x23	1535	1.5(DL+LL)	-612	2.42	1.30	423	1452	2.74	2.34	Fail
C26	23x23	3070	1.2(DL+LL-WLy)	-577	8.77	22.47	423	2405	4.55	2.34	Change Section
C27	23x23	0	1.5(DL+Ex)	-599	0.47	19.62	423	3609	6.82	2.34	Change Section
C27	23x23	1535	1.5(DL+Ex)	-596	-1.12	1.82	423	2676	5.06	2.34	Change Section
C27	23x23	3070	1.5(DL+Ex)	-593	-2.71	-15.98	423	3384	6.40	2.34	Change Section
C28	23x23	0	1.2(DL+LL-WLy)	-581	4.62	-27.74	423	2830	5.35	2.34	Change Section
C28	23x23	1535	1.5(DL+LL)	-613	-2.63	1.31	423	1547	2.92	2.34	Fail
C28	23x23	3070	1.5(DL+Ey)	-557	-17.49	4.98	423	2686	5.08	2.34	Change Section
C29	23x23	0	1.5(DL+Ex)	-588	-4.71	16.28	423	3417	6.46	2.34	Change Section
C29	23x23	1535	1.5(DL+Ey)	-595	2.94	-1.05	423	2748	5.19	2.34	Change Section
C29	23x23	3070	1.5(DL+Ex)	-582	5.79	-14.83	423	3329	6.29	2.34	Change Section
C30	23x23	0	1.2(DL+LL-WLy)	-568	-4.32	-28.43	423	2814	5.32	2.34	Change Section
C30	23x23	1535	1.5(DL+LL)	-597	2.29	0.70	423	1490	2.82	2.34	Fail
C30	23x23	3070	1.2(DL+LL-WLy)	-564	8.44	22.48	423	2476	4.68	2.34	Change Section
C31	23x23	0	1.2(DL+LL+WLy)	-468	-3.81	24.66	423	2835	5.36	2.34	Change Section
C31	23x23	1535	1.5(DL+Ex)	-519	1.16	1.01	423	1936	3.66	2.34	Fail
C31	23x23	3070	1.2(DL+LL+WLy)	-463	5.89	-19.53	423	2567	4.85	2.34	Change Section
C34	23x23	0	1.5(DL+LL)	-654	-5.53	-1.61	423	3480	6.58	2.34	Change Section
C34	23x23	1535	1.5(DL+LL)	-651	1.04	0.21	423	3129	5.91	2.34	Change Section
C34	23x23	3070	1.5(DL+LL)	-648	7.61	2.02	423	3542	6.70	2.34	Change Section
C35	23x23	0	1.2(DL+LL+WLy)	-422	-3.28	32.17	423	2394	4.53	2.34	Change Section
C35	23x23	1535	1.5(DL+LL)	-473	1.11	0.09	423	1057	2.00	2.34	OK
C35	23x23	3070	1.5(DL+Ex)	-441	5.10	-11.14	423	2259	4.27	2.34	Change Section
C36	23x23	0	1.2(DL+LL-WLy)	-228	0.34	-26.23	423	1324	2.50	2.34	Fail
C36	23x23	1535	1.2(DL+LL-WLy)	-226	-0.22	-2.45	423	423	0.80	2.34	OK
C36	23x23	3070	1.5(DL+Ey)	-141	-9.41	3.49	423	1300	2.46	2.34	Fail

C37	23x23	0	1.2(DL+LL+WLx)	-499	-2.16	31.80	423	3462	6.54	2.34	Change Section
C37	23x23	1535	1.2(DL+LL+WLy)	-497	0.75	4.43	423	2188	4.14	2.34	Change Section
C37	23x23	3070	1.2(DL+LL+WLy)	-494	3.66	-22.93	423	3037	5.74	2.34	Change Section
C38	23x23	0	1.2(DL+LL+WLy)	-629	-0.54	32.01	423	2887	5.46	2.34	Change Section
C38	23x23	1535	1.5(DL+LL)	-718	-0.14	0.61	423	1588	3.00	2.34	Fail
C38	23x23	3070	1.5(DL+Ey)	-622	-10.17	1.55	423	2873	5.43	2.34	Change Section
C39	23x23	0	1.2(DL+LL-WLy)	-682	2.25	-29.65	423	3101	5.86	2.34	Change Section
C39	23x23	1535	1.5(DL+LL)	-760	-1.33	-1.47	423	1958	3.70	2.34	Fail
C39	23x23	3070	1.2(DL+LL+Ex)	-569	-4.81	-14.59	423	3286	6.21	2.34	Change Section
C42	23x23	0	1.5(DL+Ex)	-614	1.66	17.23	423	3574	6.76	2.34	Change Section
C42	23x23	1535	1.5(DL+Ex)	-611	-0.14	3.31	423	2762	5.22	2.34	Change Section
C42	23x23	3070	1.2(DL+LL+WLx)	-582	-1.11	-23.15	423	3577	6.76	2.34	Change Section
C43	23x23	0	1.2(DL+LL-WLx)	-680	-2.66	-30.43	423	3297	6.23	2.34	Change Section
C43	23x23	1535	1.5(DL+LL)	-784	2.65	1.94	423	2152	4.07	2.34	Change Section
C43	23x23	3070	1.2(DL+LL-WLy)	-675	5.08	25.70	423	3055	5.78	2.34	Change Section
C44	23x23	0	1.2(DL+LL+WLy)	-552	-4.15	28.57	423	2756	5.21	2.34	Change Section
C44	23x23	1535	1.5(DL+LL)	-578	2.21	-1.21	423	1433	2.71	2.34	Fail
C44	23x23	3070	1.2(DL+LL+WLy)	-547	8.06	-23.39	423	2456	4.64	2.34	Change Section
C46	23x23	0	1.2(DL+LL-WLx)	-486	-1.19	-29.18	423	3349	6.33	2.34	Change Section
C46	23x23	1535	1.5(DL+LL)	-517	0.29	3.38	423	2215	4.19	2.34	Change Section
C46	23x23	3070	1.2(DL+LL-WLy)	-481	1.77	25.45	423	3137	5.93	2.34	Change Section
C47	23x23	0	1.2(DL+LL+WLy)	-588	4.68	27.59	423	2851	5.39	2.34	Change Section
C47	23x23	1535	1.5(DL+LL)	-618	-2.53	-1.30	423	1557	2.94	2.34	Fail
C47	23x23	3070	1.5(DL+Ey)	-564	-16.69	-5.24	423	2632	4.98	2.34	Change Section
C48	23x23	0	1.2(DL+LL-WLy)	-511	0.29	-28.65	423	2311	4.37	2.34	Change Section
C48	23x23	1535	1.2(DL+LL-WLy)	-508	-0.14	-3.78	423	1032	1.95	2.34	OK
C48	23x23	3070	1.2(DL+LL-Ey)	-456	-1.22	9.93	423	2084	3.94	2.34	Fail
C49	23x23	0	1.5(DL+LL)	-638	5.60	-1.85	423	3410	6.45	2.34	Change Section
C49	23x23	1535	1.5(DL+Ex)	-642	-2.74	3.12	423	3045	5.76	2.34	Change Section
C49	23x23	3070	1.5(DL+LL)	-632	-11.24	2.75	423	3561	6.73	2.34	Change Section
C52	23x35	0	1.2(DL+LL+WLy)	-617	7.66	44.21	644	4551	5.65	2.34	Change Section
C52	23x35	1500	1.5(DL+LL)	-711	-3.60	0.44	644	3317	4.12	2.34	Change Section
C52	23x35	3000	1.5(DL+Ex)	-657	-13.42	-19.45	644	3938	4.89	2.34	Change Section
C54	23x35	0	1.5(DL+Ex)	-886	-3.62	22.68	644	4958	6.16	2.34	Change Section
C54	23x35	1535	1.5(DL+LL)	-948	-1.07	-3.20	644	4321	5.37	2.34	Change Section
C54	23x35	3070	1.5(DL+Ex)	-877	0.39	-22.36	644	4839	6.01	2.34	Change Section
C55	23x35	0	1.5(DL+Ex)	-675	-31.59	1.89	644	4482	5.57	2.34	Change Section
C55	23x35	1535	1.5(DL+Ey)	-670	4.84	1.56	644	3552	4.41	2.34	Change Section
C55	23x35	3070	1.5(DL+Ex)	-666	33.25	-4.48	644	4473	5.56	2.34	Change Section
C56	23x35	0	1.5(DL+Ex)	-895	-46.95	2.71	644	4962	6.16	2.34	Change Section
C56	23x35	1535	1.5(DL+Ex)	-891	-11.46	-2.11	644	3385	4.20	2.34	Change Section
C56	23x35	3070	1.2(DL+LL+WLy)	-822	44.35	-7.09	644	4458	5.54	2.34	Change Section
C57	23x35	0	1.2(DL+LL+WLy)	-712	-3.90	40.58	644	4454	5.53	2.34	Change Section
C57	23x35	1535	1.5(DL+LL)	-828	2.22	-3.99	644	3185	3.96	2.34	Fail
C57	23x35	3070	1.2(DL+LL+WLy)	-705	7.25	-32.02	644	4009	4.98	2.34	Change Section
C58	23x35	0	1.5(DL+LL)	-920	-7.86	2.66	644	5575	6.93	2.34	Change Section
C58	23x35	1535	1.5(DL+LL)	-915	6.60	-1.42	644	5221	6.49	2.34	Change Section
C58	23x35	3070	1.5(DL+LL)	-910	21.06	-5.51	644	5761	7.16	2.34	Change Section

C65	23x35	0	1.5(DL+Ey)	-655	48.24	-4.88	644	4180	5.19	2.34	Change Section
C65	23x35	1535	1.5(DL-Ey)	-764	2.42	-0.74	644	3047	3.79	2.34	Fail
C65	23x35	3070	1.5(DL-Ey)	-760	-7.25	20.24	644	3779	4.69	2.34	Change Section
C67	23x35	0	1.2(DL+LL+WLy)	-652	-2.23	32.21	644	3020	3.75	2.34	Fail
C67	23x35	1535	1.5(DL+LL)	-719	0.83	-2.00	644	1964	2.44	2.34	Fail
C67	23x35	3070	1.2(DL+LL+WLy)	-645	3.54	-26.49	644	2679	3.33	2.34	Fail
C72	23x35	0	1.2(DL+LL-WLy)	-694	5.39	-38.90	644	2835	3.52	2.34	Fail
C72	23x35	1500	1.5(DL-Ey)	-717	-1.60	-5.11	644	1231	1.53	2.34	OK
C72	23x35	3000	1.5(DL-Ey)	-713	-9.05	16.43	644	2873	3.57	2.34	Fail
C73	23x35	0	1.2(DL+LL+WLy)	-573	-4.43	45.01	644	4368	5.43	2.34	Change Section
C73	23x35	1535	1.5(DL+Ex)	-629	-1.93	4.29	644	2872	3.57	2.34	Fail
C73	23x35	3070	1.2(DL+LL+WLy)	-565	1.45	-31.81	644	3663	4.55	2.34	Change Section
C63	23x35	0	1.5(DL+Ey)	-847	33.78	-4.76	644	2967	3.69	2.34	Fail
C63	23x35	1535	1.5(DL+LL)	-908	0.99	3.21	644	2256	2.80	2.34	Fail
C63	23x35	3070	1.5(DL-Ey)	-879	-0.23	22.39	644	2900	3.60	2.34	Fail
C77	23x35	0	1.2(DL+LL-WLy)	-686	3.93	-39.58	644	3026	3.76	2.34	Fail
C77	23x35	1535	1.5(DL+LL)	-795	-2.31	4.08	644	1888	2.35	2.34	Fail
C77	23x35	3070	1.2(DL+LL-WLy)	-678	-7.73	31.91	644	2570	3.19	2.34	Fail
C80	23x35	0	1.2(DL+LL-WLy)	-760	1.95	-33.34	644	2665	3.31	2.34	Fail
C80	23x35	1535	1.5(DL+LL)	-848	-1.38	1.44	644	1844	2.29	2.34	OK
C80	23x35	3070	1.2(DL+LL-WLy)	-753	-4.32	27.31	644	2305	2.86	2.34	Fail
C82	23x23	0	1.5(DL+Ey)	-472	-0.94	17.93	423	2717	5.14	2.34	Change Section
C82	23x23	1535	1.5(DL+LL)	-487	3.41	0.30	423	2082	3.94	2.34	Fail
C82	23x23	3070	1.2(DL+LL+Ey)	-405	6.47	-9.78	423	2418	4.57	2.34	Change Section
C84	23x35	0	1.5(DL+LL)	-842	-3.24	3.11	644	6969	8.66	2.34	Change Section
C84	23x35	1535	1.5(DL+LL)	-837	1.13	-1.60	644	6741	8.37	2.34	Change Section
C84	23x35	3070	1.5(DL+LL)	-833	5.50	-6.32	644	6858	8.52	2.34	Change Section
C89	23x23	0	1.2(DL+LL+WLy)	-506	-0.57	28.48	423	2237	4.23	2.34	Change Section
C89	23x23	1535	1.2(DL+LL+WLy)	-503	0.16	3.73	423	954	1.80	2.34	OK
C89	23x23	3070	1.5(DL+Ex)	-521	1.62	-12.30	423	2287	4.32	2.34	Change Section
C90	23x23	0	1.2(DL+LL-WLy)	-599	-6.31	-33.51	423	2938	5.55	2.34	Change Section
C90	23x23	1535	1.5(DL-Ey)	-642	2.58	-3.16	423	1478	2.79	2.34	Fail
C90	23x23	3070	1.5(DL-Ey)	-639	11.80	13.22	423	3054	5.77	2.34	Change Section
C91	23x35	0	1.2(DL+LL+WLy)	-866	1.03	30.89	644	3528	4.38	2.34	Change Section
C91	23x35	1535	1.5(DL+LL)	-1,019	-4.36	-1.75	644	3037	3.77	2.34	Fail
C91	23x35	3070	1.5(DL+Ex)	-1,011	-8.53	-18.89	644	4038	5.02	2.34	Change Section
C92	23x35	0	1.2(DL+LL+WLy)	-918	-4.03	32.63	644	3369	4.19	2.34	Change Section
C92	23x35	1500	1.5(DL+LL)	-1,037	1.37	-2.16	644	2522	3.13	2.34	Fail
C92	23x35	3000	1.5(DL+Ex)	-933	5.99	-18.36	644	3433	4.26	2.34	Change Section
C93	23x35	0	1.2(DL+LL+WLy)	-796	5.96	30.24	644	3009	3.74	2.34	Fail
C93	23x35	1500	1.5(DL+LL)	-894	-2.27	-0.99	644	2167	2.69	2.34	Fail
C93	23x35	3000	1.5(DL+Ex)	-843	-9.85	-15.95	644	3365	4.18	2.34	Change Section
C94	23x35	0	1.5(DL+Ey)	-788	32.33	4.60	644	4347	5.40	2.34	Change Section
C94	23x35	1535	1.5(DL+Ey)	-784	6.55	-2.02	644	3304	4.10	2.34	Change Section
C94	23x35	3070	1.5(DL+Ex)	-769	5.28	-20.23	644	3834	4.76	2.34	Change Section
C95	23x35	0	1.5(DL+Ey)	-801	42.86	-1.60	644	3160	3.93	2.34	Fail
C95	23x35	1535	1.5(DL+Ey)	-796	5.44	0.48	644	1877	2.33	2.34	OK
C95	23x35	3070	1.5(DL+Ey)	-792	-31.99	2.56	644	2702	3.36	2.34	Fail

C96	23x35	0	1.2(DL+LL-WLy)	-685	-14.17	-49.46	644	3971	4.93	2.34	Change Section
C96	23x35	1535	1.5(DL-Ey)	-760	9.34	-4.61	644	2258	2.80	2.34	Fail
C96	23x35	3070	1.5(DL-Ey)	-756	33.64	18.72	644	4217	5.24	2.34	Change Section
C97	23x35	0	1.2(DL+LL+WLy)	-673	2.71	39.00	644	3570	4.43	2.34	Change Section
C97	23x35	1535	1.5(DL+Ex)	-720	-1.31	4.32	644	2040	2.53	2.34	Fail
C97	23x35	3070	1.2(DL+LL+WLy)	-665	-5.53	-27.54	644	3078	3.82	2.34	Fail
C64	23x23	0	1.5(DL+LL)	-701	-5.28	2.22	423	5741	10.85	2.34	Change Section
C64	23x23	1535	1.5(DL+LL)	-698	2.84	-1.31	423	5638	10.66	2.34	Change Section
C64	23x23	3070	1.5(DL+LL)	-695	10.95	-4.83	423	5878	11.11	2.34	Change Section
C104	23x35	0	1.5(DL+Ey)	-780	40.42	-0.05	644	4162	5.17	2.34	Change Section
C104	23x35	1725	1.5(DL+LL)	-932	0.73	0.29	644	3124	3.88	2.34	Fail
C104	23x35	3450	1.5(DL+Ey)	-769	-28.40	0.51	644	3585	4.45	2.34	Change Section
C107	23x23	0	1.5(DL+Ex)	-603	1.92	16.35	423	3371	6.37	2.34	Change Section
C107	23x23	1535	1.5(DL+LL)	-641	-0.34	0.53	423	2725	5.15	2.34	Change Section
C107	23x23	3070	1.2(DL+LL+WLx)	-558	-1.64	-22.75	423	3427	6.48	2.34	Change Section
C108	23x23	0	1.2(DL+LL-WLy)	-647	-1.25	-27.93	423	2812	5.32	2.34	Change Section
C108	23x23	1535	1.5(DL+LL)	-715	0.33	-1.41	423	1644	3.11	2.34	Fail
C108	23x23	3070	1.2(DL+LL-Ex)	-615	1.25	7.09	423	3322	6.28	2.34	Change Section
C112	23x35	0	1.5(DL+Ey)	-1,023	36.01	-5.15	644	3920	4.87	2.34	Change Section
C112	23x35	1535	1.5(DL+Ey)	-1,018	11.45	1.69	644	3184	3.96	2.34	Fail
C112	23x35	3070	1.5(DL-Ey)	-1,023	9.14	18.96	644	3823	4.75	2.34	Change Section
C40	23x23	0	1.5(DL+Ex)	-564	-0.00	21.80	423	3608	6.82	2.34	Change Section
C40	23x23	1535	1.5(DL+LL)	-622	-0.03	0.08	423	2842	5.37	2.34	Change Section
C40	23x23	3070	1.5(DL+Ex)	-558	-0.06	-16.09	423	3282	6.20	2.34	Change Section
C41	23x35	0	1.5(DL+LL)	-752	-10.51	2.88	644	5983	7.43	2.34	Change Section
C41	23x35	1535	1.5(DL+LL)	-748	5.40	-1.91	644	5783	7.18	2.34	Change Section
C41	23x35	3070	1.5(DL+LL)	-743	21.30	-6.71	644	6196	7.70	2.34	Change Section
C53	23x35	0	1.5(DL+LL)	-773	-10.61	-3.81	644	6142	7.63	2.34	Change Section
C53	23x35	1535	1.5(DL+LL)	-768	5.35	1.84	644	5952	7.39	2.34	Change Section
C53	23x35	3070	1.5(DL+LL)	-764	21.31	7.49	644	6346	7.88	2.34	Change Section
C60	23x23	0	1.5(DL+LL)	-490	0.62	5.59	423	3498	6.61	2.34	Change Section
C60	23x23	1535	1.5(DL+LL)	-486	-0.33	-2.26	423	3329	6.29	2.34	Change Section
C60	23x23	3070	1.5(DL+LL)	-483	-1.28	-10.11	423	3462	6.54	2.34	Change Section
C61	23x35	0	1.2(DL+LL+WLy)	-740	1.69	32.55	644	4041	5.02	2.34	Change Section
C61	23x35	1535	1.5(DL+Ex)	-816	-2.15	1.39	644	2949	3.66	2.34	Fail
C61	23x35	3070	1.2(DL+LL+WLy)	-732	-4.22	-26.09	644	3643	4.53	2.34	Change Section
C62	23x23	0	1.2(DL+LL-WLy)	-497	-0.01	-30.86	423	2300	4.35	2.34	Change Section
C62	23x23	1535	1.5(DL+LL)	-597	-0.02	-0.11	423	1155	2.18	2.34	OK
C62	23x23	3070	1.5(DL-Ey)	-550	0.03	16.10	423	2510	4.74	2.34	Change Section
C68	23x35	0	1.5(DL+Ey)	-909	38.23	1.20	644	3069	3.81	2.34	Fail
C68	23x35	1535	1.5(DL+Ey)	-904	11.71	-0.48	644	2245	2.79	2.34	Fail
C68	23x35	3070	1.5(DL+Ex)	-901	13.07	-13.36	644	2861	3.55	2.34	Fail
C69	23x35	0	1.5(DL+Ex)	-926	-45.21	-3.34	644	4837	6.01	2.34	Change Section
C69	23x35	1535	1.2(DL+LL+WLy)	-900	-15.98	0.45	644	3354	4.17	2.34	Change Section
C69	23x35	3070	1.2(DL+LL+WLy)	-896	43.03	2.99	644	4491	5.58	2.34	Change Section
C70	23x35	0	1.2(DL+LL-WLy)	-621	-7.93	-42.71	644	4510	5.60	2.34	Change Section
C70	23x35	1500	1.5(DL+LL)	-717	3.46	-0.53	644	3345	4.16	2.34	Change Section
C70	23x35	3000	1.2(DL+LL-WLy)	-614	13.40	28.96	644	3825	4.75	2.34	Change Section

