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SEISMIC AND WIND RESPONSE OF TALL REINFORCED CONCRETE BUILDINGS WITH OUTRIGGER SYSTEMS

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Abstract: This study investigates the seismic and wind response of tall reinforced concrete buildings supported on hard, medium, and soft soils. Finite element models of geometrically regular prototypes with heights of G+50, G+55, and G+60 storeys were developed, and the structural performance was evaluated using equivalent static and dynamic analysis procedures in ETABS 2015. The study includes a comparative assessment of lateral deformation in buildings with and without outrigger systems. The results indicate that for geometrically regular and symmetrical buildings with simple grid plans, the optimal location of outriggers occurs between the 22nd and 24th storeys in a 50-storey structure, corresponding to approximately 0.44–0.48 times the total height. This placement aligns with trends observed from acceleration–velocity ratio analyses of previous earthquake records. The inclusion of outriggers at this level leads to significant reductions and in some cases near elimination of uplift and net tension forces in the columns and foundation system. Overall, the study confirms that properly designed and strategically positioned outriggers substantially enhance the lateral performance and stability of tall RC buildings under combined seismic and wind loading.

Index Terms: RC building, outrigger system, earthquake and wind effect.

I. INTRODUCTION

Outrigger is a deep, stiff beam which connects the central core to the exterior column, helping to keep the columns in their position and further reducing the lateral sway of the structure as a whole. Outrigger acts as a stiff arm connecting outer columns to the core. When lateral wind or earthquake forces act on the central core, the core tends to tilt. this induces a tension–compression couple in the outer columns, which acts in opposition to that movement at the outrigger level. The concept of outrigger is commonly used nowadays in the design of tall buildings. In this concept, "outrigger" trusses connect the exterior columns of the tall RC structure to the core wall. the core may consist of either shear walls or braced frames. Outriggers serve to reduce the overturning moment in the core that would otherwise act as a pure cantilever, and they transfer the reduced moment to columns outside the core by means of tension–compression couples, taking advantage of the increased moment arm between these columns. Several researchers have investigated the performance of tall RC buildings with different lateral load–resisting systems under seismic and wind effects. N. Herath et al. (2009) investigated the behaviour of tall buildings equipped with outrigger structural systems. The authors highlighted that as the height of a building increases, providing adequate structural stiffness becomes increasingly important to control lateral deflections. In this regard, outrigger beams are introduced between the central shear wall/core and the external columns to enhance the overall lateral stiffness and stability of the structure. The primary objective of their study was to determine the optimum location of outriggers to ensure seismic safety and achieve economy in structural design. For this purpose, nine previously recorded earthquake ground motions were considered, and their acceleration-to-velocity ratios were evaluated. The seismic performance of high-rise buildings was subsequently investigated by analysing different configurations of outrigger structural systems to identify their effectiveness under earthquake loading [1]. Kiran Kamath et al. (2012) investigated the effect of long-term differential column shortening in tall buildings equipped with an outrigger structural system. The authors highlighted that the cumulative differential shortening of columns can cause floor slabs to tilt, resulting in the rotation of partitions and other serviceability-related problems. Such differential shortening may adversely affect the functioning of elevators, cause deformation or damage to pipelines, and lead to cracking of partitions and finishing materials. Therefore, the effects of column shortening require careful consideration during the structural design of tall buildings. The primary objective of their study was to determine the optimum location of outriggers in high-rise reinforced concrete (RC) buildings to minimise differential column shortening and improve the overall serviceability of the structure [2]. Vijaya Kumari Gowda M. R. and Manohar (2015) carried out a study on lateral load-resisting structural systems in tall buildings by incorporating different configurations of belt trusses at the top and intermediate heights of the structures. The authors investigated the effectiveness of belt trusses as a cost-effective approach to improving the structural performance of buildings subjected to earthquake loading. A comparative analysis was conducted using various belt truss configurations, including X-shaped, V-shaped, inverted V-shaped, and diagonal arrangements. The study considered different seismic zones to evaluate the influence of belt truss configurations on the lateral response of buildings and to identify their effectiveness in improving structural stability and earthquake resistance [3]. Abdul Karim Mulla and Shrinivas B. N. (2015) investigated the effectiveness of an outrigger structural system with steel bracing in regular and vertically irregular buildings. The study focused on utilising the axial stiffness

