Retrofitting of structure for seismic force using post tensioning of RC shear wall

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Abstract: In the seismic design of buildings, reinforced concrete structural walls, or shear walls, act as major earthquake resisting members. Structural walls provide an efficient bracing system and offer great potential for lateral load resistance. The properties of these seismic shear walls dominate the response of the buildings, and therefore, it is important to evaluate the seismic response of the walls appropriately.

In this present study, main focus is to determine the solution to strengthen the shear wall. General practice is to apply pre-stressing and post-tensioning while design and constructing new structure, These technologies can also effectively used for retrofitting of old structures.

The lift core wall acts as a shear wall in reinforced concrete (RC) building in many cases. Major shear force is contributed by lift core wall. It is not practical and easy solution to strengthen each and every joint as well as column and beam. If we focus on shear wall strengthening we can effectively provide retrofitting solution. In this project we model the existing structure which is to be checked for any deficiencies and failure due to edge and seismic force.

We analyze the structure with the help of software. We check the existing members. The main idea is to retrofit the shear wall which is main horizontal load resisting member. This report covers the technique of retrofitting of shear wall with the help of post tensioning cables connected to top steel girder, which is supported on shear wall. The cables are anchored at the bottom in the rock. By applying post tensioning in the cable, we indirectly apply axial force which in turn reduce the negative stress due to bending moment at the bottom. Under reinforced can be made safe by this technique as long as concrete compressive stress are within the limits specified by the codes.

Index Terms— post-tensioning, retrofitting, shear wall.

I. INTRODUCTION

The primary purpose of all kinds of structural systems used in the building type of structures is to support gravity loads. The most common loads resulting from the effect of gravity are dead load, live load. Besides these vertical loads, buildings are also subjected to lateral loads caused by wind, blasting or earthquake. Lateral loads can develop high stresses. Therefore, it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces.

Shear wall are one of the excellent means of providing earthquake resistance to multistoried reinforced concrete building. The structure is still damaged due to some or the other reason during earthquakes. To reduce the effect of earthquake reinforced concrete shear walls are used in the building.

Shear walls are used to improve seismic response of buildings. Structural design of buildings for seismic loading is primarily concerned with structural safety during major earthquakes. In tall buildings, it is very important to ensure adequate lateral stiffness to resist lateral load. The provision of shear wall in building to achieve rigidity has been found effective and economical way. Although reinforced concrete walls are used in buildings to dissipate seismic-induced energy, they are also vulnerable to seismic damage.

When buildings are tall, beam, column sizes are quite heavy and steel required is large. So there is lot of congestion at these joint and it is difficult to place and vibrate concrete at these place and displacement is quite heavy. When shear wall are situated in advantageous positions in the building, they can form an efficient lateral force resisting system. In this present paper one model for building with shear wall but having inadequate reinforcement. The effectiveness of post tensioning in resisting horizontal shear is analyzed.

II. OBJECTIVES AND SCOPE OF STUDY

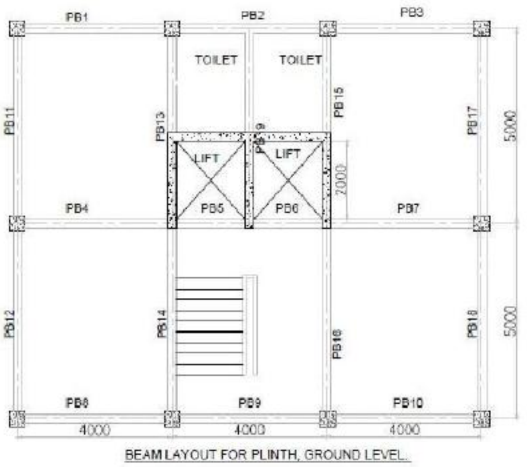
The primary objective of this study is to identify the damage in the structure especially columns and shear wall due to earthquake force. The cracks are developed during seismic force. Code has specified certain limits for crack width. Beyond that limit the structure has to be retrofitted.

