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ANALYSIS AND DESIGN OF TRANSFER STRUCTURES USING RESPONSE SPECTRUM ANALYSIS

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ABSTRACT:

In view of India's development trend of green building and building industrialization, based on the Architectural requirements may result to, development high-performance reinforced-concrete composite structural systems with adequate durability and safety of the structure by introduce the Transfer Structure (TS). A transfer structure (TS) is a structure that transfers the load path of the gravity loads(lateral loads), shifting the line of thrust indirectly to a different vertical alignment. TSs are introduced in high-rise buildings that feature discontinuities in some columns or walls and where a direct load path to the foundations is not possible.

They represent major elements of the structure and their impact on building cost and construction time can be substantial. In addition, the design of transfer structures is often outside the scope of normal code guidance and may require a degree of interpretation and engineering judgement. The transfer structure elements can be broken down into two main types: TRANSFER SLABS, TRANSFER PLATES. This study investigates the seismic performance of the high-rise transfer structure buildings with transfer slab and transfer plate provided in two different building models, which further divided into two conditions in which the height of the building and the height of transfer floor itself is taken as variable. Different high-rise buildings with storey conditions as G+4+transfer floor+20; G+5+transfer floor+25; G+6+transfer floor+30 is modelled, analysed, designed and finally subjected to analysis using linear response spectrum analysis using computer program ETABS 19. various response factors such base shear, storey shear, storey drift, storey moment, roof displacement, is determined.

I. INTRODUCTION

CONTEXT

Functional, aesthetic, or planning needs predicate changes and discontinuities in the vertical load- bearing system of a building. These demands are often outside the boundaries of normal commercial development and create special and interesting engineering problems that are usually solved with some form of transfer structure.

A transfer structure is a structure that alters the load path of the gravity loads, shifting the line of thrust laterally to a different vertical alignment. Transfer structures are introduced in buildings that feature discontinuities in some columns or walls and where a direct load path to the foundations is not possible. They create alternative paths and redistribute gravity and eventually lateral loads. These structures typically receive loadings from large areas of the building and therefore are required to accommodate very large forces, meaning that they constitute major elements of the structure. Thus, their effect on building cost and construction time can be considerable.

Thus, the design of buildings with such requirements is heavily dependent on the engineering and the ability of the designer to develop creative solutions that often involve transfer structures. Their popularity derives largely from the architectural flexibility they offer. The transfer system designed for a given building layout is ultimately the result of a compromise between economic, functional, engineering, and architectural requirements.

SCOPE OF THE THESIS

It is possible to differentiate global from local transfer structures. Local transfers are very common in any type of building and are required whenever there is a minor discontinuity such as an adjustment in column locations. Therefore, a local transfer structure is not a major element of the building. On the other hand, what is hereafter referred to as a global transfer structure is one that redirects load from a large portion of the building and, for this reason, is instantly perceived as a defining feature of the structure. This thesis will focus more on global transfer structures as these are more demanding in terms of design and construction. Notwithstanding, all principles also apply to local transfers, as they are the same as the global ones, but at a lower scale.

TRANSFER STRUCTURES

Need for transfer structures

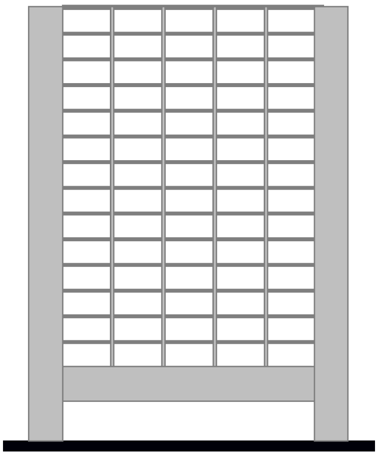
The use of transfer structures in buildings is not a modern trend. The fact that some buildings have always incorporated more than one functionality implies that the demand for transfer structures existed long before the modern construction era. For example, in Lisbon, several buildings constructed in the 18th century incorporated a form of transfer structure. The residential layout of the upper floors was composed of masonry resistant walls that had to be discontinued at the ground level to accommodate shopping areas. It was common to introduce a grid of steel beams below the wall alignments, which in turn was supported by a few columns on the ground floor.

Position of the transfer structure in elevation

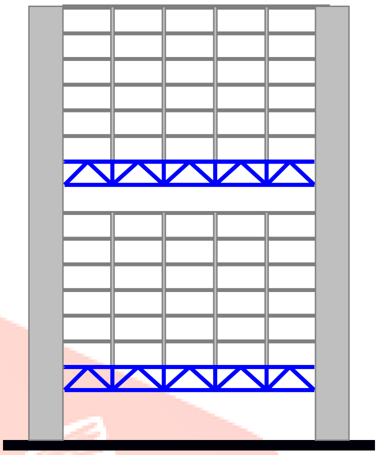
The position of the transfer structure in a building’s elevation may be influenced by various factors such as architectural constraints, the location of the mechanical plants, and construction speed and economy. In terms of structural efficiency of the transfer structure, it is equal to place it at the bottom or at the top of the building. The only difference is that, in the first case, the building has columns, whereas, in the latter, the floors are suspended by hangers. It is important to clarify that these hangers are not part of the transfer structure since they only transmit load in the vertical direction.