of external columns to resist overturning moments and improve the lateral stability of structures. The authors conducted a comparative analysis of three-dimensional, 20-storey regular and vertically irregular buildings with symmetrical plans, considering structural configurations both with and without outrigger beams. The buildings were subjected to earthquake loading, and their seismic responses were evaluated using the equivalent static force method and response spectrum method. The structural analysis was performed using ETABS software in accordance with the relevant Indian Standard codes. The study aimed to assess the effectiveness of the outrigger system in improving the seismic performance of both regular and vertically irregular buildings [4]. Thejaswini R. M. and Rashmi A. R. (2015) carried out a comparative study of different lateral load-resisting structural systems to evaluate the behaviour and performance of tall buildings under seismic loading and transient wind pressure. The study aimed to identify a suitable structural system that could ensure the safety and stability of tall buildings under the combined effects of gravity loads, live loads, and external lateral forces. The structural performance was evaluated in terms of various response parameters, including bending moments, shear forces, torsional effects, strength, and stiffness. The study emphasised the importance of selecting an appropriate lateral load-resisting system to ensure adequate structural strength, stiffness, and stability under different loading conditions [5].

2. MATERIALS AND METHOD

one problem of ETABS input validation is represented, to know that the inputs put in ETABS is correct, one problem from a text book has been taken and is solved in ETABS and the results are compared.

2.1 ETABS Input validation

For validating ETABS, example from chapter 4 has been taken from the book on Earthquake – Resistant Design of Building Structures by Dr. Vinod Hosur, and from the book on Earthquake Resistant Design of Structures by S. K. Duggal and it has been solved in ETABS and the results by ETABS & Book is compared which is matching.

Example1. A four- storey RCC special moment resisting frame (SMRF) confirming to ductile detailing provisions residential building has two equal spans of 5 m each in both x- and y-directions as shown in Fig below. The height of each storey is 3.5 m. Evaluate the base shear and determine lateral force distribution on each floor. Take the live load as 3.5 kN/m^2. The columns are of size 250 mm x 450 mm, the beams are 250 mm x 400 mm and the slabs are 100 mm thick. Consider 250 mm thick brick masonry walls along x-direction and 150 mm thick brick masonry walls along y-direction. The soil type is hard rock and the location is Delhi. The importance factor is I=1.0, Neglect the influence of stiffness of the masonry infill in the computation of natural period.

Solution Computation of seismic weight of structure

Self-weight of masonry walls (x-direction) = [(0.25 x 5 x 3.1) x 20] x 6 =465 kN
Self-weight of masonry walls (y-direction) = [(0.15 x 5 x 3.1) x 20] x 6 =279 kN
Height of wall considered is 3.5 m (storey height) – 0.4 m (depth of beam including slab as flange) = 3.1 m
Unit weight of brick masonry = 20 kN/m^2
Self-weight of columns = [(0.25 x 0.45 x 3.5) x 25] x 9 = 88.6 kN
Self-weight of beams = [(0.25 x 0.4 x 5) x 25] x 12 = 150 kN
Self-weight of slab = [0.1 x 10 x 10] x 25 = 250 kN
Total self-weight of a floor = [465+279+88.6+150+250] = 1232.6 kN
Total live load on a floor = 10 x 10 x 3.5 = 350 kN
Seismic weight of a floor = 1232.6 + (0.5 x 350) = 1407.6 kN
Seismic weight of the roof = [0.5 x (465+279+88.6)+150+250] = 816.3 kN
Total seismic weight of the structure = 3 x 1407.6+1 x 816.3 = 5039.1 kN
$T_a = 0.075h^{0.75} = 0.543$ S
S_a/g for Hard soil= $1/T_n = 1.842$
Z (for zone V) = 0.24
Response reduction factor R = 5
$A_h = (Z/2)(I/R)(Sa/g) = (0.24/2)(1/5)(1.842) = 0.0442$
Total weight of the building = 5039 kN
Base shear (V_B) = A_h x W = 222.8 kN