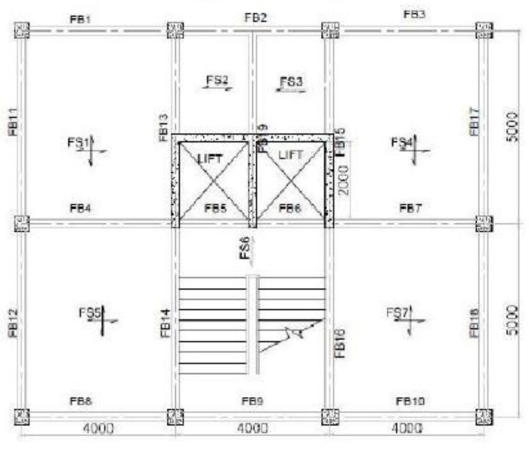
In this report we will first analyze the existing structure with the help of software STAAD to check the member forces. Then we will check the section capacities for these member forces. If section capacities are inadequate, then we have to strengthen it by certain means. Any concrete section has to resist axial force, bending moment, shear force and torsion. In case of compression member predominant forces are compression and bending moment, the cracks are developed in shear wall and columns due to bending moment. If these cracks are developed beyond certain limits it reduces the moment of inertia of section as well as section capacity of section.

We can increase the load carrying capacity of member by applying external axial force, which will effectively reduce the tensile stresses in the member. The application of external axial force through the post tensioned cables which are tied to the steel member which is supported on top of shear wall. The post tension cables are anchored to the footing, rock or firm ground at the bottom. By inducing tension in the cable we can apply necessary compression force in the shear wall which will stabilize the effect of bending moment caused due to seismic force.

Geotechnical reports are required of the site to check the firmness of ground. The base below shear wall should be strong enough to develop required anchorage force for post tensioning cables. The most challenging task is to find out the capacity of shear wall, since the shear wall has an arbitrary shape.

III. LAYOUT OF MODEL





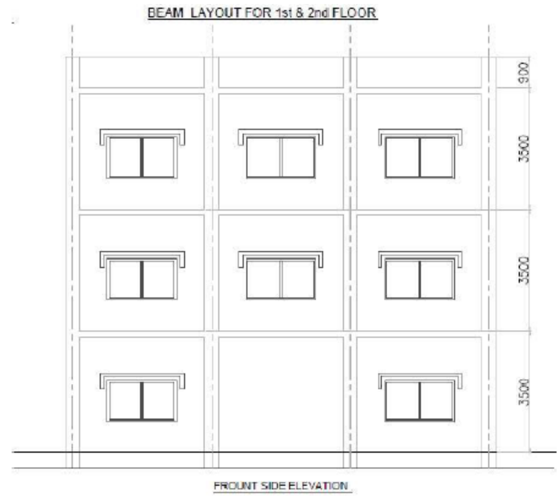


Fig. 1 Layout and elevation

IV. ANALYTICAL MODEL

Since all the previous systems have some advantages and disadvantages like availability of techniques and ease of application, effectiveness of system. The introduction of post tensioning with cables around the existing lift core RCC wall can be effective in resisting the Shear due to earthquake.

In the following article we would model reinforced concrete (RC) structure with lift core shear wall in STAAD and observe the performance of structure for seismic force when building is situated in Mumbai. It is observed that many of RC building in India have inadequate reinforcement in column as well as in shear wall. So in case of actual earthquake these systems will be incapable to sustain the seismic effects. Our main aim is to analysis the building for earthquake force. Identify the system behavior in seismic condition and apply the effective in terms of time and cost solution.

A. Project Description

The model structure consists of 1 ground plus 3 stories. Ground level will house offices and reception area. First and second floor will have offices. Third floor has dining space on major area. Two lifts and one staircase are provided for the building for accessibility.

B. Structural system

It is reinforced concrete (RC) frame structure with flat roof. Foundation system is isolated type foundations under columns and raft footing for lift core wall.

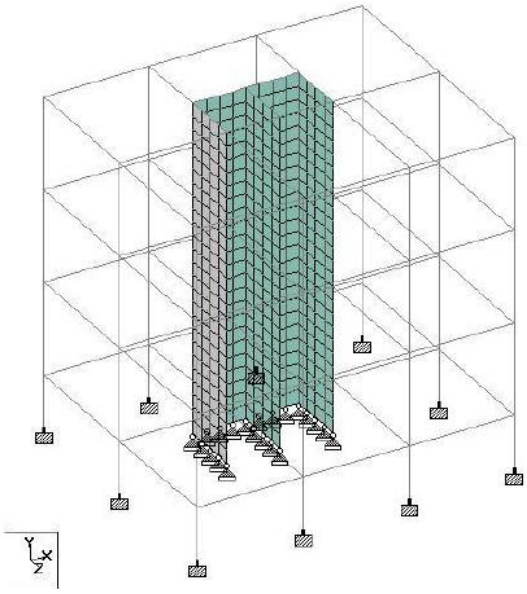


Fig. 2 STAAD Geometry

C. Analysis and Design of structure

The analysis will be based on stiffness matrix method and using the engineering software STAAD. The footing, slabs, water tanks will be made using spreadsheets developed in house and or manual calculations. The design of RC structures will be based on limit state method as per IS: 456-2000. All the structures will be idealized as 3D – frames, using beam element for Column& beams and Shell elements shear wall, as applicable.