Single-floor vs multitier systems

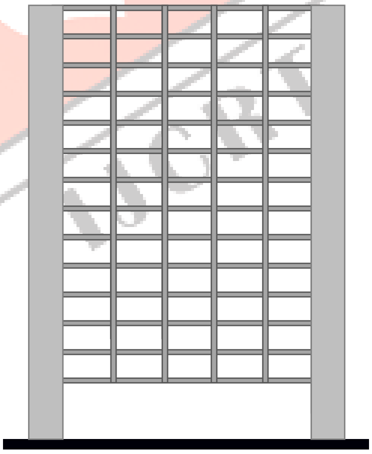
The choice between a single-storey transfer structure and a multitier transfer system also depends on factors usually unrelated with structural efficiency. The position and number of the mechanical plants, the construction method associated with each alternative and even architectural preferences are often important issues that the engineer must take into account when conceiving the transfer system. For example, in the case of a multitier transfer structure, benefits may arise from the simultaneous construction on more than one floor, as each vertical zone (that is, a stack of floors supported on each transfer level) is independent of the others.



(a) Single-storey transfer structure



(b) Multi-tier transfer structure



(c) Structural frame transfer system

Motivation and Objectives

Nowadays, some form of discontinuity in the load-bearing system is required in almost every high- rise building. There are some kinds of transfer structures commonly employed (like transfer girders or deep beams), but there are also other systems that are not so well-known such as arch transfer structures. There is a lack of in-depth research on all the existing transfer structures, as well as a study on other alternatives. This, therefore, is one of the main objectives of the thesis, which will culminate in the development of a rational typology of transfer structures with the aim of providing a complete and accurate overview of all the possibilities.

Furthermore, despite the extensive recent use of transfer structures in buildings, their design is often outside the scope of normal code guidance and may require a degree of interpretation and engineering judgement. Although building codes rarely address the design of these structures explicitly, it is generally accepted that their design should follow more severe criteria than ordinary building structures. The seismic performance of buildings with global transfer structures remains subject to research, especially since well-defined design procedures and code provisions are often in paucity. Therefore, the aim of this document is to describe the types and features of transfer structures and provide recommendations and guidance on their design and construction.

II. LITERATURE REVIEW

LITERATURE SURVEY

National Bank House - 1978 (Melbourne, Australia)

Although the transfer girder is most commonly used to deal with local discontinuities in columns, it is also employed in high-rise construction to undertake major load transfers. The National Bank House (Figure 2.2(a)) is a major office development of 45 levels in the centre of Melbourne. The structural system is composed of the central core and four corner columns as supports. Linking together the corner columns along the sides of the building at levels 1, 13 and 25 and spanning 43 m, there are 5.5 m deep prestressed concrete transfer girders (Figure 2.2(b)). These beams coincide with the levels of the plant rooms and support the bank of floors above them. At the lower transfer level, the shortening movements of the beams caused excessively high moments in the columns which required that those beams were seated on specially designed spheroidal bearings that allow rotations and movements in all directions.

Standard Bank - 1970 (Johannesburg, South Africa)

The Standard Bank Building in Johannesburg is a 35-storey skyscraper that uses a multitier transfer system to create a distinctive elevation with the maximum clear space at the plaza level (Figure 2.4(a)). The transfer system is composed of three levels of transfer girders cantilevered from the central core that suspend the stack of 10 storeys beneath. design of mass concrete.

III. METHODOLOGY

PROCEDURES FOR THE EARTHQUAKE ANALYSIS OF THE STRUCTURES

The performance criteria adopted for the seismic design of the transfer structure was that the structure must remain elastic under the IS 1893: Part-1: 2016, in accordance with Section 3.4.2.2. Regarding lateral loading, the conceptual design of the building is appropriate as the transferred columns are completely secondary. Additionally, the transfer structure has the beneficial effect of creating a frame behavior together with the lower portion of the core walls. It is not the purpose of this study to address the overall behavior of the building under the seismic action but rather to design the transfer structure itself. Therefore, instead of performing a non-linear dynamic analysis to effectively assess the response of the building and TS under the seismic event, a response spectrum analysis with a conservative behavior factor of 2.0 was carried out.

The effects of the vertical component of the seismic action were taken into account by following the provisions stated. Hence, the structure is not very sensitive to vertical ground motion. Nevertheless, a simulation of the building under the vertical component of the design earthquake (IS 1893: Part-1: 2016) was performed to ensure that the structure complies with the code requirements. As expected, this action is not important as the magnitude of the forces induced in the transfer structure is even lower than for the horizontal component. A unitary behavior factor was used in the response spectrum analysis for the vertical earthquake.