C71	23x35	0	1.2(DL+LL+WLy)	-815	3.41	30.17	644	2947	3.66	2.34	Fail
C71	23x35	1500	1.5(DL+LL)	-927	-1.50	-1.25	644	2149	2.67	2.34	Fail
C71	23x35	3000	1.5(DL+Ex)	-810	-6.21	-14.24	644	3317	4.12	2.34	Change Section
C83	23x35	0	1.2(DL+LL+WLy)	-640	1.84	30.18	644	2506	3.11	2.34	Fail
C83	23x35	1535	1.5(DL+LL)	-705	-0.95	-1.31	644	1467	1.82	2.34	OK
C83	23x35	3070	1.2(DL+LL+WLy)	-632	-3.41	-25.03	644	2255	2.80	2.34	Fail
C110	23x35	0	1.2(DL+LL+WLx)	-745	-7.32	40.63	644	4842	6.01	2.34	Change Section
C110	23x35	1500	1.5(DL+Ey)	-867	9.17	-5.20	644	4082	5.07	2.34	Change Section
C110	23x35	3000	1.5(DL+Ex)	-793	10.87	-31.05	644	4652	5.78	2.34	Change Section
C115	23x35	0	1.2(DL+LL+WLy)	-877	4.61	32.32	644	3231	4.01	2.34	Change Section
C115	23x35	1500	1.5(DL+LL)	-993	-1.02	-1.75	644	2350	2.92	2.34	Fail
C115	23x35	3000	1.5(DL+Ex)	-889	-6.65	-19.61	644	3744	4.65	2.34	Change Section
C116	23x23	0	1.5(DL+LL)	-880	17.80	-14.85	423	6332	11.97	2.34	Change Section
C116	23x23	1535	1.5(DL+LL)	-877	-10.87	7.88	423	6120	11.57	2.34	Change Section
C116	23x23	3070	1.5(DL+LL)	-874	-39.53	30.60	423	6984	13.20	2.34	Change Section
C118	23x35	0	1.2(DL+LL-WLy)	-786	75.22	-3.18	644	3501	4.35	2.34	Change Section
C118	23x35	1535	1.5(DL-Ey)	-880	12.66	1.84	644	2111	2.62	2.34	Fail
C118	23x35	3070	1.5(DL-Ey)	-875	-24.74	6.52	644	3642	4.52	2.34	Change Section
C119	23x35	0	1.2(DL+LL-WLy)	-798	65.24	1.87	644	4783	5.94	2.34	Change Section
C119	23x35	1535	1.5(DL-Ey)	-829	9.87	-0.39	644	2846	3.54	2.34	Fail
C119	23x35	3070	1.2(DL+LL-WLy)	-791	-40.15	-3.03	644	3919	4.87	2.34	Change Section
C120	23x35	0	1.5(DL-Ey)	-667	29.21	-1.30	644	2505	3.11	2.34	Fail
C120	23x35	1535	1.5(DL-Ey)	-663	-1.74	1.55	644	1472	1.83	2.34	OK
C120	23x35	3070	1.5(DL-Ey)	-658	-32.69	4.40	644	2619	3.25	2.34	Fail
C121	23x35	0	1.2(DL+LL-WLy)	-767	61.18	-3.13	644	4321	5.37	2.34	Change Section
C121	23x35	1535	1.5(DL+LL)	-874	-6.63	1.38	644	2511	3.12	2.34	Fail
C121	23x35	3070	1.2(DL+LL-WLy)	-760	-47.10	5.33	644	3757	4.67	2.34	Change Section
C122	23x35	0	1.5(DL-Ey)	-738	23.63	6.11	644	3823	4.75	2.34	Change Section
C122	23x35	1535	1.5(DL+LL)	-776	-5.20	-1.82	644	3253	4.04	2.34	Change Section
C122	23x35	3070	1.5(DL-Ey)	-728	-27.80	-8.66	644	3950	4.91	2.34	Change Section
C123	23x35	0	1.5(DL-Ey)	-728	23.17	-0.33	644	3742	4.65	2.34	Change Section
C123	23x35	1535	1.5(DL+LL)	-762	-5.22	1.83	644	3199	3.97	2.34	Fail
C123	23x35	3070	1.5(DL-Ey)	-719	-27.48	4.58	644	3877	4.82	2.34	Change Section
C124	23x35	0	1.2(DL+LL-WLy)	-771	-2.77	-33.36	644	2993	3.72	2.34	Fail
C124	23x35	1535	1.5(DL+LL)	-860	1.62	1.53	644	1968	2.44	2.34	Fail
C124	23x35	3070	1.2(DL+LL-WLy)	-763	5.34	27.38	644	2617	3.25	2.34	Fail
C125	23x35	0	1.2(DL+LL-WLy)	-637	-11.17	-38.70	644	3432	4.26	2.34	Change Section
C125	23x35	1535	1.5(DL-Ey)	-675	-2.72	-4.53	644	1948	2.42	2.34	Fail
C125	23x35	3070	1.2(DL+LL-WLy)	-630	7.26	26.94	644	2902	3.60	2.34	Fail
C126	23x35	0	1.2(DL+LL+WLy)	-476	3.99	48.88	644	2400	2.98	2.34	Fail
C126	23x35	1535	1.5(DL+Ey)	-648	6.96	1.16	644	1011	1.26	2.34	OK
C126	23x35	3070	1.5(DL+Ex)	-532	-1.86	-18.50	644	2064	2.56	2.34	Fail
C127	23x23	0	1.2(DL+LL+WLx)	-450	-1.67	29.07	423	3196	6.04	2.34	Change Section
C127	23x23	1535	1.5(DL+LL)	-490	0.45	-4.10	423	2226	4.21	2.34	Change Section
C127	23x23	3070	1.2(DL+LL+WLy)	-445	2.37	-25.95	423	3060	5.78	2.34	Change Section
C128	23x35	0	1.2(DL+LL-WLy)	-908	3.41	-33.41	644	3402	4.23	2.34	Change Section
C128	23x35	1500	1.5(DL+LL)	-1,023	-1.53	1.34	644	2455	3.05	2.34	Fail
C128	23x35	3000	1.5(DL-Ey)	-919	-5.63	16.80	644	3538	4.40	2.34	Change Section

C129	23x35	0	1.2(DL+LL-WLy)	-796	-4.43	-30.32	644	2882	3.58	2.34	Fail
C129	23x35	1500	1.5(DL+Ey)	-847	9.52	0.75	644	2074	2.58	2.34	Fail
C129	23x35	3000	1.5(DL-Ey)	-843	9.33	15.97	644	3085	3.83	2.34	Fail
C132	23x35	0	1.2(DL+LL-WLy)	-646	2.11	-29.95	644	3666	4.55	2.34	Change Section
C132	23x35	1535	1.5(DL+LL)	-712	-1.07	1.26	644	2717	3.38	2.34	Fail
C132	23x35	3070	1.2(DL+LL-WLy)	-639	-3.77	24.83	644	3400	4.22	2.34	Change Section
C133	23x35	0	1.5(DL+Ey)	-659	33.09	-4.39	644	3623	4.50	2.34	Change Section
C133	23x35	1535	1.5(DL+Ey)	-654	5.95	0.94	644	2650	3.29	2.34	Fail
C133	23x35	3070	1.2(DL+LL-WLy)	-625	3.55	25.21	644	3356	4.17	2.34	Change Section
C134	23x35	0	1.2(DL+LL-WLy)	-809	-3.57	-23.98	644	2832	3.52	2.34	Fail
C134	23x35	1500	1.5(DL+LL)	-919	1.39	1.33	644	2326	2.89	2.34	Fail
C134	23x35	3000	1.5(DL-Ey)	-802	6.24	13.49	644	3261	4.05	2.34	Change Section
C14	23x23	0	1.5(DL+Ey)	-443	19.26	0.04	423	2997	5.67	2.34	Change Section
C14	23x23	1535	1.5(DL+Ex)	-542	-0.45	-4.66	423	2904	5.49	2.34	Change Section
C14	23x23	3070	1.2(DL+LL+WLy)	-500	-0.87	-14.45	423	3131	5.92	2.34	Change Section

Table.12. Analysis Result output of Ground floor's column forces, moments & A_{st} % calculated (Model 2).

Thus, for all the stories, column forces, moments, Area of steel provided, and required amount in percentage are calculated and the final details of columns are provided below.

Level	No of Columns passed with provided reinforcement (OK)	No of Columns exceeds provided reinforcement but within 4% (FAIL)	Columns exceeds 4% reinforcement (Fail and change section)
Ground Floor	4	27	69
Storey1	32	28	40
Storey2	42	44	14
Storey3	59	36	5
Storey4	59	29	12
Headroom	18	2	2

Table.13. The final result of columns passed and failed (Model 2).

As we can see from the output result that almost 96% of the columns exceeded the limit in the Ground floor level. Thus, in order to strengthen this structure, we can introduce shear walls to reduce the lateral force effect on columns.

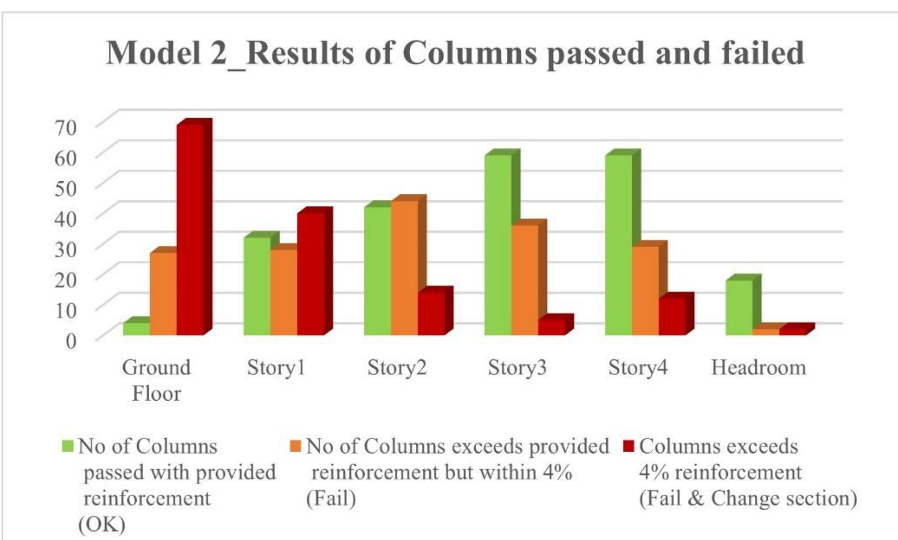

Figure.29. The final result of columns passed and failed (Model 2)

3.7 Retrofitting of the building for earthquake

The analysis of building for the earthquake loads yields dispersed at member level throughout the building. The intensity of failure is maximum at the ground and vanishes at the above stories. Different strengthening techniques have been proposed in Section 2 for the considering structure to improve its seismic resistance. Hence, reinforced concrete jacketing is proposed as it improves column Axial as well as flexural strength and ductility. In another proposed solution, the construction of additional reinforced concrete shear walls is considered since it is the greatest choice for seismically enhancing an existing structure. It gives framed buildings a lot of strength and stiffness.

3.7.1 Retrofitting Solution 1: Use of R.C.C Shear Wall

The addition of new reinforced concrete shear walls provides the best option of strengthening an existing structure for improved seismic performance. It adds significant strength and stiffness to framed structures. The location of Shear walls is presented below in the Ground floor plan.

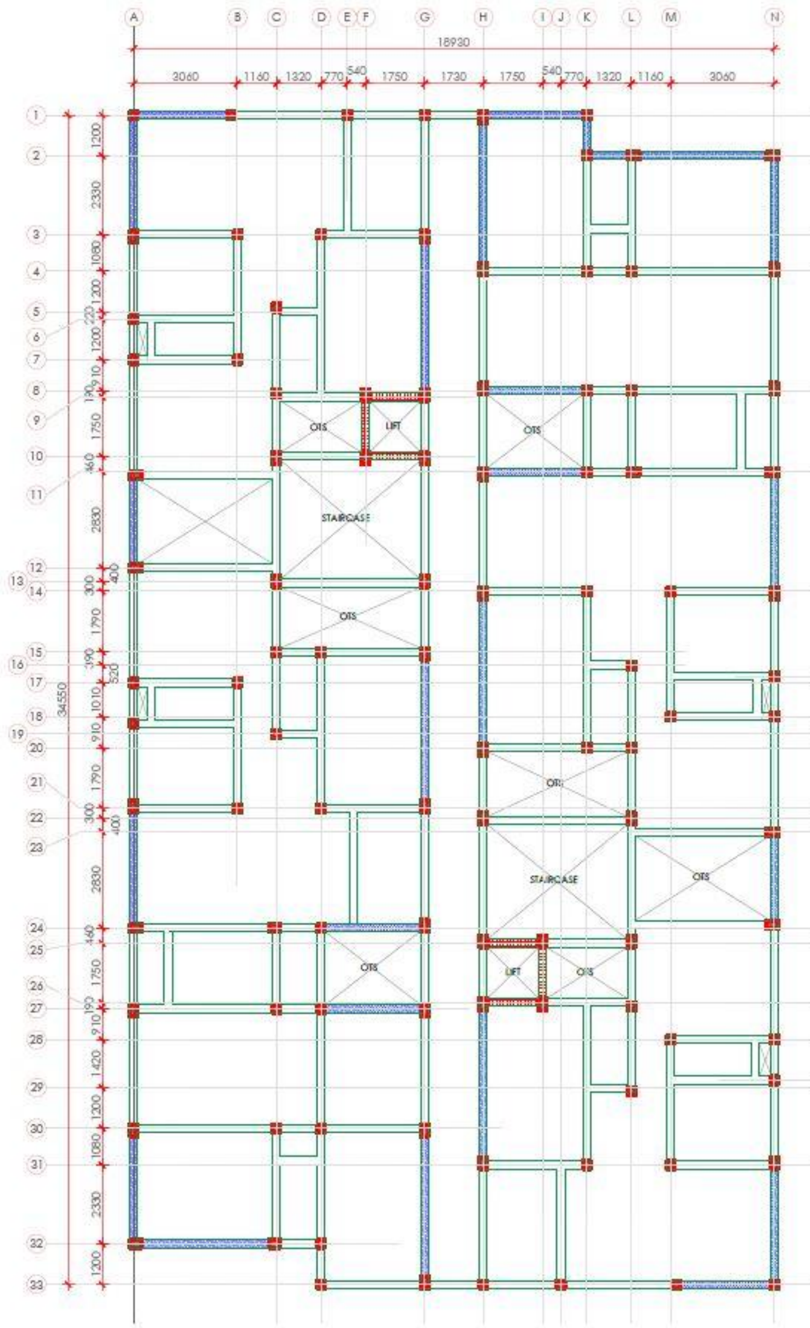

Figure.30. Shear wall markings on plan

3.7.1.1 Analysis Input

From the previous model, shear wall sections were defined in the software and were assigned according to the markings given on the plan above. As it can be seen that 96% of the columns failed on the stilt floor from the previous model's result, Shear walls were just introduced on the Ground floor of the building to increase the stiffness of the structure at that level.