Table 1 Comparison between manual and ETABS data

Storey	Weight (W_i) (kN)	h_i (m)	$W_ih_i^2$	V_B (kN)	$Q_i=V_B$ x (w_ihi^2/ sum(w_ihi^2)) (kN)	Cumulative storey shear (kN)	ETAB results (kN)
4	816.3	14.0	159994.8	222.8	88.8	88.80	87.75
3	1407.6	10.5	155187.9	222.8	86.14	174.94	173.32
2	1407.6	7.00	68972.40	222.8	38.28	213.22	291.36
1	1407.6	3.50	17243.10	222.8	9.57	222.79	220.87
Sum	5039.1		401398.20				

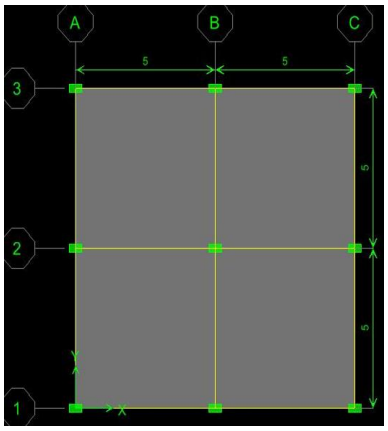

Fig. 1 Layout plans form ETABS validation model

The same problem has been solved in ETABS15.2.0, with the same inputs and the cumulative storey shear has been compared, and found solved in book.

Table 2 Storey shears form ETABS validation model

Story Shears

Edit View

Story Shears

Story	Load	Loc	P	VX	VY	T	MX	MY
STORY4	EQX	Top	0.00	-87.75	0.00	438.734	0.000	0.000
STORY4	EQX	Bottom	0.00	-87.75	0.00	438.734	0.000	-307.113
STORY3	EQX	Top	0.00	-173.32	0.00	866.615	0.000	-307.113
STORY3	EQX	Bottom	0.00	-173.32	0.00	866.615	0.000	-913.744
STORY2	EQX	Top	0.00	-211.36	0.00	1056.784	0.000	-913.744
STORY2	EQX	Bottom	0.00	-211.36	0.00	1056.784	0.000	-1653.493
STORY1	EQX	Top	0.00	-220.87	0.00	1104.327	0.000	-1653.493
STORY1	EQX	Bottom	0.00	-220.87	0.00	1104.327	0.000	-2426.522

OK

2.2 Model description

Due to the advantage, accuracy and popularity of FEM amongst the structural design engineers FEM was selected the analysis with the help of ETABS 15.2.0. The descriptions of selected models and criteria for the selection of height and plan layouts as well as different configurations of outriggers are shown here. For the analysis work ETABS 15.2.0 has been selected, the reason is, ETABS 15.2.0 is the most popular amongst structural design engineer, for their analysis work. ETABS 15.2.0 is the ultimate integrated software package for the structural analysis and design of buildings. Incorporating 40 years of continuous research and development, this latest ETABS offers unmatched 3D object-based modelling and visualization tools, blazingly fast linear and nonlinear analytical power, sophisticated and comprehensive design capabilities for a wide-range of materials, and insightful graphic displays, reports, and schematic drawings that allow users to quickly and easily decipher and understand analysis and design results. From the start of design conception through the production of schematic drawings, ETABS integrates every aspect of the engineering design process. Creation of models has never been easier – intuitive drawing commands allow for the rapid generation of floor and elevation framing. CAD drawings can be converted directly into ETABS models or used as templates onto which ETABS objects may be overlaid. The state-of-the-art SAPFire 64-bit solver allows extremely large and complex models to be rapidly analyzed, and supports nonlinear modelling techniques such as construction sequencing and time effects (e.g., creep and shrinkage). The program initiated in 1975 already has many buildings and real life structures in its credits, signifying the program's reliability and integrity.