It was concluded that the design of the transfer structure is determined by gravity loads rather than by seismic loading. Moreover, the lateral-load resisting system and the transfer system itself are extremely stiff, whereby the imposed seismic deformations do not impair the load-carrying capacity of the transfer structure.

- Linear Static Procedure
- Linear dynamic Procedure
- Response Spectrum method
- Time history method
- Nonlinear Static Procedure (Pushover analysis)
- Nonlinear dynamic procedure

ANALYSIS

For the analysis and design purpose, well-known computer software ETABS-19 shall be used for carrying out Static Analysis and dynamic analysis using IS 1893-2016. Building shall be modeled as space framed structures.

Member forces corresponding to all load combinations as indicated in section 4.5 of this report are obtained through ETABS-19 which is used for final design. Design of most of the beams and columns are an output from ETABS-19.

The salient parameters relating to Seismic Analysis used in the design will be:

i) Zone	:	II
ii) Importance Factor I	:	1.6
iii) Soil type (HARDSOIL)	:	I
iv) Seismic Zone Factor α_0	:	0.16
v) Response reduction factor (R)	:	3.0

METHODOLOGY

The design wind velocity (Vz) is given by

Vz = Vb. K1. K2. K3

The design wind pressure (Pa) is given by

Pz = 0.6Vz2

Where Vb = basic wind speed as per IS 875: PART -3, Vz is design wind pressure at height z in m/s, k1 is the probability factor given in IS 875 part 3 table 1 , k2 is the terrain roughness and height factor given in table 2, k3 is topographical factor and k4 is cyclonic factor.

Load combination:

In the limit state design of reinforced and prestressed concrete structures, the following load combinations shall be accounted for as per IS1893 (part1):2016.

All structural designs are carried out by Limit State method of design. For this purpose, the Load factor for various load combinations indicated in IS: 456-2000, IS-875 (Part 5) – 1987, IS: 1893-2016 and SP24 -1983 are as follows:

(1)**Service Load Combinations: [For Checking of Deflection & Crack Width]**

101**. DL+LL**

111. DL + EQX

112. DL - EQX

113. DL + EQY

114. DL- EQY

115. DL + .8LL + .8EQX

116. DL + .8LL - .8EQX

117. DL + .8LL + .8EQY

118. DL + .8LL - .8EQY

119. DL + WLX

120. DL - WLX

121. DL + WLY

122. DL- WLY

123. DL + .8LL + .8WLX

124. DL + .8LL - .8WLX

125. DL + .8LL + .8WLY

126. DL + .8LL - .8WLY

(2) **Static Analysis [For Design]**

200. 1.5 (DL+LL)

201. 1.5 DL + 1.5 EQX

202. 1.5 DL - 1.5 EQX

203. 1.5 DL + 1.5 EQY

204. 1.5 DL - 1.5 EQY

205. 0.9 DL + 1.5 EQX

206. 0.9 DL - 1.5 EQX

207. 0.9 DL + 1.5 EQY

208. 0.9 DL - 1.5 EQY

209. 1.2 DL + 1.2 LL + 1.2 EQX

210. 1.2 DL + 1.2 LL - 1.2 EQX

211. 1.2 DL + 1.2 LL + 1.2 EQY

212. 1.2 DL + 1.2 LL - 1.2 EQY

213. 1.5 DL + 1.5 WLX

214. 1.5 DL - 1.5 WLX

215. 1.5 DL + 1.5 WLY

216. 1.5 DL - 1.5 WLY

217. 0.9 DL + 1.5 WLX

218. 0.9 DL - 1.5 WLX

219. 0.9 DL + 1.5 WLY

220. 0.9 DL - 1.5 WLY

221. 1.2 DL + 1.2 LL + 1.2 WLX

222. 1.2 DL + 1.2 LL - 1.2 WLX

223. 1.2 DL + 1.2 LL + 1.2 WLY

224. 1.2 DL + 1.2 LL - 1.2 WLY

(3) **Response Spectrum Analysis**

301. 1.5 DL + 1.5 SPECX*

302. 1.5 DL + 1.5 SPECY*

303. 0.9 DL + 1.5 SPECX*

304. 0.9 DL + 1.5 SPECY*

305. 1.2 DL + 1.2 LL + 1.2 SPECX*

306. 1.2 DL + 1.2 LL + 1.2 SPECY*

MATERIALS PROPERTIES FOR REGULAR AND IRREGULAR CONFIGURATION.