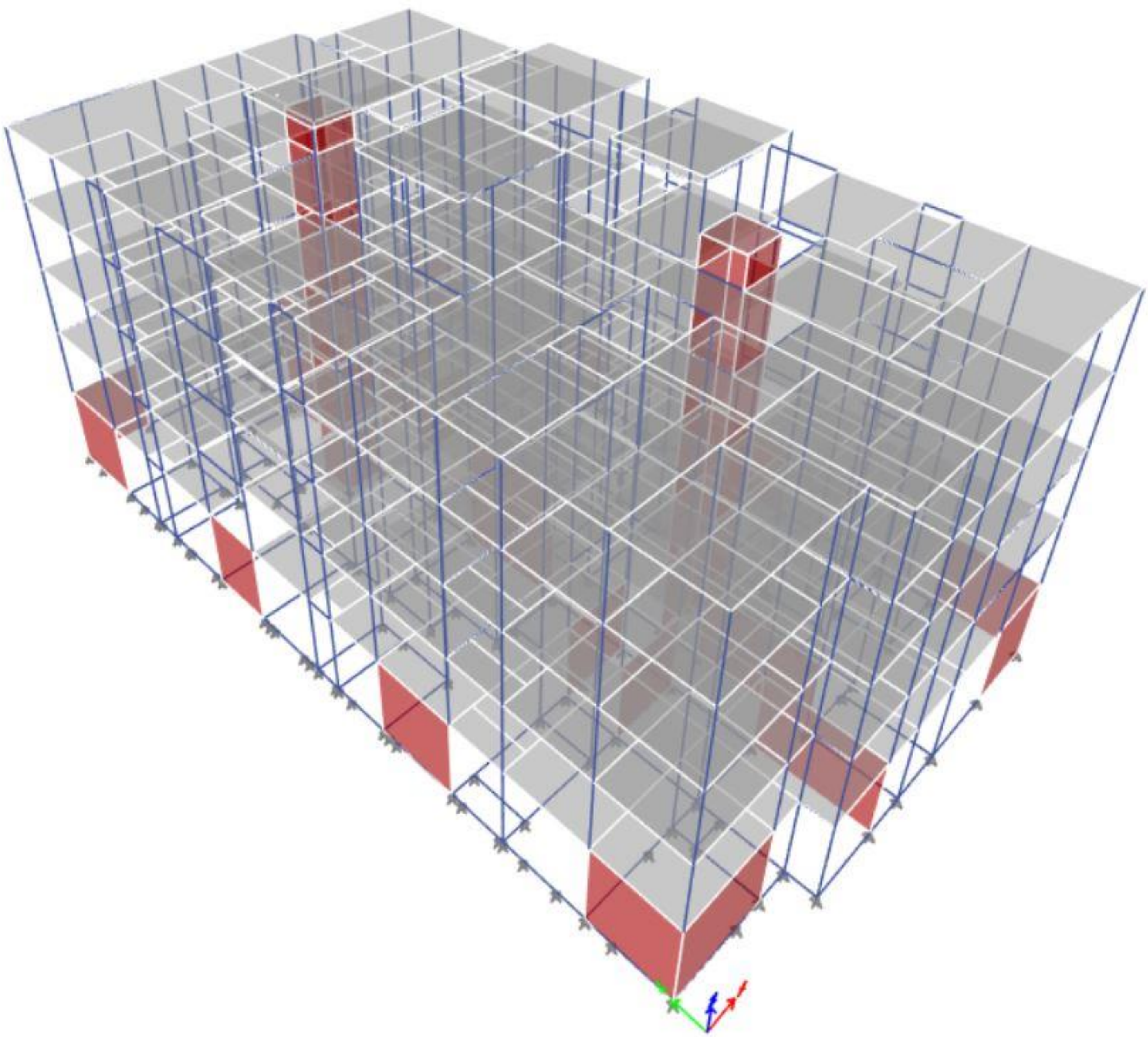

Figure.31. A 3-D view of the model with Shear wall

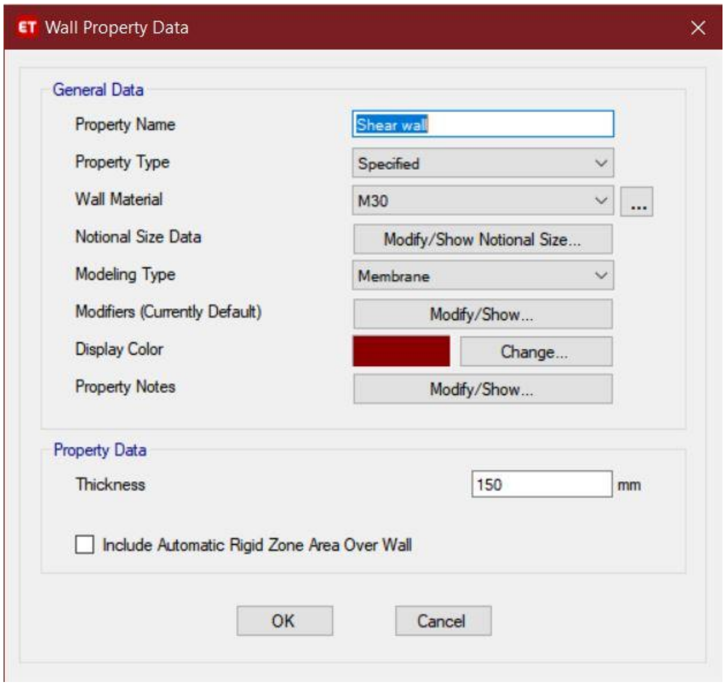

Figure.32. Shear wall property data.

3.7.1.2 VERIFICATION CRITERIA: IS 1893-1(2002), Clause 7.1_Table5.

1b) Stiffness Irregularity — Extreme Soft Story:

The lateral stiffness of an extreme soft story is less than 60% of that of the level above, or less than 70% of the average stiffness of the three stories above. For example, buildings on STILTS will fall under this category.

Level	Load case	Stiffness	$\frac{k_i}{k_{i+1}}$	Check	$\frac{k_i}{(k_{i+1} + k_{i+2} + k_{1+3}}$	Check
		(kN/m)	60%		70%	
Headroom	EQx	26220.62	-	-	-	-
Story5	EQx	44122.75	1.683	OK	-	-
Story4	EQx	130365.65	2.955	OK	-	-
Story3	EQx	232702.48	1.785	OK	3.478	OK
Story2	EQx	336307.58	1.445	OK	2.478	OK
Story1	EQx	584449.60	1.738	OK	2.507	OK
GF	EQx	4543756.69	7.774	OK	11.818	OK
Headroom	EQy	37860.266	-	-	-	-
Story5	EQy	67092.56	1.772	OK	-	-
Story4	EQy	171826.421	2.561	OK	-	-
Story3	EQy	292513.842	1.702	OK	3.171	OK
Story2	EQy	398938.173	1.364	OK	2.252	OK
Story1	EQy	627859.044	1.574	OK	2.182	OK
GF	EQy	12340084.5	19.654	OK	28.060	OK

Headroom	EQ-x	26232.236	-	-	-	-
Story5	EQ-x	44581.223	1.699	OK	-	-
Story4	EQ-x	130664.578	2.931	OK	-	-
Story3	EQ-x	233242.63	1.785	OK	3.473	OK
Story2	EQ-x	337038.743	1.445	OK	2.475	OK
Story1	EQ-x	584776.915	1.735	OK	2.503	OK
GF	EQ-x	4443175.43	7.598	OK	11.540	OK
Headroom	EQ-y	26232.236	-	-	-	-
Story5	EQ-y	44581.223	1.699	OK	-	-
Story4	EQ-y	130664.578	2.931	OK	-	-
Story3	EQ-y	233242.63	1.785	OK	3.473	OK
Story2	EQ-y	337038.743	1.445	OK	2.475	OK
Story1	EQ-y	584776.915	1.735	OK	2.503	OK
GF	EQ-y	4443175.43	7.598	OK	11.540	OK

Table.14. Extreme Soft Story Check

3.7.1.3 Analysis Output

With the help of Model 2, Shear walls have been introduced in the model and respective output results of the Ground Floor's column forces, moments, Area of steel provided and required amount in percentage, and its results were obtained and are presented below.

Label	Size	Loc	Load Comb	P (kN)	M2 (kNm)	M3 (kNm)	AsMin (mm^2)	As (mm^2)	% Of long reinf required (%)	% Of existing reinf provided (%)	Result
C1	23x23	0	0.9DL+1.5Ex	29	0.02	0.43	423	672	1.2703	2.34	OK
C1	23x23	1535	1.2(DL+LL-WLy)	-54	-0.02	-0.04	423	423	0.7996	2.34	OK
C1	23x23	3070	0.9DL+1.5Ex	32	-0.19	-0.05	423	1063	2.0095	2.34	OK
C2	23x23	0	1.5(DL+Ex)	-549	4.08	2.73	423	853	1.6125	2.34	OK
C2	23x23	1535	1.5(DL+LL)	-582	-2.25	-0.95	423	808	1.5274	2.34	OK
C2	23x23	3070	1.5(DL+Ex)	-543	-7.87	-3.27	423	934	1.7656	2.34	OK
C3	23x23	0	1.5(DL+LL)	-655	5.04	0.90	423	1064	2.0113	2.34	OK
C3	23x23	1535	1.5(DL+LL)	-652	-2.61	-0.15	423	1057	1.9981	2.34	OK
C3	23x23	3070	1.5(DL+LL)	-649	-10.26	-1.19	423	1175	2.2212	2.34	OK
C4	23x23	0	1.5(DL+Ey)	-414	1.58	1.12	423	454	0.8582	2.34	OK
C4	23x23	1535	1.2(DL+LL-WLy)	-356	-1.05	-0.44	423	423	0.7996	2.34	OK
C4	23x23	3070	1.5(DL+Ey)	-408	-2.83	-1.97	423	1415	2.6749	2.34	Fail
C5	23x23	0	0.9DL-1.5Ey	1	0.37	-0.46	423	563	1.0643	2.34	OK
C5	23x23	1535	1.2(DL+LL-WLy)	-14	-0.11	-0.07	423	423	0.7996	2.34	OK
C5	23x23	3070	0.9DL-1.5Ey	5	-0.63	0.25	423	727	1.3743	2.34	OK
C6	23x23	0	0.9DL+1.5Ey	-30	0.34	-0.16	423	656	1.2401	2.34	OK
C6	23x23	1535	1.2(DL+LL-WLy)	-78	-0.12	-0.07	423	423	0.7996	2.34	OK
C6	23x23	3070	0.9DL+1.5Ex	1	0.38	-0.33	423	1333	2.5198	2.34	Fail
C7	23x23	0	1.5(DL+LL)	-670	6.54	-3.39	423	1145	2.1645	2.34	OK
C7	23x23	1535	1.5(DL+LL)	-667	-3.73	1.53	423	1117	2.1115	2.34	OK
C7	23x23	3070	1.5(DL-Ey)	-577	-11.42	5.08	423	1452	2.7448	2.34	Fail

C8	23x23	0	1.5(DL+LL)	-587	-2.44	1.59	423	823	1.5558	2.34	OK
C8	23x23	1535	1.5(DL+LL)	-584	1.17	-0.46	423	811	1.5331	2.34	OK
C8	23x23	3070	1.2(DL+LL-Ey)	-480	3.91	-1.98	423	1048	1.9811	2.34	OK
C9	23x23	0	1.5(DL+LL)	-789	-3.02	-4.27	423	1553	2.9357	2.34	Fail
C9	23x23	1535	1.5(DL+LL)	-786	1.43	1.28	423	1538	2.9074	2.34	Fail
C9	23x23	3070	1.5(DL+Ex)	-688	4.89	5.76	423	2126	4.0189	2.34	Change section
C10	23x23	0	0.9DL-1.5Ey	17	1.13	-0.45	423	632	1.1947	2.34	OK
C10	23x23	1535	1.2(DL+LL-WLy)	-32	-0.39	-0.11	423	423	0.7996	2.34	OK
C10	23x23	3070	0.9DL-1.5Ey	21	-1.66	0.10	423	774	1.4631	2.34	OK
C11	23x23	0	1.5(DL+LL)	-652	1.65	-4.56	423	1055	1.9943	2.34	OK
C11	23x23	1535	1.5(DL+LL)	-649	-0.40	1.97	423	1043	1.9716	2.34	OK
C11	23x23	3070	1.5(DL+Ex)	-584	-2.26	6.68	423	1774	3.3535	2.34	Fail
C12	23x23	0	0.9DL-1.5Ey	8	-1.06	-0.48	423	594	1.1229	2.34	OK
C12	23x23	1535	1.2(DL+LL-WLy)	-43	0.39	-0.10	423	423	0.7996	2.34	OK
C12	23x23	3070	0.9DL-1.5Ey	12	1.59	0.14	423	748	1.4140	2.34	OK
C13	23x23	0	1.5(DL+LL)	-741	5.35	2.73	423	1400	2.6465	2.34	Fail
C13	23x23	1535	1.5(DL+LL)	-738	-2.69	-0.77	423	1389	2.6257	2.34	Fail
C13	23x23	3070	1.5(DL+LL)	-735	-10.74	-4.26	423	1468	2.7750	2.34	Fail
C15	23x23	0	1.5(DL-Ey)	-466	-0.31	-5.02	423	600	1.1342	2.34	OK
C15	23x23	1535	1.5(DL+LL)	-483	0.24	1.99	423	425	0.8034	2.34	OK
C15	23x23	3070	1.5(DL-Ey)	-460	0.83	7.48	423	723	1.3667	2.34	OK
C16	23x23	0	1.5(DL-Ey)	-556	1.77	-3.48	423	1503	2.8412	2.34	Fail
C16	23x23	1535	1.5(DL+LL)	-579	-0.73	1.31	423	795	1.5028	2.34	OK
C16	23x23	3070	1.5(DL-Ey)	-549	-3.04	4.89	423	1312	2.4802	2.34	Fail
C17	23x23	0	1.5(DL+Ex)	-590	-4.74	3.31	423	955	1.8053	2.34	OK
C17	23x23	1535	1.5(DL+LL)	-620	2.45	-1.26	423	930	1.7580	2.34	OK
C17	23x23	3070	1.5(DL+Ex)	-584	8.98	-4.46	423	1066	2.0151	2.34	OK
C18	23x23	0	1.5(DL+Ey)	-577	-1.84	-3.39	423	1548	2.9263	2.34	Fail
C18	23x23	1535	1.5(DL+LL)	-591	0.78	1.31	423	838	1.5841	2.34	OK
C18	23x23	3070	1.5(DL-Ey)	-575	3.21	4.81	423	1389	2.6257	2.34	Fail
C22	23x23	0	1.5(DL+LL)	-486	0.56	-5.20	423	571	1.0794	2.34	OK
C22	23x23	1535	1.5(DL+LL)	-483	-0.22	2.12	423	556	1.0510	2.34	OK
C22	23x23	3070	1.5(DL+LL)	-480	-1.00	9.43	423	751	1.4197	2.34	OK
C24	23x23	0	1.5(DL+LL)	-582	4.68	-2.89	423	811	1.5331	2.34	OK
C24	23x23	1535	1.5(DL+LL)	-579	-2.08	0.68	423	798	1.5085	2.34	OK
C24	23x23	3070	1.5(DL+Ey)	-507	-6.43	3.32	423	891	1.6843	2.34	OK
C25	23x23	0	1.5(DL+Ex)	-504	1.36	5.57	423	718	1.3573	2.34	OK
C25	23x23	1535	1.5(DL+LL)	-525	-0.34	-3.38	423	584	1.1040	2.34	OK
C25	23x23	3070	1.5(DL+Ex)	-498	-2.04	-10.33	423	1187	2.2439	2.34	OK
C26	23x23	0	1.5(DL-Ey)	-576	-4.23	-3.14	423	917	1.7335	2.34	OK
C26	23x23	1535	1.5(DL+LL)	-609	2.45	1.31	423	898	1.6975	2.34	OK
C26	23x23	3070	1.5(DL-Ey)	-570	8.45	4.56	423	1088	2.0567	2.34	OK
C27	23x23	0	1.5(DL+Ex)	-570	2.25	2.92	423	891	1.6843	2.34	OK
C27	23x23	1535	1.5(DL+LL)	-578	-0.64	-1.43	423	794	1.5009	2.34	OK
C27	23x23	3070	1.5(DL+Ex)	-564	-3.49	-4.60	423	1361	2.5728	2.34	Fail
C28	23x23	0	1.5(DL-Ey)	-580	4.51	-3.53	423	930	1.7580	2.34	OK
C28	23x23	1535	1.5(DL+LL)	-611	-2.58	1.35	423	903	1.7070	2.34	OK
C28	23x23	3070	1.5(DL-Ey)	-574	-9.03	4.82	423	1117	2.1115	2.34	OK

C29	23x23	0	1.5(DL+Ey)	-573	-2.14	3.41	423	898	1.6975	2.34	OK
C29	23x23	1535	1.5(DL+LL)	-586	0.59	-1.43	423	819	1.5482	2.34	OK
C29	23x23	3070	1.5(DL+Ey)	-567	3.60	-5.67	423	1366	2.5822	2.34	Fail
C30	23x23	0	1.5(DL-Ey)	-559	-4.34	-2.77	423	879	1.6616	2.34	OK
C30	23x23	1535	1.5(DL+LL)	-585	2.33	0.54	423	818	1.5463	2.34	OK
C30	23x23	3070	1.5(DL-Ey)	-553	8.28	2.95	423	956	1.8072	2.34	OK
C31	23x23	0	0.9DL-1.5Ey	36	-0.15	-0.65	423	698	1.3195	2.34	OK
C31	23x23	1535	1.2(DL+LL-WLy)	4	0.07	-0.16	423	423	0.7996	2.34	OK
C31	23x23	3070	0.9DL-1.5Ey	40	0.28	0.17	423	949	1.7940	2.34	OK
C34	23x23	0	1.5(DL+LL)	-642	-5.42	-0.78	423	1013	1.9149	2.34	OK
C34	23x23	1535	1.5(DL+LL)	-639	1.03	0.07	423	991	1.8733	2.34	OK
C34	23x23	3070	1.5(DL+LL)	-636	7.49	0.92	423	1031	1.9490	2.34	OK
C35	23x23	0	1.5(DL-Ey)	-351	-3.21	-1.90	423	1025	1.9376	2.34	OK
C35	23x23	1535	1.2(DL+LL-WLy)	-330	0.69	0.26	423	423	0.7996	2.34	OK
C35	23x23	3070	1.5(DL-Ey)	-345	4.31	2.21	423	1321	2.4972	2.34	Fail
C36	23x23	0	1.2(DL+LL-WLy)	-191	-0.06	-2.36	423	423	0.7996	2.34	OK
C36	23x23	1535	1.2(DL+LL-WLy)	-188	-0.00	0.25	423	423	0.7996	2.34	OK
C36	23x23	3070	0.9DL+1.5Ey	-64	1.31	2.26	423	473	0.8941	2.34	OK
C37	23x23	0	1.2(DL+LL-WLy)	-273	-1.57	-0.96	423	423	0.7996	2.34	OK
C37	23x23	1535	1.2(DL+LL-WLy)	-271	0.56	0.23	423	423	0.7996	2.34	OK
C37	23x23	3070	1.5(DL+Ex)	-406	3.35	1.26	423	940	1.7769	2.34	OK
C38	23x23	0	1.5(DL+LL)	-697	-0.57	-1.60	423	1240	2.3440	2.34	Fail
C38	23x23	1535	1.5(DL+LL)	-694	-0.27	0.53	423	1216	2.2987	2.34	OK
C38	23x23	3070	1.5(DL+Ex)	-606	-0.29	1.92	423	1328	2.5104	2.34	Fail
C39	23x23	0	1.5(DL-Ey)	-698	2.29	2.13	423	1897	3.5860	2.34	Fail
C39	23x23	1535	1.5(DL+LL)	-747	-1.17	-1.33	423	1414	2.6730	2.34	Fail
C39	23x23	3070	1.5(DL-Ey)	-692	-4.33	-5.09	423	2214	4.1853	2.34	Change section
C42	23x23	0	0.9DL+1.5Ex	14	0.53	0.58	423	619	1.1701	2.34	OK
C42	23x23	1535	1.2(DL+LL-WLy)	-130	-0.11	-0.12	423	423	0.7996	2.34	OK
C42	23x23	3070	0.9DL+1.5Ex	18	-0.75	-0.16	423	764	1.4442	2.34	OK
C43	23x23	0	1.5(DL+LL)	-771	-5.25	-3.67	423	1499	2.8336	2.34	Fail
C43	23x23	1535	1.5(DL+LL)	-768	2.67	1.69	423	1490	2.8166	2.34	Fail
C43	23x23	3070	1.5(DL+LL)	-765	10.58	7.05	423	1550	2.9301	2.34	Fail
C44	23x23	0	1.5(DL+Ex)	-524	-4.42	2.89	423	795	1.5028	2.34	OK
C44	23x23	1535	1.5(DL+LL)	-569	2.21	-0.95	423	761	1.4386	2.34	OK
C44	23x23	3070	1.5(DL+Ex)	-518	8.13	-3.52	423	878	1.6597	2.34	OK
C46	23x23	0	1.5(DL-Ey)	-497	-1.27	-5.62	423	699	1.3214	2.34	OK
C46	23x23	1535	1.5(DL+LL)	-516	0.29	3.39	423	546	1.0321	2.34	OK
C46	23x23	3070	1.5(DL-Ey)	-491	1.87	10.39	423	1181	2.2325	2.34	OK
C47	23x23	0	1.5(DL+Ex)	-585	4.32	3.43	423	937	1.7713	2.34	OK
C47	23x23	1535	1.5(DL+LL)	-618	-2.54	-1.28	423	924	1.7467	2.34	OK
C47	23x23	3070	1.5(DL+Ex)	-578	-8.74	-4.69	423	1120	2.1172	2.34	OK
C48	23x23	0	1.5(DL-Ey)	-505	0.38	-0.47	423	875	1.6541	2.34	OK
C48	23x23	1535	1.5(DL-Ey)	-502	-0.10	-0.24	423	478	0.9036	2.34	OK
C48	23x23	3070	1.5(DL-Ey)	-499	-0.58	-0.02	423	1001	1.8922	2.34	OK
C49	23x23	0	1.5(DL+Ex)	-604	4.83	-0.95	423	973	1.8393	2.34	OK
C49	23x23	1535	1.5(DL+LL)	-619	-2.83	0.34	423	926	1.7505	2.34	OK
C49	23x23	3070	1.5(DL+Ex)	-598	-9.61	2.00	423	1211	2.2892	2.34	OK