2.3 Solvers

ETABS 15.2.0 is suited for most engineering problems of almost every discipline of engineering and research. It has been equipped with wide range of solvers, modelling options and output styles. However, for every specific study or design, only those solvers which are applicable to that study are used. Accordingly, in this study, two types of solvers are used in the research and are described below.

2.3.1 Response Spectrum analysis solver

Response-spectrum analysis solver (Figure 5.2) determines the statistically likely response of a structure to seismic loading. This linear type of analysis uses response-spectrum ground-acceleration records based on the seismic load and site conditions, rather than time-history ground motion records. This method is extremely efficient and takes into account the dynamical behavior of the structure.

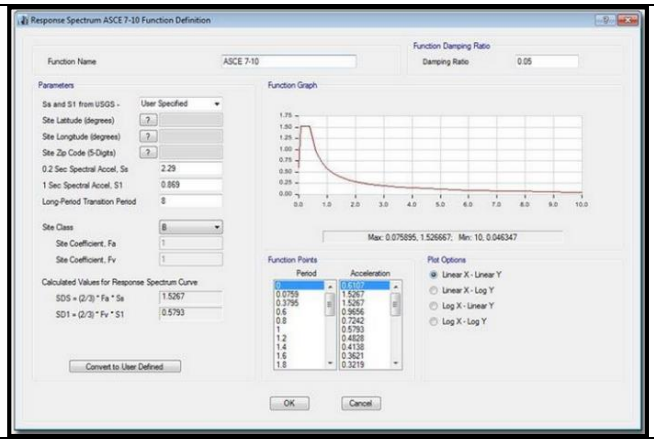

Fig. 2.1 Response Spectrum analysis solver

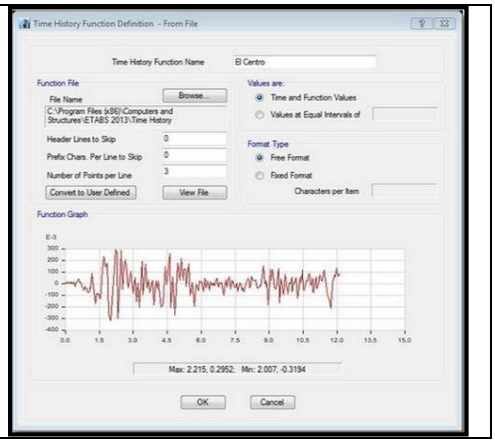

Fig. 2.2 Time history analysis solver

2.3.2 Time history analysis solver

Time-history analysis captures the step-by-step response of structures to seismic ground motion and other types of loading such as blast, machinery, wind, waves, etc. Analysis can use modal superposition or direct-integration methods, and both can be linear or nonlinear. The nonlinear modal method, also called FNA for Fast Nonlinear Analysis, is extremely efficient and accurate for a wide class of problems. The direct-integration method is even more general, and can handle large deformations and other highly nonlinear behaviour. Nonlinear time-history analyses can be chained together with other nonlinear cases (including staged construction) addressing a wide range of applications.

2.4 Loads used for analysis

The loads considered for the areas per relevant IS codes, there are four major types of loads considered

1. Dead load (IS 875 part I, 1987), DL
2. Live load (IS 875 part II,1987), LL & LLT
3. Earthquake load (IS 1893:2002), EX and EY
4. Wind load (IS 875 part III,1987), WX & WY

2.4.1 Dead Load: It includes self-weight of member and permanent finishes i.e., (wall loads, plastering and flooring). The dead load of RCC, steel bars, bricks, blocks and plaster are taken as 25 kN/m^3, 78.5 kN/m^3, 18.85 kN/m^3, 10.61 kN/m^3 and 20.4 kN/m^3 respectively.