General

a) Material used was M40 Grade Concrete. Analysis Property Data

b) Yield stress fy = 500 N/mm^2

c) Compressive Cube Strength of Concrete = 40 N/mm^2

d) Poisson's ratio = 0.2

e) Analysis was done using ETABS Software V19

Building Details

a) Type of frame: Special RC moment resisting frame fixed at the base

b) Seismic zone: II

c) Number of storey: G+40

d) Floor height: 3.0 m

e) Depth of Slab: 150 mm

f) Size of beam: (600 × 600) mm, (230 x 450) mm

g) Size of column: (4200 × 450) mm, (1500 x 1500) mm

h) Spacing between frames : (i) 6 m in X & Y direction (General), (ii) 24 m × 15 m in X & Y direction

i) Live load on floor: 2 kN/m^2

j) Floor finish: 1.5 kN/m^2

k) Wall load: 12 kN/m

l) Materials: M 40 concrete, Fe 500 steel Material

m) Thickness of wall: 230 mm

n) Thickness of shear wall: 200 mm

o) Density of concrete: 40 kN/m^3

p) Density of masonry wall : 12 kN/m^3

q) Type of soil: Medium

r) Response spectra: As per IS 1893(Part-1):2016

s) Damping of structure: 5 percent

IV. RESULTS AND DISCUSSIONS

A structural analysis program ETABS 2019 software was used for performance analysis of high rise building with transfer floor system. For this different building models were analyzed using response spectrum analysis. Different models of 30,35,40 storey building with transfer floor provided at different floor levels such as 4th floor, 5th floor, 6th floor levels were analyzed. And vertical position of transfer floor with respect to building height was investigated. For this seismic response graphs of the building such as Base Shear, storey shear, storey moment, Storey displacement and storey drift were numerically evaluated.

Table shows the plot of the base shear for the three different cases of stiffness. The comparison is made for the load cases (response spectrum) with scaling. It is evident from the figure that the base shear resulting from the non-linear response, the base shear resulting from the response spectrum using reduced stiffness actually increases the base shear values in these two analyses by this marginal ratio. Generally, base shear resulting from the non-linear time history is marginally less than that resulting from the response spectrum analysis.

The below figures shows that storey shear, storey drift, storey displacement and storey moment distribution in x and y direction for 30,35,40 storey buildings model with transfer slab provided at different floor levels resulting from linear response spectrum analysis. And from the figure it is clear that, storey shear, storey drift, storey displacement and storey moment is more for transfer slab provided at higher level. Also, below figures shows the displacement of building along the storey height. And it is concluded that every building has flexural mode up to a transfer floor level and then displacement goes on increase above the transfer level. Provision of shear wall results in a huge decrease in base shear and roof displacement both in symmetrical building and un-symmetrical building. It is observed that in the regular frame, there is no torsional effect in the frame because of symmetry. In an irregular frame, there is torsional rotation in the structure. Shear walls in buildings must be symmetrically located in plan to reduce ill-effects of twist in buildings. They should be placed symmetrically along one or both directions in plan. Shear walls are more effective when located along exterior perimeter of the building – such a layout increases resistance of the building to twisting. A shear wall elevator core can provide a major part of the bending and torsional resistance in a building structure. A plot of the story-moment distribution over the building height is shown in Figures. The figure reveals that the story-moment distribution has a counter flection point at the vicinity of the transfer floor level. Reduction of the vertical element's stiffness has an effect of reducing the values of story moment by about 10%. Transfer slab stiffness almost has no significant effect on the values of the story moment distribution. The building is behaving like a cantilever where the value at the top floor is almost the same regardless adopting reduced or full stiffness for the structural elements. On the other hand, reduction the stiffness of all horizontal and vertical elements decreases the story moment by about 30% below the transfer floor level.

Base Shear:

Base shear is the maximum expected lateral force that will occur due to seismic ground acceleration at the base of the structure. The base shear, or earthquake force, is given by the symbol "V_B". The weight of the building is given as the symbol "W". Base shear for considered structures for different load cases or load conditions are shown below in graph data.

V_b = Ah x W

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

For the response spectrum function the scale factor is given by,

Scale Factor = I.G/R

Where, I = Importance factor

G= gravity force`

R= Response modification factor.

Re-scaling,

As per IS 1893:2016 – Cl. 7.7.3; when the base shear computed with response spectrum (VB) is less than base shear computed with equivalent static method ($\tilde{V}$B), than

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forces are to be scaled with the ratio of (ṼB/VB). For Modified dynamic analysis, scale factor SpecX and SpecY are to be modified

Table 7.1 Response Spectrum Base Reaction with Shear wall for G+30 Storey Building.

Response Spectrum Base Reaction with Shear wall						
Spec	FX	FY	FZ	M1	M2	M3
EQX	2602.99	0	0	0	25856.8	61092.6
EQY	0	2963.9	0	29442.4	0	59517.3

Table: Response Spectrum Base Reaction with Shear wall for G+35 Storey Building

Response Spectrum Base Reaction with Shear wall						
Spec	FX	FY	FZ	M1	M2	M3
EQX	2721.3	0	0	0	26925.4	61092.6
EQY	0	3106.5	0	30736.8	0	62455.1

Table: Response Spectrum Base Reaction with Shear wall for G+40 Storey Building.