C52	23x35	0	1.2(DL+LL-WLy)	-86	0.24	-0.46	644	644	0.8000	2.34	OK
C52	23x35	1500	1.2(DL+LL-WLy)	-82	-0.10	-0.11	644	644	0.8000	2.34	OK
C52	23x35	3000	0.9DL+1.5Ex	21	-0.36	-0.48	644	1032	1.2820	2.34	OK
C54	23x35	0	1.2(DL+LL-WLy)	-175	0.38	6.38	644	644	0.8000	2.34	OK
C54	23x35	1535	1.2(DL+LL-WLy)	-172	-0.24	-3.15	644	644	0.8000	2.34	OK
C54	23x35	3070	0.9DL+1.5Ey	-62	-0.76	-7.61	644	873	1.0845	2.34	OK
C55	23x35	0	1.2(DL+LL-WLy)	-18	0.81	0.18	644	644	0.8000	2.34	OK
C55	23x35	1535	1.2(DL+LL-WLy)	-14	0.29	-0.11	644	644	0.8000	2.34	OK
C55	23x35	3070	0.9DL-1.5Ey	22	-0.79	-0.31	644	882	1.0957	2.34	OK
C56	23x35	0	1.2(DL+LL-WLy)	-104	1.20	3.73	644	644	0.8000	2.34	OK
C56	23x35	1535	1.2(DL+LL-WLy)	-100	0.21	-2.05	644	644	0.8000	2.34	OK
C56	23x35	3070	1.2(DL+LL-WLy)	-96	-0.79	-7.83	644	644	0.8000	2.34	OK
C57	23x35	0	1.5(DL+LL)	-799	-3.84	7.41	644	907	1.1267	2.34	OK
C57	23x35	1535	1.5(DL+LL)	-795	2.09	-4.12	644	882	1.0957	2.34	OK
C57	23x35	3070	1.5(DL+Ey)	-724	12.36	-13.34	644	1247	1.5491	2.34	OK
C58	23x35	0	1.2(DL+LL-WLy)	-149	-6.81	-0.01	644	644	0.8000	2.34	OK
C58	23x35	1535	1.2(DL+LL-WLy)	-145	6.64	-0.01	644	644	0.8000	2.34	OK
C58	23x35	3070	0.9DL-1.5Ey	-88	15.44	0.00	644	670	0.8323	2.34	OK
C65	23x35	0	1.5(DL-Ey)	-724	13.28	-5.04	644	675	0.8385	2.34	OK
C65	23x35	1535	1.2(DL+LL-WLy)	-594	1.64	1.19	644	644	0.8000	2.34	OK
C65	23x35	3070	1.5(DL-Ey)	-715	-8.83	7.46	644	1063	1.3205	2.34	OK
C67	23x35	0	0.9DL-1.5Ey	53	-1.35	-0.82	644	703	0.8733	2.34	OK
C67	23x35	1535	1.2(DL+LL-WLy)	-49	0.85	-0.18	644	644	0.8000	2.34	OK
C67	23x35	3070	0.9DL-1.5Ey	58	2.40	0.19	644	715	0.8882	2.34	OK
C72	23x35	0	0.9DL+1.5Ex	176	0.33	-0.26	644	1252	1.5553	2.34	OK
C72	23x35	1500	0.9DL+1.5Ex	179	-0.34	0.81	644	688	0.8547	2.34	OK
C72	23x35	3000	0.9DL+1.5Ex	181	-1.02	1.89	644	1647	2.0460	2.34	OK
C73	23x35	0	0.9DL+1.5Ey	215	-3.27	0.01	644	1000	1.2422	2.34	OK
C73	23x35	1535	0.9DL-1.5Ey	246	0.11	-0.96	644	888	1.1031	2.34	OK
C73	23x35	3070	0.9DL-1.5Ey	249	0.29	-2.25	644	2122	2.6360	2.34	Fail
C63	23x35	0	1.2(DL+LL-WLy)	-176	-0.03	-5.25	644	644	0.8000	2.34	OK
C63	23x35	1535	1.2(DL+LL-WLy)	-173	0.18	2.45	644	644	0.8000	2.34	OK
C63	23x35	3070	0.9DL+1.5Ex	-97	1.08	8.21	644	706	0.8770	2.34	OK
C77	23x35	0	1.5(DL-Ey)	-704	4.35	-5.94	644	783	0.9727	2.34	OK
C77	23x35	1535	1.5(DL+LL)	-764	-2.19	4.30	644	748	0.9292	2.34	OK
C77	23x35	3070	1.5(DL-Ey)	-695	-7.81	11.40	644	1234	1.5329	2.34	OK
C80	23x35	0	1.2(DL+LL-WLy)	-157	0.28	-3.49	644	644	0.8000	2.34	OK
C80	23x35	1535	1.2(DL+LL-WLy)	-153	0.06	1.06	644	644	0.8000	2.34	OK
C80	23x35	3070	1.2(DL+LL-WLy)	-150	-0.16	5.62	644	644	0.8000	2.34	OK
C82	23x23	0	1.5(DL+LL)	-475	-1.12	-0.70	423	524	0.9905	2.34	OK
C82	23x23	1535	1.5(DL+LL)	-472	3.42	0.19	423	506	0.9565	2.34	OK
C82	23x23	3070	1.5(DL+Ex)	-449	5.88	0.85	423	696	1.3157	2.34	OK
C84	23x35	0	1.2(DL+LL-WLy)	-136	-0.09	2.72	644	644	0.8000	2.34	OK
C84	23x35	1535	1.2(DL+LL-WLy)	-132	0.03	-1.86	644	644	0.8000	2.34	OK
C84	23x35	3070	1.2(DL+LL-WLy)	-128	0.16	-6.44	644	644	0.8000	2.34	OK
C89	23x23	0	1.5(DL+Ey)	-452	-0.15	0.27	423	743	1.4045	2.34	OK
C89	23x23	1535	1.5(DL+Ex)	-500	0.19	0.23	423	469	0.8866	2.34	OK
C89	23x23	3070	1.5(DL+Ex)	-497	0.57	-0.01	423	1006	1.9017	2.34	OK

C90	23x23	0	1.5(DL-Ey)	-603	-5.07	0.90	423	970	1.8336	2.34	OK
C90	23x23	1535	1.5(DL+LL)	-619	2.73	-0.34	423	927	1.7524	2.34	OK
C90	23x23	3070	1.5(DL-Ey)	-597	9.75	-1.98	423	1221	2.3081	2.34	OK
C91	23x35	0	1.5(DL+LL)	-1,019	2.17	4.77	644	1720	2.1366	2.34	OK
C91	23x35	1535	1.5(DL+LL)	-1,015	-4.25	-1.70	644	1716	2.1317	2.34	OK
C91	23x35	3070	1.5(DL+Ex)	-1,007	-10.93	-6.90	644	1796	2.2311	2.34	OK
C92	23x35	0	1.2(DL+LL-WLy)	-132	0.09	3.72	644	644	0.8000	2.34	OK
C92	23x35	1500	1.2(DL+LL-WLy)	-128	0.05	-2.30	644	644	0.8000	2.34	OK
C92	23x35	3000	0.9DL+1.5Ey	-38	-0.24	-4.94	644	653	0.8112	2.34	OK
C93	23x35	0	1.2(DL+LL-WLy)	-120	0.19	3.05	644	644	0.8000	2.34	OK
C93	23x35	1500	1.2(DL+LL-WLy)	-117	-0.05	-1.37	644	644	0.8000	2.34	OK
C93	23x35	3000	1.2(DL+LL-WLy)	-113	-0.29	-5.79	644	644	0.8000	2.34	OK
C94	23x35	0	1.5(DL+Ex)	-733	-3.39	4.96	644	663	0.8236	2.34	OK
C94	23x35	1535	1.2(DL+LL-WLy)	-552	1.33	-1.94	644	644	0.8000	2.34	OK
C94	23x35	3070	1.5(DL+Ex)	-724	6.62	-7.43	644	833	1.0348	2.34	OK
C95	23x35	0	1.5(DL-Ey)	-800	7.45	-1.16	644	1018	1.2646	2.34	OK
C95	23x35	1535	1.5(DL-Ey)	-795	-4.28	-0.34	644	889	1.1043	2.34	OK
C95	23x35	3070	1.5(DL-Ey)	-791	-16.01	0.48	644	975	1.2112	2.34	OK
C96	23x35	0	0.9DL+1.5Ex	212	-0.19	-0.91	644	1329	1.6509	2.34	OK
C96	23x35	1535	0.9DL+1.5Ex	214	-0.13	1.06	644	721	0.8957	2.34	OK
C96	23x35	3070	0.9DL+1.5Ex	217	-0.07	3.02	644	2015	2.5031	2.34	Fail
C97	23x35	0	0.9DL+1.5Ey	331	-0.15	0.26	644	1446	1.7963	2.34	OK
C97	23x35	1535	0.9DL+1.5Ey	333	1.47	-0.19	644	1246	1.5478	2.34	OK
C97	23x35	3070	0.9DL+1.5Ey	336	3.09	-0.64	644	1586	1.9702	2.34	OK
C64	23x23	0	1.5(DL+LL)	-698	-5.12	2.11	423	1246	2.3554	2.34	Fail
C64	23x23	1535	1.5(DL+LL)	-695	2.83	-1.04	423	1234	2.3327	2.34	OK
C64	23x23	3070	1.5(DL+LL)	-692	10.78	-4.18	423	1339	2.5312	2.34	Fail
C104	23x35	0	0.9DL-1.5Ey	-5	-0.62	-0.10	644	921	1.1441	2.34	OK
C104	23x35	1725	1.2(DL+LL-WLy)	-91	0.22	-0.16	644	644	0.8000	2.34	OK
C104	23x35	3450	1.2(DL+LL-WLy)	-86	0.74	-0.06	644	644	0.8000	2.34	OK
C107	23x23	0	0.9DL+1.5Ex	16	0.79	0.55	423	798	1.5085	2.34	OK
C107	23x23	1535	1.2(DL+LL-WLy)	-142	-0.35	-0.13	423	423	0.7996	2.34	OK
C107	23x23	3070	0.9DL+1.5Ex	20	-1.17	-0.16	423	1155	2.1834	2.34	OK
C108	23x23	0	1.5(DL-Ey)	-598	-1.41	3.49	423	1583	2.9924	2.34	Fail
C108	23x23	1535	1.5(DL+LL)	-647	0.33	-1.88	423	1033	1.9527	2.34	OK
C108	23x23	3070	1.5(DL-Ey)	-592	2.01	-6.80	423	1983	3.7486	2.34	Fail
C112	23x35	0	1.5(DL+LL)	-1,030	-5.15	-4.66	644	1783	2.2149	2.34	OK
C112	23x35	1535	1.5(DL+LL)	-1,026	3.17	1.72	644	1756	2.1814	2.34	OK
C112	23x35	3070	1.5(DL-Ey)	-1,018	11.55	6.81	644	1780	2.2112	2.34	OK
C40	23x23	0	1.2(DL+LL-WLy)	-47	-0.01	-0.34	423	423	0.7996	2.34	OK
C40	23x23	1535	1.2(DL+LL-WLy)	-44	0.00	-0.04	423	423	0.7996	2.34	OK
C40	23x23	3070	0.9DL-1.5Ey	10	0.22	0.23	423	1266	2.3932	2.34	Fail
C41	23x35	0	1.2(DL+LL-WLy)	-146	-8.64	0.01	644	644	0.8000	2.34	OK
C41	23x35	1535	1.2(DL+LL-WLy)	-142	5.50	-0.02	644	644	0.8000	2.34	OK
C41	23x35	3070	0.9DL+1.5Ey	-46	11.80	-0.09	644	710	0.8820	2.34	OK
C53	23x35	0	1.2(DL+LL-WLy)	-147	-8.72	-0.05	644	644	0.8000	2.34	OK
C53	23x35	1535	1.2(DL+LL-WLy)	-144	5.51	0.02	644	644	0.8000	2.34	OK
C53	23x35	3070	0.9DL-1.5Ey	-91	16.76	0.07	644	679	0.8435	2.34	OK

C60	23x23	0	1.5(DL+Ex)	-448	0.53	5.37	423	547	1.0340	2.34	OK
C60	23x23	1535	1.2(DL+LL-WLy)	-364	-0.08	-2.01	423	423	0.7996	2.34	OK
C60	23x23	3070	1.5(DL+Ex)	-442	-0.70	-8.21	423	674	1.2741	2.34	OK
C61	23x35	0	1.2(DL+LL-WLy)	-150	-0.37	2.98	644	644	0.8000	2.34	OK
C61	23x35	1535	1.2(DL+LL-WLy)	-146	0.19	-1.38	644	644	0.8000	2.34	OK
C61	23x35	3070	1.2(DL+LL-WLy)	-143	0.75	-5.75	644	644	0.8000	2.34	OK
C62	23x23	0	0.9DL+1.5Ex	32	-0.00	0.65	423	833	1.5747	2.34	OK
C62	23x23	1535	1.2(DL+LL-WLy)	-137	0.03	-0.16	423	423	0.7996	2.34	OK
C62	23x23	3070	0.9DL+1.5Ex	35	-0.26	-0.33	423	1233	2.3308	2.34	OK
C68	23x35	0	1.5(DL+Ex)	-912	-5.17	1.15	644	1327	1.6484	2.34	OK
C68	23x35	1535	1.5(DL+Ex)	-907	2.93	0.41	644	1307	1.6236	2.34	OK
C68	23x35	3070	1.5(DL+Ex)	-903	11.03	-0.32	644	1413	1.7553	2.34	OK
C69	23x35	0	1.5(DL+LL)	-886	7.61	-2.25	644	1233	1.5317	2.34	OK
C69	23x35	1535	1.5(DL+LL)	-882	-4.96	0.66	644	1223	1.5193	2.34	OK
C69	23x35	3070	1.5(DL+Ex)	-827	-17.16	2.87	644	1703	2.1155	2.34	OK
C70	23x35	0	0.9DL+1.5Ey	-7	0.58	0.62	644	646	0.8025	2.34	OK
C70	23x35	1500	1.2(DL+LL-WLy)	-88	0.12	-0.37	644	644	0.8000	2.34	OK
C70	23x35	3000	0.9DL+1.5Ey	-1	-0.01	-0.71	644	1045	1.2981	2.34	OK
C71	23x35	0	1.2(DL+LL-WLy)	-132	0.07	3.07	644	644	0.8000	2.34	OK
C71	23x35	1500	1.2(DL+LL-WLy)	-128	-0.00	-1.52	644	644	0.8000	2.34	OK
C71	23x35	3000	1.2(DL+LL-WLy)	-125	-0.08	-6.12	644	644	0.8000	2.34	OK
C83	23x35	0	0.9DL-1.5Ey	61	1.55	-0.87	644	710	0.8820	2.34	OK
C83	23x35	1535	1.2(DL+LL-WLy)	-43	-0.83	-0.21	644	644	0.8000	2.34	OK
C83	23x35	3070	0.9DL-1.5Ey	66	-2.23	0.16	644	1033	1.2832	2.34	OK
C110	23x35	0	0.9DL-1.5Ey	161	-0.30	0.45	644	1173	1.4571	2.34	OK
C110	23x35	1500	0.9DL-1.5Ey	164	0.32	-0.79	644	670	0.8323	2.34	OK
C110	23x35	3000	1.5(DL-Ey)	136	1.12	-2.15	644	1707	2.1205	2.34	OK
C115	23x35	0	1.2(DL+LL-WLy)	-172	-0.24	3.48	644	644	0.8000	2.34	OK
C115	23x35	1500	1.2(DL+LL-WLy)	-169	0.15	-2.02	644	644	0.8000	2.34	OK
C115	23x35	3000	0.9DL+1.5Ex	-12	-0.95	-2.88	644	673	0.8360	2.34	OK
C116	23x23	0	1.5(DL+LL)	-640	8.58	-10.18	423	1137	2.1493	2.34	OK
C116	23x23	1535	1.5(DL+LL)	-637	-4.86	5.28	423	987	1.8658	2.34	OK
C116	23x23	3070	1.5(DL-Ey)	-592	-16.20	16.78	423	2409	4.5539	2.34	Change section
C118	23x35	0	0.9DL-1.5Ey	16	2.82	-2.46	644	707	0.8783	2.34	OK
C118	23x35	1535	1.2(DL+LL-WLy)	-67	0.32	1.76	644	644	0.8000	2.34	OK
C118	23x35	3070	0.9DL-1.5Ey	22	-1.51	5.11	644	709	0.8807	2.34	OK
C119	23x35	0	1.5(DL+LL)	-762	-8.42	2.34	644	743	0.9230	2.34	OK
C119	23x35	1535	1.5(DL+LL)	-757	4.58	-0.73	644	718	0.8919	2.34	OK
C119	23x35	3070	1.5(DL-Ey)	-741	16.76	-3.15	644	1598	1.9851	2.34	OK
C120	23x35	0	1.2(DL+LL-WLy)	-80	1.50	-0.01	644	644	0.8000	2.34	OK
C120	23x35	1535	1.2(DL+LL-WLy)	-77	0.08	0.08	644	644	0.8000	2.34	OK
C120	23x35	3070	0.9DL+1.5Ex	41	0.76	0.48	644	859	1.0671	2.34	OK
C121	23x35	0	1.2(DL+LL-WLy)	-138	6.30	0.06	644	644	0.8000	2.34	OK
C121	23x35	1535	1.2(DL+LL-WLy)	-134	-4.69	0.04	644	644	0.8000	2.34	OK
C121	23x35	3070	0.9DL+1.5Ey	-52	-11.52	-0.09	644	710	0.8820	2.34	OK
C122	23x35	0	1.2(DL+LL-WLy)	-142	8.44	0.11	644	644	0.8000	2.34	OK
C122	23x35	1535	1.2(DL+LL-WLy)	-138	-3.13	0.00	644	644	0.8000	2.34	OK
C122	23x35	3070	0.9DL+1.5Ey	-53	-10.98	-0.11	644	707	0.8783	2.34	OK