2.4.1.1 Walls

Brick wall – 230 mm thick, with 20 mm thick external plaster and 15 mm thick internal plaster. Calculations are (18.85 x 0.23) + (20.4 x 0.02) (20.4 x 0.015) = 5.04 KN/m^2, for floor height of 3.5 m with 600 mm Beam depth, uniformly distributed load (udl) on beam supporting 230 mm thick Wall = 5.04 x (3.5-0.6) =14.62 kN/m

Brick wall – 150 mm thick, with 15 mm thick external plaster and 15 mm thick internal plaster, calculations are (18.85 x 0.15) + (20.4 x 0.015) + (20.4 x 0.015) = 3.45 kN/m^2, for floor height of 3.5 m with 600 mm beam Depth, udl on beam supporting 230 mm thick Wall = 3.45 x (3.5 -0.6) = 10.00 kN/m

Brick wall – 150 mm thick, with 15 mm thick external plaster and 15 mm thick internal plaster are (10.61 x 0.23) + (20.4 x 0.02) + (20.4 x 0.015) = 3.16 kN/m^2, for floor height of 3.5 m with 600 mm beam Depth, udl on beam supporting 230 mm thick Wall = 3.16 x (3.5-0.6) = 9.16

Brick wall – 150 mm thick, with 15 mm thick external plaster and 15 mm thick internal plaster, calculations are (10.61 x 0.15) + (20.4 x 0.015) + (20.4 x 0.015) = 2.10 KN/m^2, for floor height of 3.5 m with 600 mm beam Depth, udl on beam supporting 230 mm thick Wall = 2.10 x (3.5-0.6) = 6.09 kN/m

Wall loads will be applied on beams supporting walls, wherever applicable.

2.4.1.2 Flooring

100 mm thick. 1.47 say 1.5 KN/m^2 IS 875 part I.

Flooring loads will be applied on floor slabs.

2.4.2 Live Load: For residential buildings, live loads are as under, IS 875 Part 3 table1

All rooms and Kitchens = 2.0 KN/m^2

Toilet and Bath rooms = 2.0 KN/m^2

Corridors, passages, staircase, store rooms, fire escapes = 3.0 kN/m^2

Balconies = 3.0 kN/m^2

2.4.3 Earthquake Load: Earthquake loads will automatically be generated by the ETABS 15.2.0, by providing the corresponding inputs as under

Seismic zone factor – Z = 0.36 for seismic zone – V

Response Reduction Factor – R = 5

Damping – 5 % = 0.05

Soil type - I, II OR III, for Hard, Medium and Soft soil respectively.

Modal Combination – CQC

Directional Combination – CQC3

Minimum Eccentricity – 0.05

Excitation angle – as applicable

Eccentricity override – yes as applicable
Mass source – DL + 0.25 LL
Function – sine or as applicable
Period – as applicable
Number of steps per cycle – as applicable
Number of cycles – as applicable
Amplitude – as applicable
Analysis type – Non-linear
Number of Output Time steps – As applicable
Output time steps size –as applicable
Start from previous History – as applicable
Before using the automatic generation of earthquake load facility in ETABS 15.0.0, we have validated ETABS for the same and ETABS15.0.0 validation is included in this report, refer chapter no. 4 for more information.

2.4.4 Wind Loads:

Wind loads will automatically be generated by the ETABS 15.2.0, by providing the corresponding inputs as under for exposure from extents of diaphragm.
Wind Direction Angle – 0, 90^0

Windward coefficient, Cp – as applicable	Leeward Coefficient, Cp – as applicable
Basic Wind Sped V_b (m/s) – 50	Terrain category – 1
Structure class – B	Risk Coefficient, K1 – as applicable
Topography factor – K3 – as applicable	Bottom Storey – Ground
Top Storey – Terrace	Include parapet height – 1.2 m

Additionally, wind loadings using GUST FACTOR approach has been calculated and applied on diaphragm in separate wind load case, for dynamic wind analysis, and the severest among both has been taken for analysis.

2.5 Load combinations used for analysis.

Below mentioned Load Combinations are selected to be used for the analysis of all ETABS model, and are as per Table 18 of IS456:2000

2.6 Material properties used for analysis

Concrete Grade – M 70 for walls, columns and M 35 for beams and slabs
Compressive strength of concrete – 70 MPa after 28 days
Modulus of Elasticity of Concrete – 35355.34 MPa
Rebars – Fe 415 grade
Yield strength of Rebar material – 415 MPa
Shear strength of Rebar material – 415 MPa
Modulus of Elasticity of Rebar material – 200000 MPa
Concrete grade of M 70 has chosen to reduce the sizes of shear walls
Rebar of Fe 415 has chosen to satisfy the ductility requirement of IS13920 of clause – 5.3, which states that steel grade of Fe 415 or less only should be used, However, high strength deformed steel bars, produced by the thermo-mechanical treatment process, of grades Fe 500 and Fe 550, having elongation more than 14.5% and confirming to other requirements of IS 1786: 1985 may also be used for the reinforcement. As Fe 500 and Fe 550 fail the ductility criteria of 14.5%, it is advantageous to use Fe 415.