Response Spectrum Base Reaction with Shear wall						
Spec	FX	FY	FZ	M1	M2	M3
EQX	3053.8	0	0	0	30119.3	71679.6
EQY	0	3198.9	0	31551	0	64256.1

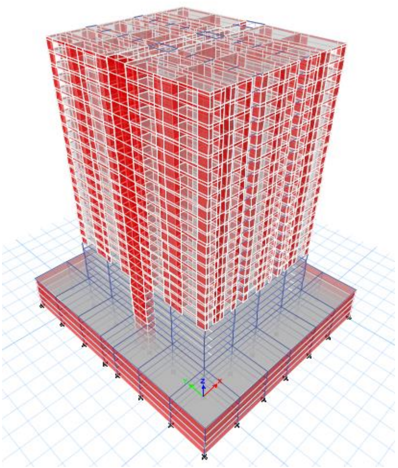


Fig: G+4,TS & 25 Stories

G+30 Storey Building

$$= \frac{I.G}{R} \times 0.85 \times \frac{\text{Static base shear}}{\text{Response spectrum base shear}}$$

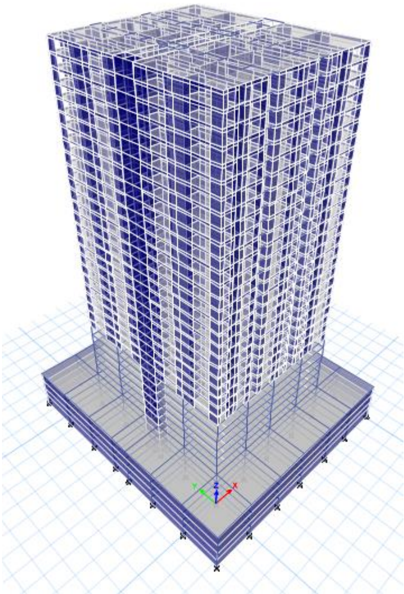


Fig: G+5, TS & 30 Stories

G+35 Storey Building

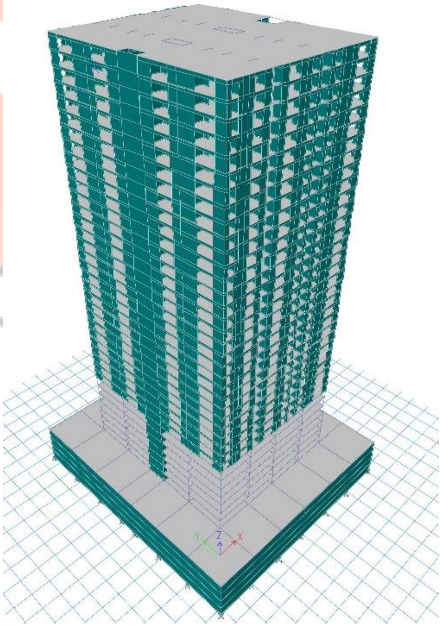


Fig: G+6,TS & 35 Stories

G+40 Storey Building

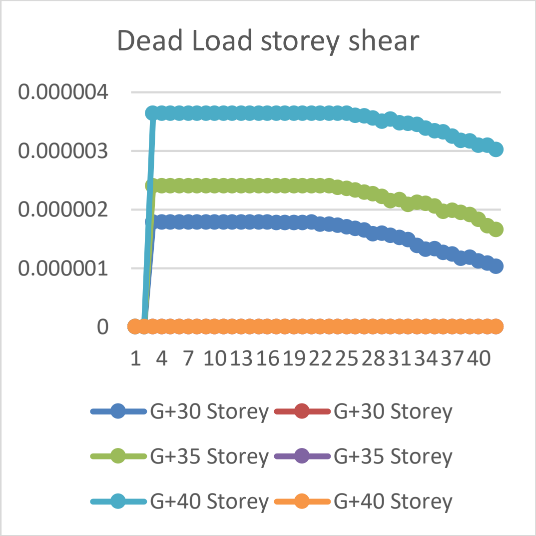
Storey Shear

It will calculate all the lateral loads at each floor of the building. Building is designed as ductile shear wall with Ordinary moment resisting frame. As per IS 1893:2016 (Part 1), response reduction factor ‘R’ is taken as 4.5. Time period is considered as per IS 1893:2016, considering infill time period formula:

$T_a = 0.09 \times h / \sqrt{d}$

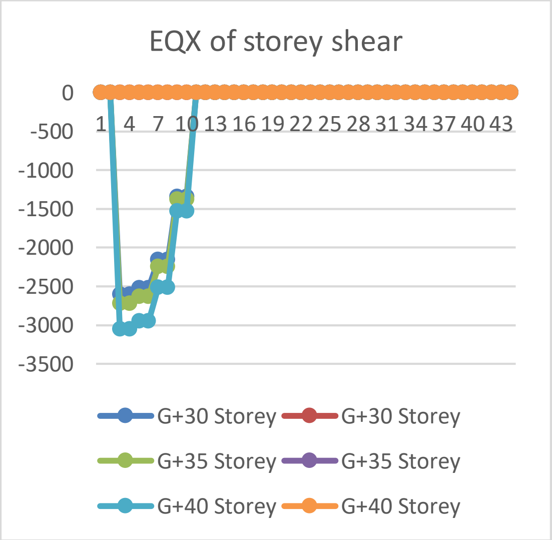
Time period for x and y direction is found as 1.108 and 1.25 sec, respectively.