C123	23x35	0	1.2(DL+LL-WLy)	-162	8.42	0.06	644	644	0.8000	2.34	OK
C123	23x35	1535	1.2(DL+LL-WLy)	-158	-3.10	0.05	644	644	0.8000	2.34	OK
C123	23x35	3070	0.9DL+1.5Ex	-77	-16.96	0.08	644	689	0.8559	2.34	OK
C124	23x35	0	1.2(DL+LL-WLy)	-146	0.32	-3.42	644	644	0.8000	2.34	OK
C124	23x35	1535	1.2(DL+LL-WLy)	-142	-0.05	1.07	644	644	0.8000	2.34	OK
C124	23x35	3070	1.2(DL+LL-WLy)	-138	-0.42	5.56	644	644	0.8000	2.34	OK
C125	23x35	0	0.9DL+1.5Ex	329	-7.97	-0.48	644	1255	1.5590	2.34	OK
C125	23x35	1535	0.9DL+1.5Ex	332	-1.89	0.93	644	1245	1.5466	2.34	OK
C125	23x35	3070	0.9DL+1.5Ex	334	4.20	2.34	644	1603	1.9913	2.34	OK
C126	23x35	0	0.9DL-1.5Ey	209	-0.02	0.75	644	1323	1.6435	2.34	OK
C126	23x35	1535	0.9DL-1.5Ey	212	0.12	-1.11	644	718	0.8919	2.34	OK
C126	23x35	3070	0.9DL-1.5Ey	214	0.27	-2.98	644	2008	2.4944	2.34	Fail
C127	23x23	0	1.5(DL+Ex)	-457	-1.67	7.46	423	583	1.1021	2.34	OK
C127	23x23	1535	1.5(DL+LL)	-482	0.46	-3.96	423	431	0.8147	2.34	OK
C127	23x23	3070	1.5(DL+Ex)	-451	2.41	-14.19	423	1358	2.5671	2.34	Fail
C128	23x35	0	1.2(DL+LL-WLy)	-148	0.06	-3.59	644	644	0.8000	2.34	OK
C128	23x35	1500	1.2(DL+LL-WLy)	-144	-0.01	1.01	644	644	0.8000	2.34	OK
C128	23x35	3000	1.2(DL+LL-WLy)	-140	-0.09	5.62	644	644	0.8000	2.34	OK
C129	23x35	0	1.2(DL+LL-WLy)	-119	0.00	-3.25	644	644	0.8000	2.34	OK
C129	23x35	1500	1.2(DL+LL-WLy)	-115	0.10	0.73	644	644	0.8000	2.34	OK
C129	23x35	3000	1.2(DL+LL-WLy)	-112	0.21	4.70	644	644	0.8000	2.34	OK
C132	23x35	0	0.9DL+1.5Ex	35	1.39	0.74	644	685	0.8509	2.34	OK
C132	23x35	1535	1.2(DL+LL-WLy)	-190	-0.79	-0.15	644	644	0.8000	2.34	OK
C132	23x35	3070	0.9DL+1.5Ex	40	-2.55	-0.18	644	937	1.1640	2.34	OK
C133	23x35	0	1.2(DL+LL-WLy)	-191	-2.11	-0.42	644	644	0.8000	2.34	OK
C133	23x35	1535	1.2(DL+LL-WLy)	-187	0.87	-0.16	644	644	0.8000	2.34	OK
C133	23x35	3070	0.9DL+1.5Ex	42	2.23	-0.17	644	706	0.8770	2.34	OK
C134	23x35	0	1.2(DL+LL-WLy)	-132	0.13	-2.80	644	644	0.8000	2.34	OK
C134	23x35	1500	1.2(DL+LL-WLy)	-128	0.02	1.02	644	644	0.8000	2.34	OK
C134	23x35	3000	1.2(DL+LL-WLy)	-125	-0.08	4.84	644	644	0.8000	2.34	OK
C14	23x23	0	1.5(DL+Ex)	-538	0.58	0.03	423	766	1.4480	2.34	OK
C14	23x23	1535	1.5(DL+Ex)	-535	-0.29	-1.30	423	761	1.4386	2.34	OK
C14	23x23	3070	1.5(DL+Ex)	-532	-1.17	-2.64	423	793	1.4991	2.34	OK

Table.15. Analysis Result output of Ground floor's column forces, moments & A_{st} % calculated (Model 3).

Thus, for all the stories, column forces, moments, Area of steel provided, and required amount in percentage are calculated and the final details of columns are provided below.

Level	No of Columns passed with provided reinforcement	No of Columns exceeds provided reinforcement but within 4%	Columns exceeds 4% reinforcement
Ground Floor	45	31	24
Story1	56	38	6
Story2	66	30	4
Story3	72	26	2
Story4	54	33	13
Headroom	19	1	2

Table.16. The final result of columns passed and failed (Model 3).

As we can see from the output result that almost 50% of the columns are passed with the provided reinforcement in the Ground floor level. Thus, in order to strengthen the rest of the columns, we can do Column jacketing in order to increase the strength of the columns.

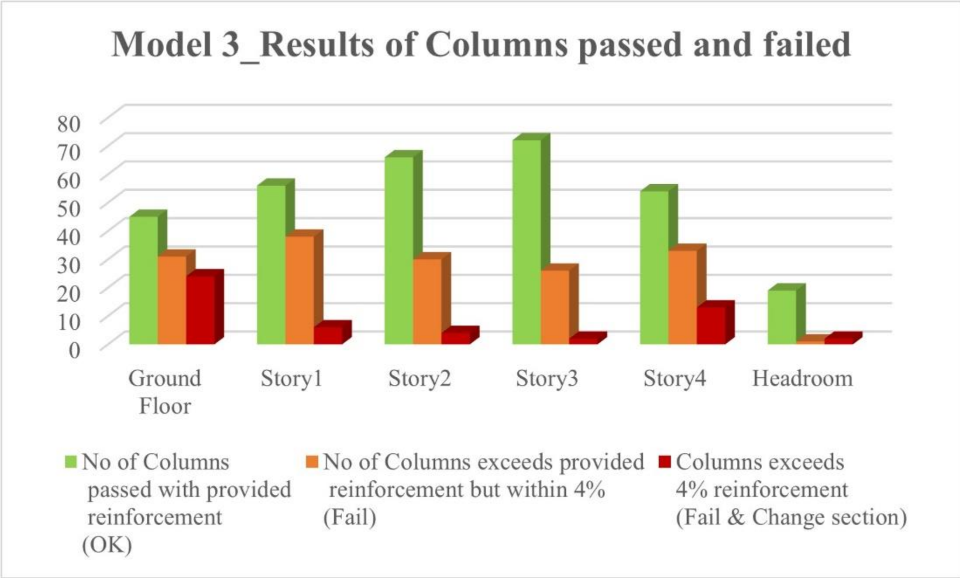

Figure.33. The final result of columns passed and failed (Model 3)

3.7.2 Retrofitting Solution 2: Column Jacketing

Column's Axial, flexural strength and ductility improves by Reinforced concrete jacketing. Transverse reinforcements that are placed closely in jackets improves the shear strength and ductility of the column. The procedure for reinforced concrete jacketing is,

(i) The seismic demand on the columns is calculated in terms of axial load P and moment M.
(ii) As indicated above, the column size and section details for P and M are estimated.
(iii) In the jacket, the existing column size is deducted from the estimated column size, to obtain the amount of concrete and steel to be provided in addition to the already provided column.
(iv) larger section is selected and steel to be provided as follows to account for losses.

$$A_c = (3/2)A'_c$$
$$A_s = (4/3)A'_s$$

(v) The spacing of ties that should be put in the jacket to prevent column shear failure and provide enough confinement to the longitudinal steel along the jacket is specified as:

$$s = \frac{f_y}{\sqrt{f_{ck}}} \frac{d_h^2}{t_j}$$

(vi) If the transfer of axial load to new longitudinal steel is not critical then friction present at the interface can be relied on for the shear transfer, which can be enhanced by roughening the old surface.
(vii) Dowels with epoxy grout and a 90-degree hook can also be used to improve the anchorage of new concrete jackets.
(viii) In order to transfer the additional axial load from the old to the new longitudinal reinforcement, bent-down bars intermittent lap welded to bars of jacket and longitudinal bars in the existing column can be used. Moreover, bent-down bars help in good anchorage between existing and new concrete jacket.

3.7.2.1 The minimum specifications for jacketing columns

a) The new materials must have the same or higher strength as the existing column.
Concrete strength shall be at least 5 MPa greater than the strength of the existing concrete.
b) For columns where extra longitudinal reinforcement is not required, a minimum of 12φ bars in the four corners and ties of 8φ @ 100 c/c should be provided with 135° bends and 10φ leg lengths.
c) Minimum jacket thickness shall be 100 mm.
d) Ties with an incorporated angle of not more than 135° shall give lateral support to all longitudinal bars.
e) Minimum diameter of ties must be 8 mm and not less than one-third of the longitudinal bar diameter.
f) Vertical spacing of ties shall not exceed 200 mm, whereas the spacing close to the joints within a length of ¼ of the clear height shall not exceed 100 mm. Preferably, the spacing of ties shall not exceed the thickness of the jacket or 200 mm whichever is less.

Design of RC Column Jacketing Using Is 15988: 2013.
<u>Column Type 1:</u> The details of existing column are as follows,
Height of the Column = 3000 mm,
Cross-Section = (230 x 230) mm,
Effective Cover = 40 mm,
Grade of Concrete = 20 N/mm^2
Grade of steel = 415 N/mm^2
Load, = 880 kN,
Moment, M = 35 kNm,
Existing Reinforcement = 4nos of 20mmØ bars
Procedure:
$P_u = 0.4\ f_{ck}\ A_c + 0.67\ f_y\ A_{sc}$
According to the provisions provided in to 8.5.1.2 (a) of IS 15988: 2013, Concrete strength shall be at least 5 MPa greater than the strength of the existing concrete.
Thus, taking value of = 25 N/mm^2 and assuming $A_{sc} = 0.8\%\ A_c$
$880 \times 10^3 = 0.4 \times 25\ A_c + 0.67 \times 500 \times (0.8\ \%\ A_c) \Rightarrow 880000 = 12.7\ A_c \Rightarrow A_c = 69291\ mm^2$
According to 8.5.1.1 (e) of IS 15988:2013,
$A_c = 1.5A'_c$
Thus, $A_c = 1.5 \times 69291 \Rightarrow A_c = 103937\ mm^2$
As per 8.5.1.2 (c) of IS 15988:2013, Minimum jacket thickness shall be 100 mm.
Thus, New size of the column:
B = 230 +100 +100 = 430 mm,
D = 230 +100 +100 = 430 mm.
New concrete area = 430 x 430 = 184900 mm^2 > = 103937 mm^2
Area of steel, = 0.8% x 430 x 430 = 1479 mm^2
But according to 8.5.1.1 (e) IS 15988:2013, $A_s = (4/3)\ A'_s$
$A_s = (4/3) \times 1479 = 1973\ mm^2$
Assuming 16mm Ø bar and 12mm Ø bar,
=> (4 x 201) + (12 x 113) = 2160 mm^2
Provide 4nos of 16mm Ø bars and 12nos of 12mm Ø bars.

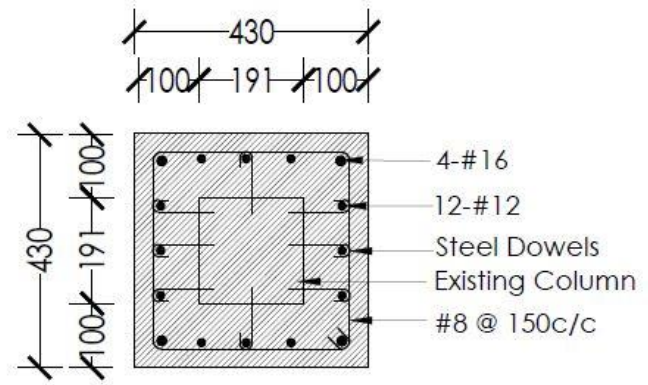

Figure.34. (43x43) cm column detailing

<u>Column Type 2:</u> The details of existing column are as follows,
Height of the Column = 3000 mm,
Cross-Section = (230 x 350) mm,
Effective Cover = 40 mm,
Grade of Concrete = 20 N/mm^2
Grade of steel = 415 N/mm^2
Load, = 1037 kN,
Moment, M = 2.2 kNm,
Existing Reinforcement = 4nos of 20mmØ bars & 2nos of 16mmØ bars

Procedure:

$P_u = 0.4\ f_{ck}\ A_c + 0.67\ f_y\ A_{sc}$

According to the provisions provided in to 8.5.1.2 (a) of IS 15988: 2013, Concrete strength shall be at least 5 MPa greater than the strength of the existing concrete.

Thus, taking value of = 25 N/mm^2 and assuming A_{sc} = 0.8% A_c

$1037 \times 10^3 = 0.4 \times 25\ A_c + 0.67 \times 500 \times (0.8\ \%\ A_c)$ => $1037000 = 12.7\ A_c$ => $A_c = 81654\ mm^2$

According to 8.5.1.1 (e) of IS 15988:2013,

$A_c = 1.5A'_c$

Thus, $A_c = 1.5 \times 81654$ => $A_c = 122481\ mm^2$

As per 8.5.1.2 (c) of IS 15988:2013, Minimum jacket thickness shall be 100 mm.

Thus, New size of the column:

B = 230 +100 +100 = 430 mm,
D = 230 +100 +100 = 550 mm.
New concrete area = 430 x 550 = 236500 mm^2 > = 122481 mm^2
Area of steel, = 0.8% x 430 x 550 = 1892 mm^2
But according to 8.5.1.1 (e) IS 15988:2013, $A_s = (4/3)\ A'_s$
$A_s = (4/3) \times 1892 = 2522\ mm^2$
Assuming 16mm Ø bar and 12mm Ø bar,
=> (4 x 314) + (14 x 113) = 2838 mm^2
Provide 4nos of 20mm Ø bars and 14nos of 12mm Ø bars.

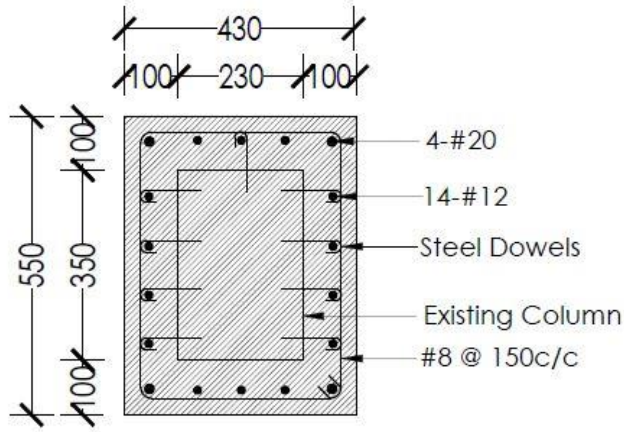

Figure.35. (43x55) cm column detailing

Design of Lateral Ties

As per 8.5.1.2 (e) of IS15988: 2013, Minimum diameter of ties shall be 8 mm and not less than one-third of the longitudinal bar diameter.
Diameter of bar =1/3 of Ø of largest longitudinal bar = (1/3) x 16 = 6mm …. take 8mm.
Spacing of ties as per 8.5.1.1 (f) of IS 15988:2013- The code suggests that the spacing (s) of ties to be provided in the jacket in order to avoid flexural shear failure of column and provide adequate confinement to the longitudinal steel along the jacket is given as:

$$s = \frac{f_y \ d_h^2}{\sqrt{f_{ck}} \ t_j}$$

Where, f_y = yield strength of steel, f_{ck} = cube strength of concrete, d_h = diameter of stirrup, and t_j = thickness of jacket

$$s = \frac{(500).(16^2)}{(\sqrt{25}).(200)}$$

$$s = 150\text{mm}$$

Provide 8mm Ø @150mm c/c.

3.7.2.2 Analysis Input

With reference to previous Model, column sizes are changed according to the calculations made as per IS 15988: 2013. Thus, in this Model 4, column sizes of (23x23)cm are changed to (43x43)cm and columns (23x35)cm are changed to (43x55)cm using Section Designer in ETABS.

Define → Section Properties → Frame Section Properties → Select Col23x23 and Col23x35 in properties → Modify/ Show properties → Select Section Designer and design the column reinforcement as per the number of rods in the calculations.
Once this is done, the model is analysed, and output is taken.