3 Selection of Parameters for the validation

3.1 Parameters

This thesis is a comparative study between various building heights. Hence, based on the above criteria and considering the local general practice, three types of parameters are selected:

Model heights, Model plan layout, and Soil Types (Hard, Medium and Soft)

3.1.1 Model Height Selection

The following heights are selected based on the above considerations:

1. 50-storey is 155.50 m high, given the storey heights as 3 m. This is chosen to study the effects of wind and seismic loads calculated according to Indian standards on a maximum given building elevation.
2. 55-storey is 170.50 m high. This is most common type of multi-storey within the urban environment. Many office and residential buildings are constructed around this height.
3. 60-storey is 185.50 m. This height is selected to establish a comparison and to find out the benefits (if any) of outriggers on such a short elevation.

3.1.2 Layout selection for models

This layout consists with four no. of core wall which extends up to terrace, in this layout for the first configuration at two levels outriggers systems will be provided, and for the second configuration 3 levels of outriggers will be provided and the behaviour of the buildings will be studied and briefed in report. This layout is actually chosen to compare the feasibility of outrigger system when the building is supported on different types of soil.

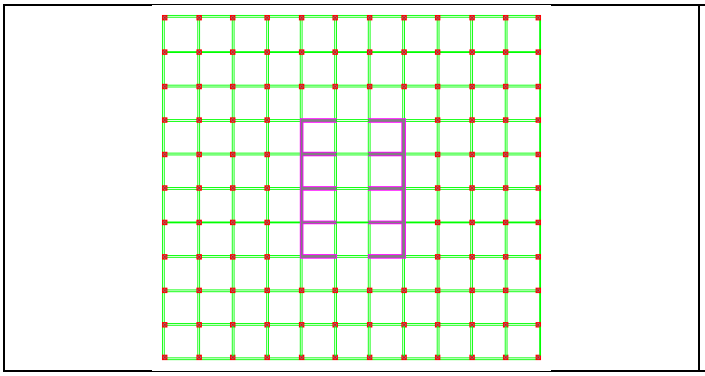

Fig. 3 Typical floor Plan

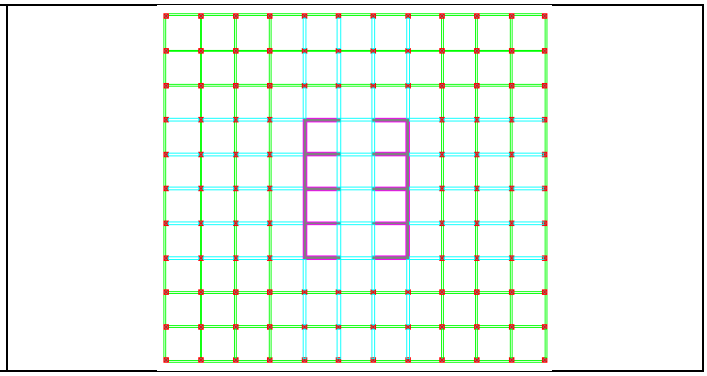

Fig. 4 Outrigger level Plan

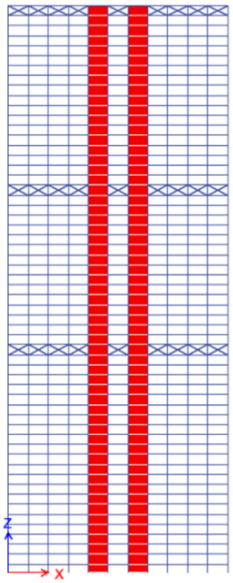

Fig. 5.1 Outrigger Elevation

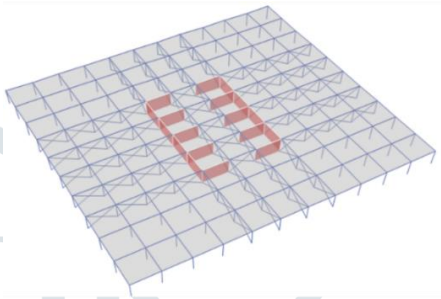

Fig. 5.2 Outrigger 3D

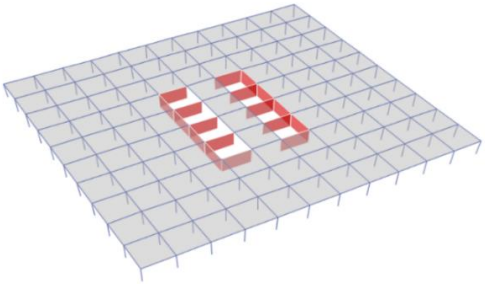

Fig. 5.3 3D View Terrace

3.1.3 Soil Types

The aim of this thesis is to study the behaviour of tall RC Buildings with outrigger systems supported on different types of soil mentioned in IS Standards. All structures considered have been modelled for all three types of soil types and the report and comparison of all the models supported on different type of soils have been presented.