Graph 1: Dead Load of Storey Shear with Shear wall for different storey building.



For the worst Dead load combination storey shear is plotted on y-axis against at each storey level. From the Graph.1, it is observed that maximum storey shear in storey one is 0.000003635 kN and maximum storey shear in storey 33 is 0.00000111 kN for G+40 Storey Building and observe that storey shear will differ at Y-direction up to the top of the building from base storey and no changes near(below & above) the transfer slab.

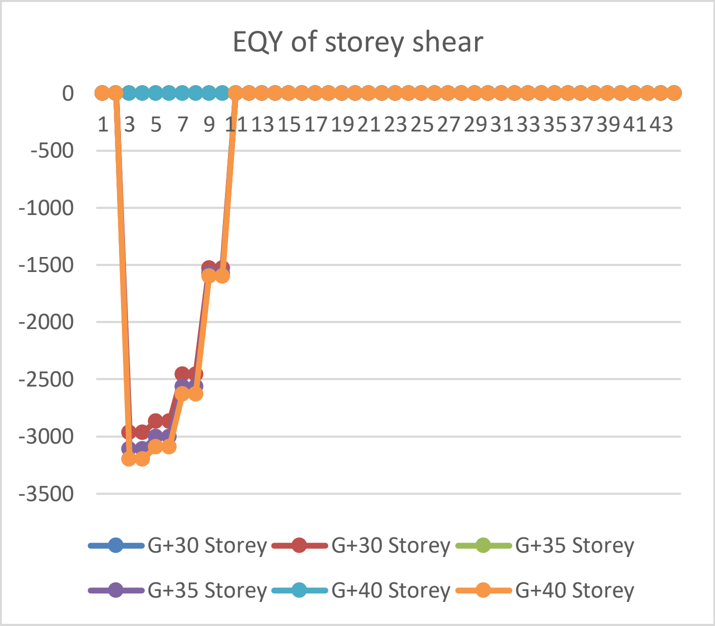
Graph 2: EQX Load of Storey Shear with Shear wall for different storey building.



For the worst EQX load combination storey shear is plotted on X-axis against at each storey level. From the Graph.2, it is observed that maximum storey shear in base is -3053.7985 kN and maximum storey shear in storey 4 is -1525.7919 kN for G+40 Storey Building and observe that storey shear will continue constantly at X-direction up to the top of the building from the transfer slab and changes due to lateral load(EQX) near(below) the transfer slab.

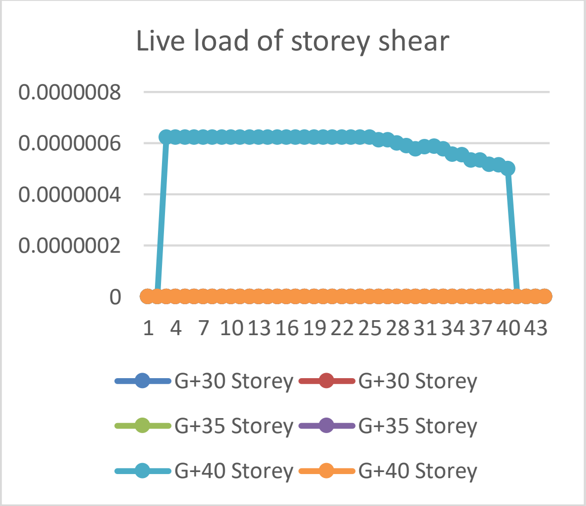
Graph 3: EQY Load of Storey Shear with Shear wall for different storey building.

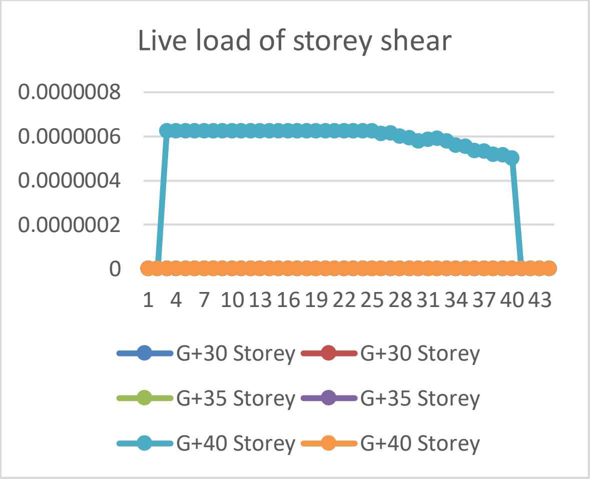
Shear with Shear wall for different storey building.