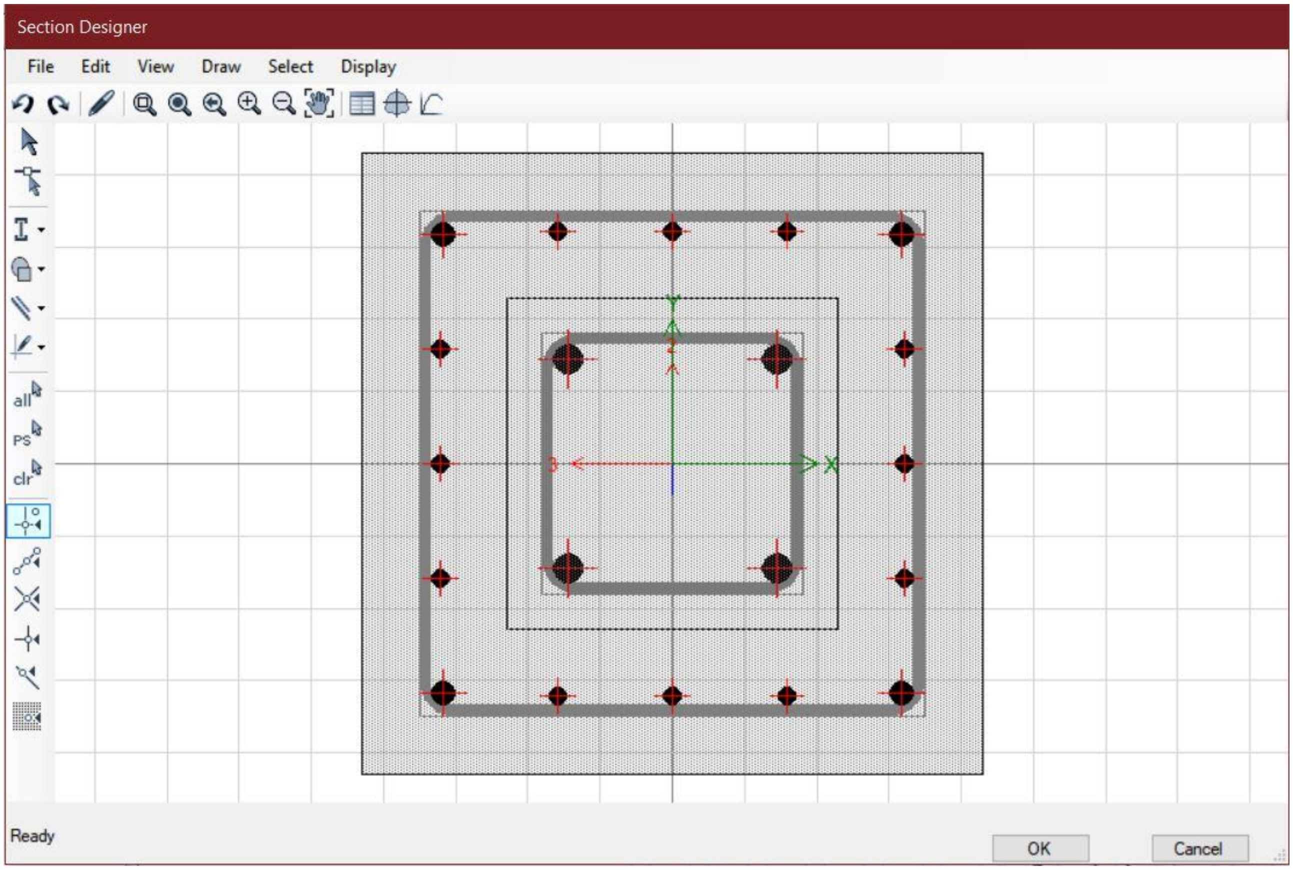

Figure.36. Section Designer for (43x43) cm column in ETABS

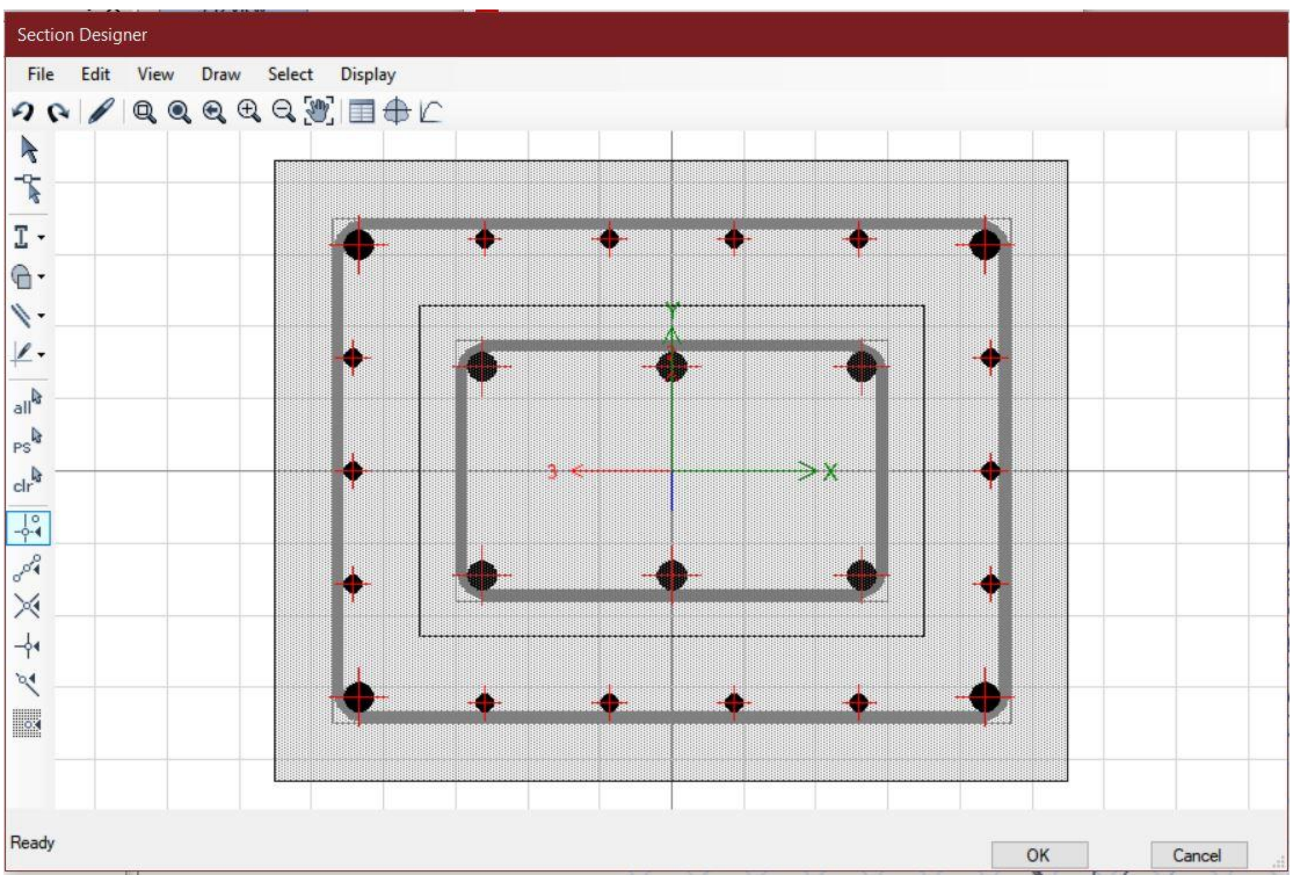

Figure.37. Section Designer for (43x55) cm column in ETABS

3.7.2.3 Analysis Output

With the help of Model 3, columns have been designed as per IS 15988: 2013 and introduced in the model. The output results of the Ground Floor's column forces, moments, Area of steel provided in percentage, its results were obtained and are presented below.

Label	Design Section	Loc	Load Combination	A_s provided (mm^2)	P (kN)	M2 (kNm)	M3 (kNm)	% Of long reinf provided (%)	Result
C1	Col43x43	0	1.5(DL-Ey)	3418	-279.76	2.07	-5.68	1.849	OK
C1	Col43x43	1535	1.5(DL-Ey)	3418	-269.12	0.17	-1.26	1.849	OK
C1	Col43x43	3070	1.5(DL-Ey)	3418	-258.48	-1.74	3.15	1.849	OK
C2	Col43x43	0	1.5(DL+LL)	3418	-667.39	3.37	3.65	1.849	OK
C2	Col43x43	1535	1.5(DL+LL)	3418	-656.75	-4.19	-2.31	1.849	OK
C2	Col43x43	3070	1.5(DL+LL)	3418	-646.11	-11.76	-8.26	1.849	OK
C3	Col43x43	0	1.5(DL+LL)	3418	-759.96	2.44	2.09	1.849	OK
C3	Col43x43	1535	1.5(DL+LL)	3418	-749.32	-6.50	-0.97	1.849	OK
C3	Col43x43	3070	1.5(DL+LL)	3418	-738.68	-15.43	-4.04	1.849	OK
C4	Col43x43	0	1.5(DL+Ey)	3418	-558.56	-0.75	2.14	1.849	OK
C4	Col43x43	1535	1.5(DL+LL)	3418	-549.60	-4.01	-0.48	1.849	OK
C4	Col43x43	3070	1.5(DL+LL)	3418	-538.96	-9.75	-2.57	1.849	OK
C5	Col43x43	0	1.5(DL+Ey)	3418	-227.65	3.20	-0.53	1.849	OK
C5	Col43x43	1535	1.5(DL+Ey)	3418	-217.01	1.31	-0.16	1.849	OK
C5	Col43x43	3070	1.5(DL+Ey)	3418	-206.37	-0.58	0.21	1.849	OK
C6	Col43x43	0	1.5(DL-Ey)	3418	-306.78	3.97	-6.71	1.849	OK
C6	Col43x43	1535	1.5(DL-Ey)	3418	-296.14	-1.57	-1.61	1.849	OK
C6	Col43x43	3070	1.5(DL-Ey)	3418	-285.50	-7.11	3.49	1.849	OK
C7	Col43x43	0	1.5(DL+LL)	3418	-716.79	2.89	-2.25	1.849	OK
C7	Col43x43	1535	1.5(DL+LL)	3418	-706.15	-6.23	4.24	1.849	OK
C7	Col43x43	3070	1.5(DL+LL)	3418	-695.51	-15.35	10.73	1.849	OK
C8	Col43x43	0	1.5(DL-Ey)	3418	-707.74	-2.24	4.99	1.849	OK
C8	Col43x43	1535	1.5(DL-Ey)	3418	-697.10	3.08	-5.28	1.849	OK
C8	Col43x43	3070	1.5(DL-Ey)	3418	-686.46	8.39	-15.55	1.849	OK
C9	Col43x43	0	1.5(DL+Ex)	3418	-917.52	-1.41	-7.90	1.849	OK
C9	Col43x43	1535	1.5(DL+Ex)	3418	-906.88	2.36	9.79	1.849	OK
C9	Col43x43	3070	1.5(DL+Ex)	3418	-896.24	6.12	27.48	1.849	OK
C10	Col43x43	0	1.5(DL+Ex)	3418	-367.49	2.35	6.55	1.849	OK
C10	Col43x43	1535	1.5(DL+Ex)	3418	-356.85	-1.73	1.75	1.849	OK
C10	Col43x43	3070	1.5(DL+Ex)	3418	-346.21	-5.82	-3.04	1.849	OK
C11	Col43x43	0	1.5(DL+Ex)	3418	-809.67	2.39	-4.16	1.849	OK
C11	Col43x43	1535	1.5(DL+Ex)	3418	-799.03	-1.63	11.46	1.849	OK
C11	Col43x43	3070	1.5(DL+Ex)	3418	-788.39	-5.66	27.08	1.849	OK
C12	Col43x43	0	1.5(DL+Ex)	3418	-388.00	-2.05	6.56	1.849	OK
C12	Col43x43	1535	1.5(DL+Ex)	3418	-377.36	0.25	1.80	1.849	OK
C12	Col43x43	3070	1.5(DL+Ex)	3418	-366.72	2.55	-2.95	1.849	OK
C13	Col43x43	0	1.5(DL+LL)	3418	-827.99	3.15	3.58	1.849	OK
C13	Col43x43	1535	1.5(DL+LL)	3418	-817.35	-4.83	-2.06	1.849	OK
C13	Col43x43	3070	1.5(DL+LL)	3418	-806.71	-12.81	-7.70	1.849	OK
C15	Col43x43	0	1.5(DL+Ey)	3418	-686.70	-4.98	-5.36	1.849	OK
C15	Col43x43	1535	1.5(DL+Ey)	3418	-676.06	6.86	2.05	1.849	OK

C15	Col43x43	3070	1.5(DL+Ey)	3418	-665.42	18.70	9.45	1.849	OK
C16	Col43x43	0	1.5(DL+LL)	3418	-652.64	2.50	-3.72	1.849	OK
C16	Col43x43	1535	1.5(DL+LL)	3418	-642.00	-3.32	2.70	1.849	OK
C16	Col43x43	3070	1.5(DL+LL)	3418	-631.36	-9.15	9.12	1.849	OK
C17	Col43x43	0	1.5(DL+LL)	3418	-689.23	-3.02	3.67	1.849	OK
C17	Col43x43	1535	1.5(DL+LL)	3418	-678.59	5.31	-2.53	1.849	OK
C17	Col43x43	3070	1.5(DL+LL)	3418	-667.95	13.64	-8.73	1.849	OK
C18	Col43x43	0	1.5(DL+Ey)	3418	-773.15	-6.33	-3.55	1.849	OK
C18	Col43x43	1535	1.5(DL+Ey)	3418	-762.51	8.73	1.47	1.849	OK
C18	Col43x43	3070	1.5(DL+Ey)	3418	-751.87	23.79	6.48	1.849	OK
C22	Col43x43	0	1.5(DL+LL)	3418	-610.50	1.73	-4.92	1.849	OK
C22	Col43x43	1535	1.5(DL+LL)	3418	-599.86	-1.45	4.23	1.849	OK
C22	Col43x43	3070	1.5(DL+Ex)	3418	-507.53	-2.86	26.58	1.849	OK
C24	Col43x43	0	1.5(DL+LL)	3418	-659.79	3.58	-4.08	1.849	OK
C24	Col43x43	1535	1.5(DL+LL)	3418	-649.15	-4.00	1.64	1.849	OK
C24	Col43x43	3070	1.5(DL+LL)	3418	-638.51	-11.58	7.35	1.849	OK
C25	Col43x43	0	1.5(DL+Ey)	3418	-660.72	0.55	2.79	1.849	OK
C25	Col43x43	1535	1.5(DL+Ey)	3418	-650.08	6.87	-5.82	1.849	OK
C25	Col43x43	3070	1.5(DL+Ey)	3418	-639.44	13.19	-14.43	1.849	OK
C26	Col43x43	0	1.5(DL+LL)	3418	-679.84	-2.29	-3.24	1.849	OK
C26	Col43x43	1535	1.5(DL+LL)	3418	-669.20	5.23	2.65	1.849	OK
C26	Col43x43	3070	1.5(DL+LL)	3418	-658.56	12.75	8.55	1.849	OK
C27	Col43x43	0	1.5(DL+Ex)	3418	-692.70	5.18	0.84	1.849	OK
C27	Col43x43	1535	1.5(DL+Ex)	3418	-682.06	-3.75	3.74	1.849	OK
C27	Col43x43	3070	1.5(DL+Ex)	3418	-671.42	-12.68	6.64	1.849	OK
C28	Col43x43	0	1.5(DL+LL)	3418	-680.17	2.53	-3.67	1.849	OK
C28	Col43x43	1535	1.5(DL+LL)	3418	-669.53	-5.60	2.53	1.849	OK
C28	Col43x43	3070	1.5(DL+LL)	3418	-658.89	-13.73	8.73	1.849	OK
C29	Col43x43	0	1.5(DL+Ey)	3418	-752.86	-6.75	3.59	1.849	OK
C29	Col43x43	1535	1.5(DL+Ey)	3418	-742.22	9.09	-2.38	1.849	OK
C29	Col43x43	3070	1.5(DL+Ey)	3418	-731.58	24.93	-8.35	1.849	OK
C30	Col43x43	0	1.5(DL+LL)	3418	-669.81	-3.33	-3.50	1.849	OK
C30	Col43x43	1535	1.5(DL+LL)	3418	-659.17	4.37	1.19	1.849	OK
C30	Col43x43	3070	1.5(DL+LL)	3418	-648.53	12.06	5.87	1.849	OK
C31	Col43x43	0	1.5(DL+Ex)	3418	-291.64	-0.55	7.70	1.849	OK
C31	Col43x43	1535	1.5(DL+Ex)	3418	-281.00	0.08	1.68	1.849	OK
C31	Col43x43	3070	1.5(DL+Ex)	3418	-270.36	0.70	-4.33	1.849	OK
C34	Col43x43	0	1.5(DL+LL)	3418	-743.82	-6.91	-2.01	1.849	OK
C34	Col43x43	1535	1.5(DL+LL)	3418	-733.18	1.98	0.52	1.849	OK
C34	Col43x43	3070	1.5(DL+Ey)	3418	-638.68	27.48	4.89	1.849	OK
C35	Col43x43	0	1.5(DL+LL)	3418	-563.34	-4.87	-1.05	1.849	OK
C35	Col43x43	1535	1.5(DL+LL)	3418	-552.70	2.57	0.57	1.849	OK
C35	Col43x43	3070	1.5(DL+LL)	3418	-542.06	10.02	2.20	1.849	OK
C36	Col43x43	0	1.5(DL+LL)	3418	-374.72	-0.82	-3.57	1.849	OK
C36	Col43x43	1535	1.5(DL+LL)	3418	-364.08	0.04	1.42	1.849	OK
C36	Col43x43	3070	1.5(DL+Ex)	3418	-331.35	1.91	16.26	1.849	OK
C37	Col43x43	0	1.5(DL+Ex)	3418	-591.09	-3.56	0.93	1.849	OK
C37	Col43x43	1535	1.5(DL+Ex)	3418	-580.45	2.35	5.17	1.849	OK
C37	Col43x43	3070	1.5(DL+Ey)	3418	-552.66	21.82	1.21	1.849	OK
C38	Col43x43	0	1.5(DL+Ex)	3418	-810.15	-3.32	-1.72	1.849	OK