Table 3 Model title with model arrangement

Sl. No.	Model Title	Model arrangements
50 STOREY		
1	G+50-SOIL TYPE I-CONVENTIONAL	Without outrigger on soil type I
2	G+50-SOIL TYPE I-OUTRIGGER	Outrigger at 0.4H,0.7H &1H on soil type I
3	G+50-II-CON.	Without outrigger on soil type II
4	G+50-II-OUT.	Outrigger at 0.4H, 0.7H & 1H on soil type II
5	G+50-III-CON.	Without outrigger on soil type III
6	G+50-III-OUT.	Outrigger at 0.4H, 0.7H & 1H on soil type III
55 STOREY		
7	G+55-I-CON.	Without outrigger on soil type I
8	G+55-I-OUT.	Outrigger at 0.4H, 0.7H & 1H on soil type I
9	G+55-II-CON.	Without outrigger on soil type II
10	G+55-II-OUT.	Outrigger at 0.4H, 0.7H & 1H on soil type II
11	G+55-III-CON.	Without outrigger on soil type III
12	G+55-III-OUT.	Outrigger at 0.4H, 0.7H & 1H on soil type III
60 STOREY		
13	G+60-I-CON.	Without outrigger on soil type I

14	G+60-I-OUT.	Outrigger at 0.4H, 0.7H & 1H on soil type I
15	G+60-II-CON.	Without outrigger on soil type II
16	G+60-II-OUT.	Outrigger at 0.4H, 0.7H & 1H on soil type II
17	G+60-III-CON.	Without outrigger on soil type III
18	G+60-III-OUT.	Outrigger at 0.4H, 0.7H & 1H on soil type III

IV. RESULTS AND DISCUSSION

4.1 Base Shear& Base moment

Base shear is the maximum when lateral force generated at the base of structure.

Table 4.1 Base Shear (FX) and Base Moment (MY) (kN-m) in X-Direction

Load Case	FX	MY	FX	MY	FX	MY
	G+50-I-CON		G+50-II-CON		G+50-III-CON	
EQ X	34467.5	4619703.0	46875.8	6282796.0	57560.7	7714903.0
GUST X	31153.6	2997135.0	31153.6	2997135.0	31153.6	2997135.0
TIME HISTORY X	22889.5	1703162.0	30061.0	1887713.0	30274.1	2657020.0
Wind X	21491.8	2100384.0	21491.8	2100384.0	21491.8	2100384.0
	G+50-I-OUT		G+50-II-OUT		G+50-III-OUT	
EQ X	34210.7	4296162.0	46526.6	5842781.0	57117.4	7172334.0
GUST X	31153.6	2816457.0	31153.6	2816457.0	31153.6	2816406.0
TIME HISTORY X	30820.0	2320019.0	40715.7	2995729.0	37370.1	3064399.0
Wind X	21491.8	1974013.0	21491.8	1974013.0	21491.8	1973978.0