For the worst EQY load combination storey shear is plotted on X-axis against at each storey level. From the Graph.3, it is observed that maximum storey shear in base is -3198.9594 kN and maximum storey shear in storey 6 is -1598.3197 kN for G+40 Storey Building and observe that storey shear will continue constantly at Y-direction up to the top of the building from transfer slab and changes due to lateral load(EQX) near(below) the transfer slab.

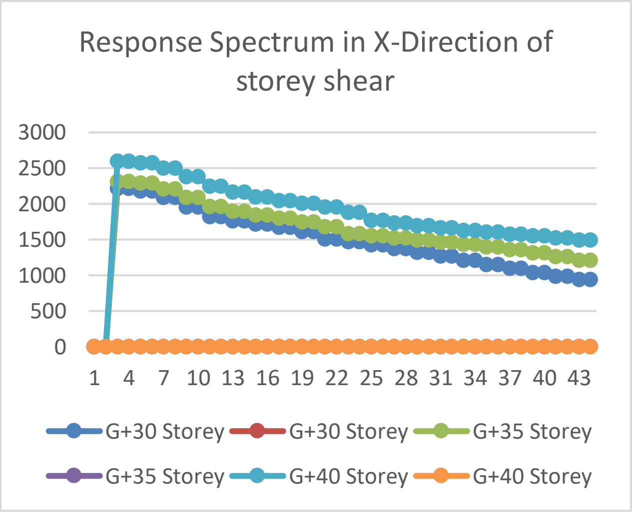
Graph 4: Live Load of Storey Shear with Shear wall for different storey building.





For the worst Live load combination storey shear is plotted on y-axis against at each storey level. From the Graph.4, it is observed that maximum storey shear in storey one is 0.0000006238 kN and maximum storey shear in storey 18 is 0.0000005009 kN for G+40 Storey Building and observe that storey shear will continue constantly at Y-direction up to the top of the building from base storey. It is very less and no changes near(below & above) the transfer slab.

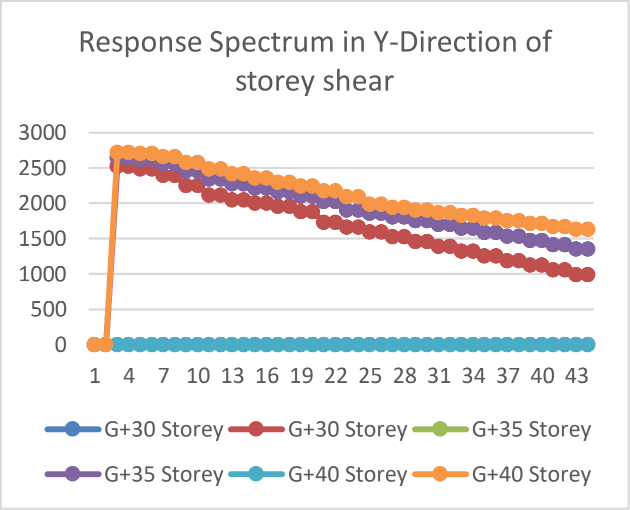
Graph 5: Response Spectrum in X-direction Load of Storey Shear with Shear wall for different storey building.



From the Graph.5, it is observed that maximum storey shear in storey one is 2595.729 kN and maximum storey shear in storey 40 is 139.445 kN for G+40 Storey Building and observe that storey shear will differ constantly at X-direction up to the top of the building from base storey and no changes near(below & above) the transfer slab.

From the Graph.5, it is observed that maximum storey shear in storey one is 0.5569 kN and maximum storey shear in storey 40 is 0.0346 kN for G+40 Storey Building and observe that storey shear will differ at X-direction up to the top of the building from base storey and no changes near(below & above) the transfer slab.

Graph 6: Response Spectrum in Y-direction Load of Storey Shear with Shear wall for different storey building.



For the worst Response Spectra load combination storey shear is plotted on X-axis against at each storey level. From the Graph.6, it is observed that maximum storey shear in storey one is 0.555 kN and maximum storey shear in storey 40 is 0.0254 kN for G+40 Storey Building and observe that storey shear will differ constantly at Y-direction up to the top of the building from base storey and no changes near(below & above) the transfer slab.

For the worst Response Spectra load combination storey shear is plotted on Y-axis against at each storey level. From the Graph.6, it is observed that maximum storey shear in storey one is 2719.1111 kN and maximum storey shear in storey 40 is 128.0031 kN for G+40 Storey Building and observe that storey shear will differ at Y-direction up to the top of the building from base storey and no changes near(below & above) the transfer slab.