C38	Col43x43	1535	1.5(DL+Ex)	3418	-799.51	-1.31	6.04	1.849	OK
C38	Col43x43	3070	1.5(DL+Ex)	3418	-788.87	0.71	13.80	1.849	OK
C39	Col43x43	0	1.5(DL-Ey)	3418	-898.90	1.29	2.96	1.849	OK
C39	Col43x43	1535	1.5(DL-Ey)	3418	-888.26	-2.14	-11.66	1.849	OK
C39	Col43x43	3070	1.5(DL-Ey)	3418	-877.62	-5.56	-26.29	1.849	OK
C42	Col43x43	0	1.5(DL-Ey)	3418	-442.67	2.08	-8.39	1.849	OK
C42	Col43x43	1535	1.5(DL-Ey)	3418	-432.03	-0.14	-2.39	1.849	OK
C42	Col43x43	3070	1.5(DL-Ey)	3418	-421.39	-2.36	3.61	1.849	OK
C43	Col43x43	0	1.5(DL+LL)	3418	-871.36	-2.95	-2.44	1.849	OK
C43	Col43x43	1535	1.5(DL+LL)	3418	-860.72	4.80	4.71	1.849	OK
C43	Col43x43	3070	1.5(DL+LL)	3418	-850.07	12.54	11.86	1.849	OK
C44	Col43x43	0	1.5(DL+LL)	3418	-650.18	-3.65	3.70	1.849	OK
C44	Col43x43	1535	1.5(DL+LL)	3418	-639.54	4.21	-2.52	1.849	OK
C44	Col43x43	3070	1.5(DL+LL)	3418	-628.90	12.07	-8.74	1.849	OK
C46	Col43x43	0	1.5(DL+LL)	3418	-630.01	-2.14	-3.11	1.849	OK
C46	Col43x43	1535	1.5(DL+LL)	3418	-619.37	0.83	6.24	1.849	OK
C46	Col43x43	3070	1.5(DL+LL)	3418	-608.73	3.80	15.60	1.849	OK
C47	Col43x43	0	1.5(DL+LL)	3418	-687.65	2.38	3.71	1.849	OK
C47	Col43x43	1535	1.5(DL+LL)	3418	-677.01	-5.48	-2.68	1.849	OK
C47	Col43x43	3070	1.5(DL+LL)	3418	-666.37	-13.33	-9.07	1.849	OK
C48	Col43x43	0	1.5(DL-Ey)	3418	-737.79	0.14	-0.11	1.849	OK
C48	Col43x43	1535	1.5(DL-Ey)	3418	-727.15	0.61	-6.35	1.849	OK
C48	Col43x43	3070	1.5(DL-Ey)	3418	-716.51	1.08	-12.60	1.849	OK
C49	Col43x43	0	1.5(DL+Ex)	3418	-802.82	3.04	-3.55	1.849	OK
C49	Col43x43	1535	1.5(DL+Ex)	3418	-792.18	-4.24	6.84	1.849	OK
C49	Col43x43	3070	1.5(DL+Ex)	3418	-781.54	-11.51	17.23	1.849	OK
C52	Col43x55	0	1.5(DL-Ey)	4725	-279.92	1.57	-7.27	1.998	OK
C52	Col43x55	1500	1.5(DL+Ey)	4725	-272.29	1.42	-0.13	1.998	OK
C52	Col43x55	3000	1.5(DL+Ey)	4725	-258.99	-3.57	0.78	1.998	OK
C54	Col43x55	0	1.5(DL+LL)	4725	-473.23	1.44	6.97	1.998	OK
C54	Col43x55	1535	1.5(DL+LL)	4725	-459.62	-1.07	-5.45	1.998	OK
C54	Col43x55	3070	1.5(DL-Ey)	4725	-406.08	-4.24	-30.42	1.998	OK
C55	Col43x55	0	1.5(DL+Ex)	4725	-310.99	-13.17	0.34	1.998	OK
C55	Col43x55	1535	1.5(DL+Ex)	4725	-297.38	-1.63	-0.45	1.998	OK
C55	Col43x55	3070	1.5(DL+Ex)	4725	-283.77	9.91	-1.24	1.998	OK
C56	Col43x55	0	1.5(DL+Ex)	4725	-299.79	-14.24	2.84	1.998	OK
C56	Col43x55	1535	1.5(DL+Ex)	4725	-286.18	-4.03	-4.62	1.998	OK
C56	Col43x55	3070	1.5(DL+Ex)	4725	-272.57	6.17	-12.08	1.998	OK
C57	Col43x55	0	1.5(DL+LL)	4725	-916.96	-3.09	3.00	1.998	OK
C57	Col43x55	1535	1.5(DL+LL)	4725	-903.35	3.56	-8.00	1.998	OK
C57	Col43x55	3070	1.5(DL+Ey)	4725	-849.18	47.41	-18.79	1.998	OK
C58	Col43x55	0	1.5(DL+Ey)	4725	-504.99	-2.42	3.76	1.998	OK
C58	Col43x55	1535	1.5(DL+Ey)	4725	-491.38	10.97	1.12	1.998	OK
C58	Col43x55	3070	1.5(DL-Ey)	4725	-346.57	49.21	0.13	1.998	OK
C65	Col43x55	0	1.5(DL-Ey)	4725	-868.48	20.90	-4.48	1.998	OK
C65	Col43x55	1535	1.5(DL-Ey)	4725	-854.87	5.60	-6.95	1.998	OK
C65	Col43x55	3070	1.5(DL-Ey)	4725	-841.26	-9.69	-9.43	1.998	OK
C67	Col43x55	0	1.5(DL+Ex)	4725	-604.25	-2.67	8.48	1.998	OK
C67	Col43x55	1535	1.5(DL+Ex)	4725	-590.64	0.33	2.19	1.998	OK
C67	Col43x55	3070	1.5(DL+Ex)	4725	-577.03	3.34	-4.09	1.998	OK

C72	Col43x55	0	1.5(DL-Ey)	4725	-1,110.88	-2.10	1.53	1.998	OK
C72	Col43x55	1500	1.5(DL-Ey)	4725	-1,097.58	1.51	-9.04	1.998	OK
C72	Col43x55	3000	0.9DL+1.5Ex	4725	499.49	-6.03	16.46	1.998	OK
C73	Col43x55	0	0.9DL-1.5Ey	4725	680.02	-0.38	1.80	1.998	OK
C73	Col43x55	1535	0.9DL-1.5Ey	4725	688.18	0.51	-9.26	1.998	OK
C73	Col43x55	3070	0.9DL-1.5Ey	4725	696.35	1.39	-20.33	1.998	OK
C63	Col43x55	0	1.5(DL+Ey)	4725	-545.54	4.03	-4.73	1.998	OK
C63	Col43x55	1535	1.5(DL+Ey)	4725	-531.93	3.31	5.03	1.998	OK
C63	Col43x55	3070	1.5(DL+Ey)	4725	-518.32	2.59	14.79	1.998	OK
C77	Col43x55	0	1.5(DL+LL)	4725	-888.30	3.16	-2.58	1.998	OK
C77	Col43x55	1535	1.5(DL+LL)	4725	-874.69	-4.26	8.19	1.998	OK
C77	Col43x55	3070	1.5(DL+LL)	4725	-861.08	-11.67	18.95	1.998	OK
C80	Col43x55	0	1.5(DL+Ey)	4725	-463.07	6.89	-3.53	1.998	OK
C80	Col43x55	1535	1.5(DL+Ey)	4725	-449.46	2.51	1.17	1.998	OK
C80	Col43x55	3070	1.5(DL+Ey)	4725	-435.85	-1.88	5.87	1.998	OK
C82	Col43x43	0	1.5(DL+Ey)	3418	-691.82	-0.14	-6.38	1.849	OK
C82	Col43x43	1535	1.5(DL+Ey)	3418	-681.18	5.81	7.32	1.849	OK
C82	Col43x43	3070	1.5(DL+Ey)	3418	-670.54	11.75	21.02	1.849	OK
C84	Col43x55	0	1.5(DL+Ex)	4725	-395.49	-0.84	2.02	1.998	OK
C84	Col43x55	1535	1.5(DL+Ex)	4725	-381.88	0.01	7.41	1.998	OK
C84	Col43x55	3070	1.5(DL-Ey)	4725	-317.46	1.58	-24.49	1.998	OK
C89	Col43x43	0	1.5(DL+Ex)	3418	-733.11	0.24	0.14	1.849	OK
C89	Col43x43	1535	1.5(DL+Ex)	3418	-722.47	-0.56	6.21	1.849	OK
C89	Col43x43	3070	1.5(DL+Ex)	3418	-711.82	-1.36	12.29	1.849	OK
C90	Col43x43	0	1.5(DL-Ey)	3418	-804.50	-2.57	3.35	1.849	OK
C90	Col43x43	1535	1.5(DL-Ey)	3418	-793.86	4.51	-6.97	1.849	OK
C90	Col43x43	3070	1.5(DL-Ey)	3418	-783.22	11.60	-17.29	1.849	OK
C91	Col43x55	0	1.5(DL+Ex)	4725	-1,129.31	-0.25	4.53	1.998	OK
C91	Col43x55	1535	1.5(DL+Ex)	4725	-1,115.70	-9.01	6.08	1.998	OK
C91	Col43x55	3070	1.5(DL+Ex)	4725	-1,102.09	-17.77	7.62	1.998	OK
C92	Col43x55	0	1.5(DL+LL)	4725	-423.25	-0.12	2.83	1.998	OK
C92	Col43x55	1500	1.5(DL+LL)	4725	-409.95	0.26	-3.92	1.998	OK
C92	Col43x55	3000	1.5(DL-Ey)	4725	-285.23	0.12	-27.75	1.998	OK
C93	Col43x55	0	1.5(DL+Ey)	4725	-416.03	5.89	3.69	1.998	OK
C93	Col43x55	1500	1.5(DL+Ey)	4725	-402.73	1.74	-2.52	1.998	OK
C93	Col43x55	3000	1.5(DL-Ey)	4725	-289.76	-1.90	-24.83	1.998	OK
C94	Col43x55	0	1.5(DL+Ex)	4725	-876.80	-2.77	4.36	1.998	OK
C94	Col43x55	1535	1.5(DL+Ex)	4725	-863.19	1.98	6.82	1.998	OK
C94	Col43x55	3070	1.5(DL+Ey)	4725	-847.46	40.91	-12.84	1.998	OK
C95	Col43x55	0	1.5(DL-Ey)	4725	-951.15	2.73	-1.20	1.998	OK
C95	Col43x55	1535	1.5(DL-Ey)	4725	-937.54	-5.80	-7.13	1.998	OK
C95	Col43x55	3070	1.5(DL-Ey)	4725	-923.93	-14.33	-13.06	1.998	OK
C96	Col43x55	0	0.9DL+1.5Ex	4725	676.92	-1.31	-6.15	1.998	OK
C96	Col43x55	1535	0.9DL+1.5Ex	4725	685.08	-0.51	9.87	1.998	OK
C96	Col43x55	3070	0.9DL+1.5Ex	4725	693.25	0.30	25.88	1.998	OK
C97	Col43x55	0	0.9DL-1.5Ey	4725	699.10	1.77	3.87	1.998	OK
C97	Col43x55	1535	0.9DL-1.5Ey	4725	707.27	-0.48	-8.48	1.998	OK
C97	Col43x55	3070	0.9DL-1.5Ey	4725	715.44	-2.73	-20.83	1.998	OK
C64	Col43x43	0	1.5(DL+LL)	3418	-763.10	-2.52	1.22	1.849	OK
C64	Col43x43	1535	1.5(DL+LL)	3418	-752.46	4.81	-3.14	1.849	OK

C64	Col43x43	3070	1.5(DL+LL)	3418	-741.81	12.14	-7.50	1.849	OK
C104	Col43x55	0	1.5(DL+Ex)	4725	-419.32	1.42	-0.28	1.998	OK
C104	Col43x55	1725	1.5(DL+Ex)	4725	-404.02	-1.73	8.97	1.998	OK
C104	Col43x55	3450	1.5(DL+Ex)	4725	-388.73	-4.89	18.23	1.998	OK
C107	Col43x43	0	1.5(DL-Ey)	3418	-459.18	2.73	-7.78	1.849	OK
C107	Col43x43	1535	1.5(DL-Ey)	3418	-448.54	-0.21	-2.27	1.849	OK
C107	Col43x43	3070	1.5(DL-Ey)	3418	-437.90	-3.14	3.24	1.849	OK
C108	Col43x43	0	1.5(DL-Ey)	3418	-805.14	-2.15	5.50	1.849	OK
C108	Col43x43	1535	1.5(DL-Ey)	3418	-794.50	1.50	-10.97	1.849	OK
C108	Col43x43	3070	1.5(DL-Ey)	3418	-783.86	5.15	-27.44	1.849	OK
C112	Col43x55	0	1.5(DL+Ey)	4725	-1,152.92	-7.03	-4.59	1.998	OK
C112	Col43x55	1535	1.5(DL+Ey)	4725	-1,139.31	20.07	1.70	1.998	OK
C112	Col43x55	3070	1.5(DL+Ey)	4725	-1,125.70	47.17	7.99	1.998	OK
C40	Col43x43	0	1.5(DL+Ex)	3418	-449.76	-0.00	5.51	1.849	OK
C40	Col43x43	1535	1.5(DL+Ex)	3418	-439.12	0.39	2.17	1.849	OK
C40	Col43x43	3070	1.5(DL+Ex)	3418	-428.48	0.79	-1.16	1.849	OK
C41	Col43x55	0	1.5(DL+LL)	4725	-411.23	-10.16	0.12	1.998	OK
C41	Col43x55	1535	1.5(DL-Ey)	4725	-377.77	23.39	-0.35	1.998	OK
C41	Col43x55	3070	1.5(DL-Ey)	4725	-364.16	57.16	-0.35	1.998	OK
C53	Col43x55	0	1.5(DL+Ey)	4725	-525.24	-10.17	3.20	1.998	OK
C53	Col43x55	1535	1.5(DL+Ey)	4725	-511.63	6.58	1.78	1.998	OK
C53	Col43x55	3070	1.5(DL-Ey)	4725	-339.59	55.97	0.92	1.998	OK
C60	Col43x43	0	1.5(DL+LL)	3418	-606.98	1.48	5.71	1.849	OK
C60	Col43x43	1535	1.5(DL+LL)	3418	-596.34	-1.34	-4.70	1.849	OK
C60	Col43x43	3070	1.5(DL-Ey)	3418	-517.57	-4.95	-30.30	1.849	OK
C61	Col43x55	0	1.5(DL+Ey)	4725	-464.77	4.84	3.42	1.998	OK
C61	Col43x55	1535	1.5(DL+Ey)	4725	-451.16	2.89	-1.32	1.998	OK
C61	Col43x55	3070	1.5(DL-Ey)	4725	-309.11	4.31	-28.80	1.998	OK
C62	Col43x43	0	1.5(DL-Ey)	3418	-515.56	0.00	-8.17	1.849	OK
C62	Col43x43	1535	1.5(DL-Ey)	3418	-504.92	-0.36	-2.72	1.849	OK
C62	Col43x43	3070	1.5(DL-Ey)	3418	-494.28	-0.72	2.74	1.849	OK
C68	Col43x55	0	1.5(DL+Ey)	4725	-1,053.63	-8.05	1.58	1.998	OK
C68	Col43x55	1535	1.5(DL+Ey)	4725	-1,040.02	21.33	-1.12	1.998	OK
C68	Col43x55	3070	1.5(DL+Ey)	4725	-1,026.41	50.71	-3.83	1.998	OK
C69	Col43x55	0	1.5(DL+Ex)	4725	-1,064.93	4.16	-1.96	1.998	OK
C69	Col43x55	1535	1.5(DL+Ex)	4725	-1,051.32	-22.68	-0.35	1.998	OK
C69	Col43x55	3070	1.5(DL+Ex)	4725	-1,037.71	-49.52	1.26	1.998	OK
C70	Col43x55	0	1.5(DL-Ey)	4725	-296.15	0.59	2.75	1.998	OK
C70	Col43x55	1500	1.5(DL-Ey)	4725	-282.85	0.66	-10.08	1.998	OK
C70	Col43x55	3000	1.5(DL-Ey)	4725	-269.55	0.73	-22.91	1.998	OK
C71	Col43x55	0	1.5(DL+Ey)	4725	-448.90	5.08	3.45	1.998	OK
C71	Col43x55	1500	1.5(DL+Ey)	4725	-435.61	2.09	-1.51	1.998	OK
C71	Col43x55	3000	1.5(DL-Ey)	4725	-275.48	-1.61	-27.98	1.998	OK
C83	Col43x55	0	1.5(DL+Ex)	4725	-599.05	2.44	8.97	1.998	OK
C83	Col43x55	1535	1.5(DL+Ex)	4725	-585.45	-1.62	2.40	1.998	OK
C83	Col43x55	3070	1.5(DL+Ex)	4725	-571.84	-5.69	-4.16	1.998	OK
C110	Col43x55	0	1.5(DL+Ex)	4725	-994.62	1.07	-3.26	1.998	OK
C110	Col43x55	1500	1.5(DL+Ex)	4725	-981.32	-1.25	8.34	1.998	OK
C110	Col43x55	3000	1.5(DL+Ex)	4725	-968.02	-3.57	19.93	1.998	OK
C115	Col43x55	0	1.5(DL-Ey)	4725	-414.75	-1.00	3.03	1.998	OK

C115	Col43x55	1500	1.5(DL-Ey)	4725	-401.45	1.21	-9.63	1.998	OK
C115	Col43x55	3000	1.5(DL-Ey)	4725	-388.15	3.43	-22.30	1.998	OK
C116	Col43x43	0	1.5(DL+LL)	3418	-820.61	4.69	-4.81	1.849	OK
C116	Col43x43	1535	1.5(DL+LL)	3418	-809.97	-10.00	11.04	1.849	OK
C116	Col43x43	3070	1.5(DL+LL)	3418	-799.33	-24.68	26.88	1.849	OK
C118	Col43x55	0	1.5(DL+Ex)	4725	-503.52	-16.15	-3.20	1.998	OK
C118	Col43x55	1535	1.5(DL+Ex)	4725	-489.91	-4.15	3.02	1.998	OK
C118	Col43x55	3070	1.5(DL+Ex)	4725	-476.30	7.84	9.24	1.998	OK
C119	Col43x55	0	1.5(DL-Ey)	4725	-977.32	-5.97	2.20	1.998	OK
C119	Col43x55	1535	1.5(DL-Ey)	4725	-963.71	21.91	0.17	1.998	OK
C119	Col43x55	3070	1.5(DL-Ey)	4725	-950.10	49.78	-1.85	1.998	OK
C120	Col43x55	0	1.5(DL-Ey)	4725	-342.74	16.83	1.31	1.998	OK
C120	Col43x55	1535	1.5(DL-Ey)	4725	-329.13	2.37	0.62	1.998	OK
C120	Col43x55	3070	1.5(DL-Ey)	4725	-315.52	-12.09	-0.06	1.998	OK
C121	Col43x55	0	1.5(DL+LL)	4725	-423.17	1.97	-0.25	1.998	OK
C121	Col43x55	1535	1.5(DL+Ex)	4725	-382.72	-23.07	-0.13	1.998	OK
C121	Col43x55	3070	1.5(DL+Ex)	4725	-369.11	-48.27	0.98	1.998	OK
C122	Col43x55	0	1.5(DL+LL)	4725	-420.94	10.14	0.21	1.998	OK
C122	Col43x55	1535	1.5(DL+Ex)	4725	-396.78	-22.61	-0.48	1.998	OK
C122	Col43x55	3070	1.5(DL+Ex)	4725	-383.17	-55.65	-0.10	1.998	OK
C123	Col43x55	0	1.5(DL+Ey)	4725	-514.42	9.99	3.29	1.998	OK
C123	Col43x55	1535	1.5(DL+Ey)	4725	-500.81	-3.57	1.68	1.998	OK
C123	Col43x55	3070	1.5(DL+Ex)	4725	-330.96	-57.08	1.13	1.998	OK
C124	Col43x55	0	1.5(DL+LL)	4725	-408.72	0.61	-3.66	1.998	OK
C124	Col43x55	1535	1.5(DL+Ex)	4725	-369.45	-1.30	12.58	1.998	OK
C124	Col43x55	3070	1.5(DL+Ex)	4725	-355.84	-2.27	29.79	1.998	OK
C125	Col43x55	0	0.9DL+1.5Ex	4725	806.48	-13.81	-2.58	1.998	OK
C125	Col43x55	1535	0.9DL+1.5Ex	4725	814.65	-4.73	8.59	1.998	OK
C125	Col43x55	3070	0.9DL+1.5Ex	4725	822.81	4.35	19.76	1.998	OK
C126	Col43x55	0	0.9DL-1.5Ey	4725	613.50	-0.11	4.48	1.998	OK
C126	Col43x55	1535	0.9DL-1.5Ey	4725	621.67	0.57	-10.30	1.998	OK
C126	Col43x55	3070	0.9DL-1.5Ey	4725	629.84	1.25	-25.09	1.998	OK
C127	Col43x43	0	1.5(DL+LL)	3418	-623.53	-2.34	3.78	1.849	OK
C127	Col43x43	1535	1.5(DL+LL)	3418	-612.89	0.97	-8.33	1.849	OK
C127	Col43x43	3070	1.5(DL-Ey)	3418	-475.62	3.44	-36.51	1.849	OK
C128	Col43x55	0	1.5(DL+Ey)	4725	-479.53	5.38	-3.49	1.998	OK
C128	Col43x55	1500	1.5(DL+Ey)	4725	-466.23	1.91	0.75	1.998	OK
C128	Col43x55	3000	1.5(DL+Ey)	4725	-452.93	-1.56	4.99	1.998	OK
C129	Col43x55	0	1.5(DL+LL)	4725	-363.67	-0.48	-3.66	1.998	OK
C129	Col43x55	1500	1.5(DL+LL)	4725	-350.37	0.74	1.92	1.998	OK
C129	Col43x55	3000	1.5(DL+Ex)	4725	-289.04	1.78	24.44	1.998	OK
C132	Col43x55	0	1.5(DL-Ey)	4725	-583.71	2.62	-8.02	1.998	OK
C132	Col43x55	1535	1.5(DL-Ey)	4725	-570.10	-0.64	-2.29	1.998	OK
C132	Col43x55	3070	1.5(DL-Ey)	4725	-556.49	-3.90	3.43	1.998	OK
C133	Col43x55	0	1.5(DL-Ey)	4725	-572.46	-2.49	-7.60	1.998	OK
C133	Col43x55	1535	1.5(DL-Ey)	4725	-558.85	1.53	-2.27	1.998	OK
C133	Col43x55	3070	1.5(DL-Ey)	4725	-545.24	5.55	3.05	1.998	OK
C134	Col43x55	0	1.5(DL+LL)	4725	-400.54	0.45	-6.24	1.998	OK
C134	Col43x55	1500	1.5(DL+LL)	4725	-387.24	0.02	1.36	1.998	OK
C134	Col43x55	3000	1.5(DL+Ex)	4725	-310.03	-0.52	29.08	1.998	OK

C14	Col43x43	0	1.5(DL+Ex)	3418	-691.16	0.75	0.00	1.849	OK
C14	Col43x43	1535	1.5(DL+Ex)	3418	-680.52	-1.25	2.30	1.849	OK
C14	Col43x43	3070	1.5(DL+Ex)	3418	-669.88	-3.25	4.60	1.849	OK

Table.17. Analysis Result output of Ground floor's column forces, moments & A_{st} % calculated (Model 4).