Table 4.2 Base Shear (FY) and Base Moment (MX) (kN-m) in Y-Direction

Load Case	FY	MX	FY	MX	FY	MX
	G+50-I-CON		G+50-II-CON		G+50-III-CON	
EQ Y	34467.5	4207671.0	46875.8	5722432.0	57560.7	7026810.0
GUST Y	34268.9	2999704.0	34268.9	2999704.0	34268.9	2999704.0
TIME HISTORY Y	34558.8	2790444.0	45456.4	4157409.0	62967.8	4520881.0
Wind Y	23641.0	2101979.0	23641.0	2101979.0	23641.0	2101979.0
	G+50-I-OUT		G+50-II-OUT		G+50-III-OUT	
EQ Y	34210.7	4122729.0	46526.6	5606911.0	57117.4	6883076.0
GUST Y	34268.9	2961084.0	34268.9	2961084.0	34268.9	2961153.0
TIME HISTORY Y	57136.0	2762150.0	62643.9	4582462.0	91219.6	5414568.0
Wind Y	23641.0	2075003.0	23641.0	2075003.0	23641.0	2075052.0
	G+55-I-CON		G+55-II-CON		G+55-III-CON	
EQ Y	35280.1	4761849.0	47980.9	6476114.0	58917.8	7952287.0
GUST Y	39455.6	3826361.0	39455.6	3826361.0	39455.6	3826361.0
TIME HISTORY Y	35512.3	2754944.0	51828.8	4515414.0	48021.0	4048689.0
Wind Y	26366.3	2587813.0	26366.3	2587813.0	26366.3	2587813.0
	G+55-I-OUT		G+55-II-OUT		G+55-III-OUT	
EQ Y	35040.4	4653407.0	47654.9	6328634.0	58515.3	7770852.0
GUST Y	39455.6	3766696.0	39455.6	3766696.0	39455.6	3766698.0
TIME HISTORY Y	46845.4	3307251.0	49046.6	4985498.0	73357.5	5948808.0
Wind Y	26366.3	2547608.0	26366.3	2547608.0	26366.3	2547609.0
	G+60-I-CON		G+60-II-CON		G+60-III-CON	

EQ Y	36029.7	5340959.0	49000.4	7263705.0	60169.6	8919402.0
GUST Y	44997.7	4801692.0	44997.7	4801692.0	44997.7	4801692.0
TIME HISTORY Y	43726.1	3274301.0	56367.2	4809487.0	42671.9	4501758.0
Wind Y	29132.0	3135448.0	29132.0	3135448.0	29132.0	3135448.0
	G+60-I-OUT		G+60-II-OUT		G+60-III-OUT	
EQ Y	35766.5	5201228.0	48642.5	7073670.0	59730.1	8686051.0
GUST Y	44997.8	4714343.0	44997.8	4714343.0	44997.8	4714343.0
TIME HISTORY Y	40010.8	3667287.0	60491.1	5357021.0	67462.9	5596786.0
Wind Y	29132.0	3078650.0	29132.0	3078650.0	29132.0	3078650.0

5. Conclusion

The present study investigated the behaviour of tall reinforced concrete (RC) buildings equipped with an outrigger system under earthquake and wind loading. Based on the analytical results, the following conclusions have been drawn:

1. The incorporation of an outrigger system in tall RC buildings significantly enhances the overall structural stiffness and improves their performance under seismic and wind loading.
2. A reduction of more than 40% in lateral displacement has been observed after incorporating outriggers at different locations, i.e., 0.4H, 0.7H, and 1.0H, where H represents the total height of the structure.
3. The incorporation of outrigger systems results in an increase in the base shear and base moment, indicating improved lateral load resistance and a more effective transfer of forces through the structural system.
4. It has been observed that the maximum soil reaction develops in Soil Type III (soft soil) for all three building configurations, namely G+50, G+55, and G+60, indicating the significant influence of soil conditions on the structural response.

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