DESIGN DETAILS

Design of slab

Lx=2.40 m	From Etab results,
Ly=4.37 m	Negative moment at interior support, Mu = 449 kN-m
LY/Lx =1.80 < 2 (Hence slab designed as two way)	Positive moment at center of span, Mu = 255 kN-m
Total load on slab = 9.35 kN/m^2	Maximum shear force at support section, Vu = 289 KN
Factored moment =10 Kn-m	= 0.33 %
Assuming depth of slab = 150 mm	
Design of the as over reinforced	

Slab cover =25 mm	Main reinforcement
Bend the alternative bars@ a distance of L/7 from the face of the wall = 2.40 / 7= 0.342 m	For -ve B.M,
Assuming dia 8mm 150 c/c (main reinforcement)	Mu = 0.87 fyAstd[1-Astfy/bdfck]
Distribution reinforcement	For +ve B.M,
Ast min as distribution reinforcement = 0.12% *b*D =0.12 %*1000*150 =180 mm2	$449x10^6$ =0.87x500xAstx600x[1-Astx500/600x600x40]
Spacing of 10 mm dia = (π *10^2 *100)/180 = 200 mm	Ast = 3360.63 mm^2
Provide 8 mm dia @ 150 mm c/c	Provide 6 bars of 25 mm dia and 2 bars of 20mm dia (Ast=3361mm2) @ top tension face near supports
Check for deflection:	Mu = 0.87 fyAstd[1-Astfy/bdfck]
Assuming span to depth ratio = L/d < 20 = 2.4/125 <20 =19.2<20,Hencesafe	$255x10^6$ = 0.87x500xAstx600x[1-Astx500/600x600x40]
DESIGN OF BEAM	Ast = 1528 mm^2
Data Grid beam no 1-A	Provide 4 bars of 20 mm dia and 2 bars of 16mm dia (1528 mm2) at bottom tension face at centre of span section.
Characteristic compressive strength of concrete = fck = 40 N/mm^2	Shear reinforcement
Characteristic strength of steel = fy = 500 N/mm^2	τ_v= vu/ b d = $289x10^3$/600x600
Adopt d = 400 mm D = 450 mm	= 0.68 N/mm2

b = 230 mm Length = L =7.6 m	
Pt = 100x Ast / b d = 100x3360 / 600x600	Longitudinal reinforcement = Pu =0.4 * fck *AC + 0.67 * fy * Asc
= 0.33 %	=0.4* fck *Ag + (0.67 *415 – 0.4 *20)*Asc
Refer table 19 (IS 456) read out,	
τ_c = 0.42 N/mm^2	$15898*10^3$ =0.4*40*4200*450 +(0.67*500-0.4*40)*Ast
Hence shear reinforcement is required. Vus = vu - b d =289 – (0.42x600x600)10^3 = 200.16 kN	Ast = 15120 mm^2
Use 10 mm dia two legged stirrups,	Provide # 20 bars of 32 mm diameter
Sv = (0.87fyAsv d) / Vus	Design of lateral ties
= (0.87x 500 x 289 x 600) / 200.16x1000	Tie diameter
Sv = 2550 mm Adopt 10 mm dia two legged stirrups @ 125 mm c/c	So , provide lateral reinforcement 10mm ties
Check for deflection	Tie spacing St
At centre of span: Pt = 100 Ast / b d = 100x3360 / 600x600	
From fig,4 of IS 456 , Kt = 1.2 , Kc =1 ,Kf =1	
(L/d) max = (L/d) basic x Kt x Kf	
=26 x 1.2 x 1	
= 31.2	
(L/d) actual = 7600/600 = 12.66	

L/d) actual < (L/d) max	
Hence deflection control is satisfied	
DESIGN OF COLUMNS	
Data,	
Characteristic compressive strength of concrete = fck = 40 N/mm2	
Characteristic strength of steel = fy = 500 N/mm^2	
Pu = 15898 KN (taken from Etabs)	
b = 450 mm	
D = 4200 mm	
Length = L = 3000 mm	

V. CONCLUSIONS

- Location of the transfer floor within the building height also controls the maximum drift location. this is the issue which will enable designers to take the suitable precautions to have a safe design from serviceability point of view.
- Roof drift for building with lower-level transfer floor is higher than that of building with transfer floor located at higher level. Storey drift is decreasing the height of structure in each model. This study also represents the end forces decrease if transfer beam is started from 4th,5th,6th floor levels of 30,35,45 storey buildings.
- A significant increase in the storey base shear is observed in the building with the lowest transfer system located at 10% of the total building height.
- The total base shear moment is increase as transfer floor lies at higher level.
- The displacement distribution shown in displacement graph reveals that every building has a flexural behavior mode up to its transfer floor level.
- From the results it is inferred that shear walls are more resistant to lateral loads in regular/Irregular structure.
- The moments in the columns got reduced when shear wall is introduced in the structure. The maximum storey displacement of the building is reduced by 50% when shear wall is provided.
- As per code, the actual drift is less than permissible drift. The parallel arrangement of shear wall in the center core and outer periphery is giving very good result in controlling drift in both the direction. The better performance for all the structures with soft soil because it has low storey drift
- Shear wall with openings and with varying thickness is still strong & stable enough to resist seismic loads. For safer design, the thickness of the shear wall should range between 150mm to 400mm.
- Provision of shear wall results in a huge decrease in base shear and roof displacement both in symmetrical building and un-symmetrical building.

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