From this Model 4, we can clearly see that all the columns are passed and are adequate to withstand seismic forces. Thus, by providing shear walls on the ground floor and by retrofitting the columns, we are able to increase the capacity of the column and thereby increase the strength of the building.

Section 4

4.1 Column Jacketing at site

4.1.1 Procedure

1. Preparation of existing column’s surface by making it rough to have better friction between the old and new concrete.
2. The longitudinal and transverse reinforcement as per design is placed around the existing column.
3. The shear key is provided by drilling holes of specified diameter and depth.
4. The drilled holes are cleaned by blowing air.
5. Epoxy bonding paste is injected in drilled holes.
6. A shear key of L-shaped is inserted inside the hole and allowed to cure with epoxy.
7. Reinforcement is properly tied with a shear key using binding wire and welded with longitudinal reinforcement.
8. The column shoe is prepared at the base and then formwork is installed around the existing column and proper support is provided to withstand it.
9. Finally, concrete of the desired mix is poured and curing is done after the removal of formwork.

Figure.38. Preparation of column’s surface

Figure.39. Provision of longitudinal reinforcement

Figure.40. Provision of shear key

Figure.41. Preparation of column's shoe

Figure.42. Installation of Formwork

Figure.43. Retrofitted Column

4.2 Shear wall and column connection

4.2.1 Procedure

1. Selection of proper epoxy.
2. Drilling holes in columns of the required length.
3. Injection of epoxy.
4. Placing the dowels bar.
5. Longitudinal and Transverse reinforcement as per design is placed and connected with dowels bar using binding wire and then welded.
6. Formwork is installed and proper support is provided to withstand it.
7. Finally, concrete of the desired mix is poured and curing is done after the removal of formwork.

Figure.44. Dowels bar placing

Figure.45. Provision of Longitudinal and Transverse reinforcement

Figure.46. Shear wall shuttering and support

Figure.47. Shear wall concreting

4.3 Basic comparison of IS 1893(Part1):2016 and EN 1998-1:2004

Comparison between the codes is done based on the most vital factors that are used in this modelling.

4.3.1 DUCTILITY CLASSES

IS 1893(Part1): 2016 classifies RC frame buildings as Ordinary Moment Resisting Frames (OMRF) and Special Moment Resisting Frames (SMRF). EUROCODE 8 (EN 1998-1) classifies the building ductility as Low (DCL), Medium (DCM) and High (DCH).

Category	Ductility Class	
	IS 1893	EC 8
Low dissipative structures	Ordinary Moment Resisting Frames (OMRF)	Ductility Class Low (DCL)
Medium dissipative structures	Special Moment Resisting Frames (SMRF)	Ductility Class Medium (DCM)
High dissipative structures	-	Ductility Class High (DCH)

Table.18. Ductility class of IS 1893 and EC8

The Ductility class used in this project is Ordinary Moment Resisting Frames (OMRF).

4.3.2 RESPONSE REDUCTION FACTOR

The response reduction factor, in design codes, depends on over strength and ductility of the structure. Building codes define different ductility classes and specify corresponding response reduction factors based on the structural material, configuration, and detailing.
Structural Types as per IS 1893,

1) Moment Frames Systems
2) Braced Frames Systems
3) Structural Wall Systems
4) Dual Systems
5) Flat Slab- Structural Wall Systems

In this project, the structural type is Moment Frame Systems. Thus, the Response Reduction Factor for Ordinary Moment Resisting Frames (OMRF) and Special Moment Resisting Frames (SMRF) is 3 and 5 respectively as per Clause 7.2.6, Table 9.
Structural types as per EC8,

1) Frame system
2) Dual Frame or Wall system
3) Ductile coupled or uncoupled system
4) System of large lightly reinforced walls
5) Inverted pendulum system
6) Tortionally flexible system

Thus, the behaviour factor, $\mathbf{q = q_0 k_w \geq 1.5}$ for Frame system for Ductility Class Low (DCL), Ductility Class Medium (DCM) and Ductility Class High (DCH) is 1.5, $3.0\alpha_u/\alpha_1$, $4.5\ \alpha_u/\alpha_1$, respectively.
α_u/α_1 for Multistorey Multi-Bay Frame systems is 1.3 and kw is 1.0 for Frame systems.
Thus, behaviour factor for Frame system for Ductility Class Low (DCL), Ductility Class Medium (DCM) and Ductility Class High (DCH) is 1.5, 3.9 and 5.85, respectively. (As per Cl 5.3.3 and Cl 5.2.2.2)

4.3.3 IMPORTANCE CLASS & FACTOR

As per IS 1893 (Part 1): 2016, Clause 7.2.3, Table8,

Table 8 Importance Factor (*I*)
(*Clause* 7.2.3)

Sl No. (1)	Structure (2)	*I* (3)
i)	Important service and community buildings or structures (for example, critical governance buildings, schools), signature buildings, monument buildings, lifeline and emergency buildings (for example, hospital buildings, telephone exchange buildings, television station buildings, radio station buildings, bus station buildings, metro rail buildings and metro rail station buildings), railway stations, airports, food storage buildings (such as warehouses), fuel station buildings, power station buildings, and fire station buildings), and large community hall buildings (for example, cinema halls, shopping malls, assembly halls and subway stations)	1.5
ii)	Residential or commercial buildings [other than those listed in Sl No. (i)] with occupancy more than 200 persons	1.2
iii)	All other buildings	1.0

Table.19. Importance Factor of IS 1893

The importance factor used in this building is 1.2.

As per EN 1998-1:2004, Clause 4.2.5, Table 4.3,

Importance class	Buildings
I	Buildings of minor importance for public safety, e.g. agricultural buildings, etc.
II	Ordinary buildings, not belonging in the other categories.
III	Buildings whose seismic resistance is of importance in view of the consequences associated with a collapse, e.g. schools, assembly halls, cultural institutions etc.
IV	Buildings whose integrity during earthquakes is of vital importance for civil protection, e.g. hospitals, fire stations, power plants, etc.

Table.20. Importance class of IS 1893

As per Importance class I, II, III & IV, the Importance factor γ_I is 0.8, 1.0, 1.2 and 1.4, respectively.

4.3.4 SEISMIC ZONE

As per IS 1893 (Part 1): 2016, Clause 6.4.2, Table 3,

Table 3 Seismic Zone Factor *Z*
(*Clause* 6.4.2)

Seismic Zone Factor (1)	II (2)	III (3)	IV (4)	V (5)
Z	0.10	0.16	0.24	0.36

Table.21. Seismic Zone factor of IS 1893

In IS code, zones range from low (II) to high(V).

Pondicherry lies in Zone II and seismic zone factor is 0.10.

As per EN 1998, seismic zones are subdivided as per National territories depending on the local hazard.
For most of the applications of EN 1998, the hazard is described in terms of a single parameter, i.e., the value of the reference peak ground acceleration on type A ground, a_gR. Additional parameters required for specific types of structures are given in the relevant Parts of EN 1998.
The reference peak ground acceleration, chosen by the National Authorities for each Seismic zone, corresponds to the reference return period of the seismic action for the no-collapse requirement (or equivalently the reference probability of exceedance in 50 years) chosen by the National Authorities.

In Italy:

Four seismic zones are defined according to the value of the maximum ground acceleration ag, whose probability of exceedance is 10% in 50 years.

Seismic zone	Ground acceleration with probability of exceedance equal to 10% in 50 years (a_g)
1	> 0.25g
2	0.15g – 0.25g
3	0.05g – 0.15g
4	< 0.05g

Table.22. Seismic zone wrt to Ground acceleration

In National Annex, the seismicity zone ranges from High (1) to low (4).

4.4 Discussion and Conclusion

Seismic up-gradation or retrofitting of building aims at enhancing the aseismic performance of structures so that they can resist a stipulated earthquake forces and also maintain the required performance level without damaging the structure to ensure the safety of the people. The seismic capacity of the building is increased by providing new lateral load-carrying elements such as shear walls on the Ground Floor (Parking). RC jacketing of columns at all floor levels was done to increase the overall capacity of the structure and also to satisfy strong column and week beam concept.

Seismic up-gradation of a 23 years old five-storied RCC building has been analyzed and desired results have been obtained. The building was not designed to take seismic actions which were failing under the action of earthquake and wind load. But now with the help of column jacketing and the addition of shear walls, the building is safe and can be opened for intended purpose. Introduction of shear wall and column jacketing has been made on the ground floor of the building. It was found that all the columns were able to withstand the seismic load and building functions well under all circumstances. With the help of ETABS software, analysis and design has been carried out.

Model 1: Analysis of the structure as per present condition with Dead load & Live load.

It can be seen from this model that 86% of the columns failed on the ground floor concerning DL and LL alone. This shows that the building is not even designed for DL and LL cases.

Model 2: Analysis of structure as per present condition with dead load, live load, wind load, and seismic load.

For this Model, almost 96% of the columns failed on the ground floor as per existing reinforcement present in the column.

Model 3: Analysis of structure by introducing shear wall at ground floor level.

In this model, shear walls are introduced on the ground floor level of the structure to increase the building’s stiffness. From the result, it is obtained that 55% of the columns are passed with the existing reinforcement.

Model 4: Analysis of structure by introducing Column jacketing.

RC column jacketing is designed using IS 15988: 2013. These parameters were modified in the software and columns were designed using section designer. With the help of column jacketing and shear wall introduction on the ground floor, all the columns are safe for seismic actions and story displacements and drifts are well within permissible limit as per IS 1893: 2016 Part 1.

Floor Level	Height, H (m)	Load Case/Combo	Model 2		Model 4	
			Story Displacement, Di (mm)	Story Drift(Di/H) (mm)	Story Displacement, Di (mm)	Story Drift(Di/H) (mm)
Story 4	15.45	DL+EQx	34.934	0.00226	16.047	0.00104
Story 3	12.45	DL+EQx	31.212	0.00251	11.639	0.00093
Story 2	9.45	DL+EQx	25.29	0.00268	7.096	0.00075
Story 1	6.45	DL+EQx	18	0.00279	3.055	0.00047
Ground Floor	3.45	DL+EQx	9.992	0.00290	0.377	0.00011
Base	0	DL+EQx	0	0	0	0

Table.23. Story displacement and Story Drift along X direction

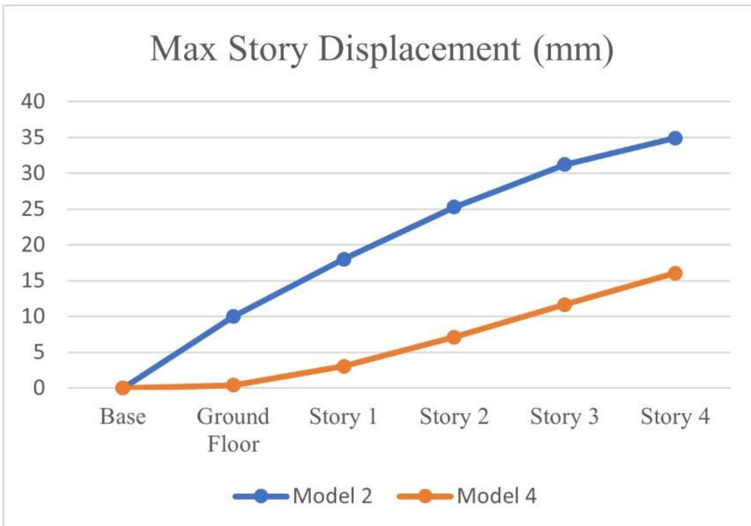

Figure.48. Maximum Story Displacement in X direction

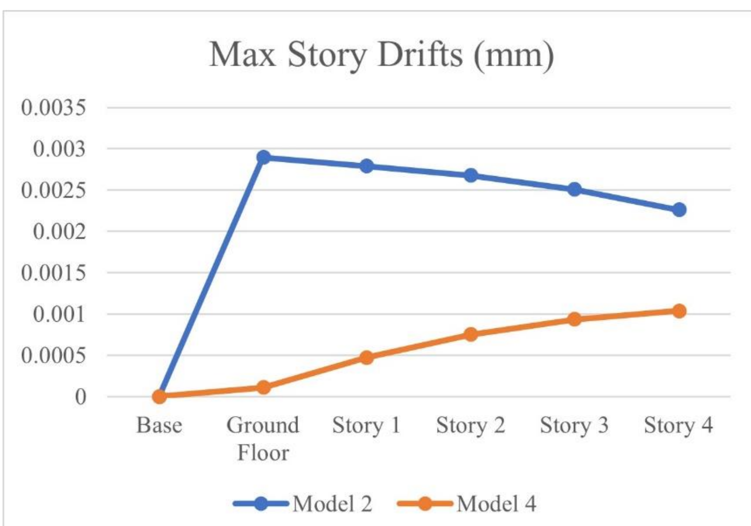

Figure.49. Maximum Story Drift in X direction

Floor Level	Height, H (m)	Load Case/Combo	Model 2		Model 4	
			Story Displacement, Di (mm)	Story Drift(Di/H) (mm)	Story Displacement, Di (mm)	Story Drift(Di/H) (mm)
Story 4	15.45	DL+EQy	26.478	0.0017	13.231	0.00086
Story 3	12.45	DL+EQy	23.796	0.0019	9.812	0.00079
Story 2	9.45	DL+EQy	19.346	0.0020	6.085	0.00064
Story 1	6.45	DL+EQy	13.787	0.0021	2.555	0.00040
Ground Floor	3.45	DL+EQy	7.641	0.0022	0.173	0.00005
Base	0	DL+EQy	0	0	0	0

Table.24. Story displacement and Story Drift along Y direction

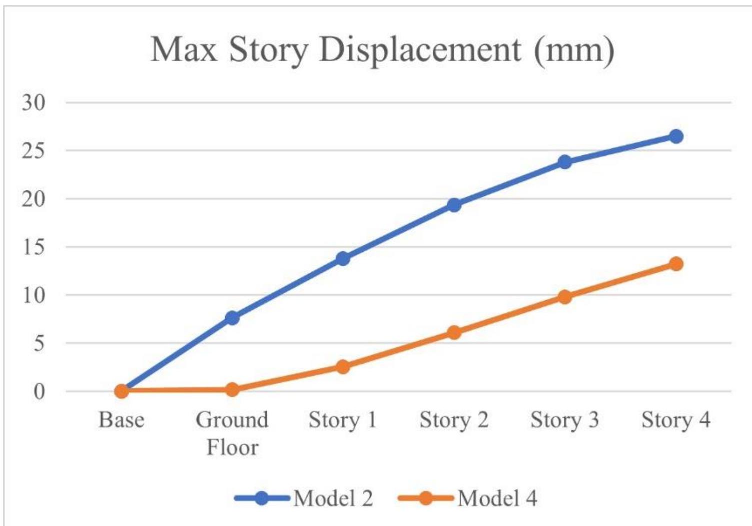

Figure.50. Maximum Story Displacement in Y direction

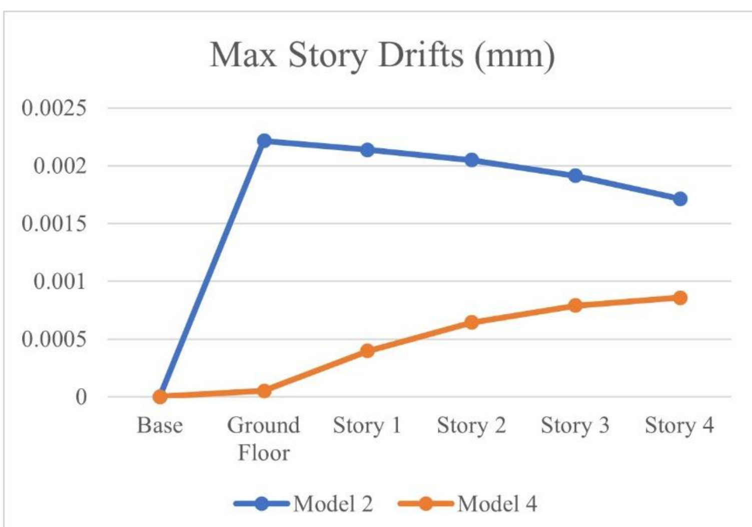

Figure.51. Maximum Story Displacement in Y direction

As we can see from these results that the displacement and drift of Model 4 are less when compared to Model 2 in both X and Y direction and also the drifts are less than 0.4% as per clause 7.11.1.1 of IS 1893 Part 1. Also, from the analysis of Model 4, we can say that the stiffness and capacity of the structure are increased thus able to withstand the seismic load.

The 23 years old structure which was not put into use due to safety reasons has been retrofitted successfully with minimum cost and put into use by adopting appropriate techniques. The retrofitting methods suggested has been mostly completed and the present status of the structure as on 05 July 2021 is presented below.

Figure.52. Jacketed Columns

Figure.53. Shear wall and Jacketed column

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