The structures shall be analyzed for individual load cases and load combinations shall be performed (see table I-II). The performance of the structures in various states of Collapse and Serviceability will be checked accordingly. For sizing of foundation, the critical load combination for serviceability will be used.

Allowable increase in safe bearing capacity (SBC) will be considered in seismic or wind load combinations. In the design of foundation, column, beam and slab factored bending moment and Shear values will be considered.

Table I Basic load cases

Number	Name
1	SEISMIC LOAD IN X DIR
2	SEISMIC LOAD IN Z DIR
3	DEAD LOAD
4	LIVE LOAD
5	ROOF LIVE

Table II Load combinations as per IS875

Comb.	Combination L/C Name
6	1.5DL 1.5LL
7	1.2DL 1.2LL
8	1.2DL 1.2LL 1.2SLX
9	1.2DL 1.2LL 1.2SLZ
10	1.2DL 1.2LL 1.2(-VE SLX)
11	1.2DL 1.2LL 1.2(-VE SLZ)
12	1.5DL
13	1.5DL 1.5SLX
14	1.5DL 1.5SLZ
15	1.5DL 1.5(-VE SLX)
16	1.5DL 1.5(-VE SLZ)
17	0.9DL 1.5SLX
18	0.9DL 1.5SLZ
19	0.9DL 1.5(-VE SLX)
20	0.9DL 1.5(-VE SLZ)

Materials

1) Concrete

Minimum grade for structural concrete used M30.

2) Reinforcement

High strength deformed steel bar, produced by the thermo-mechanical treatment (TMT) process, of grades Fe 500(D) having elongation more than 16 percent and conforming to the requirements of IS 1786 : 2008 will be used for the reinforcement.

E. Shear wall strength check

Possible shear wall failure modes due to horizontal loads are Flexural

Horizontal shear Vertical shear

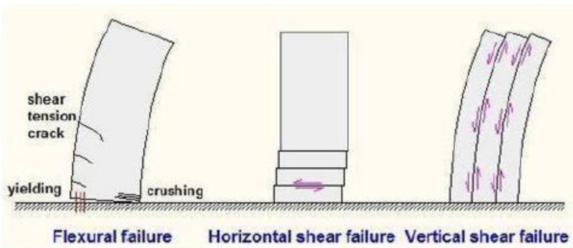


Fig. 3 Failure modes of the shear walls

Our structure in this project has insufficient reinforcement in column as well as shear wall, so shear wall in our model fails due to flexural failure.

Design of shear walls is a complex procedure, especially if the cross section of the shear wall is not regular in shape.

The first task is to find out the support reaction at the bottom of shear wall since the shear wall is modeled as plate element is STAAD, the element is divided in to finer mesh to achieve a more accurate results. The bottom of shear wall elements bottom node acts as support node.

The support reaction of shear wall can be obtained by summing up the reactions of all nodes at the bottom of wall. The overall reactions are calculated with the help of excel sheet for each basic load case as well as each load combination. The critical load is the combination which produces maximum bending moment with less axial load. Since concrete compressive stress in not utilized completely we can make use of this unutilized compressive strength of concrete, which in turn reduces the tensile stresses in reinforcement.

V. ANALYSIS

Linear strain distribution is adopted over the section confirming to the classical theory of bending as suggested by IS: 456 (2000). Based on the strains at each point, the value of stress can be computed. The stress corresponding to strain for concrete is considered as per IS: 456 (2000) (see Fig. 4a & 4b)

The reinforcement in shear wall reaches the limiting strain before completely reaching the compressive strength of concrete.

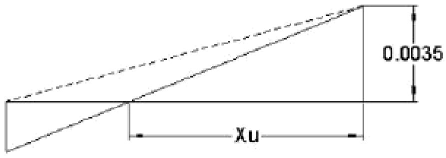


Fig. 4 (a) Strain diagram

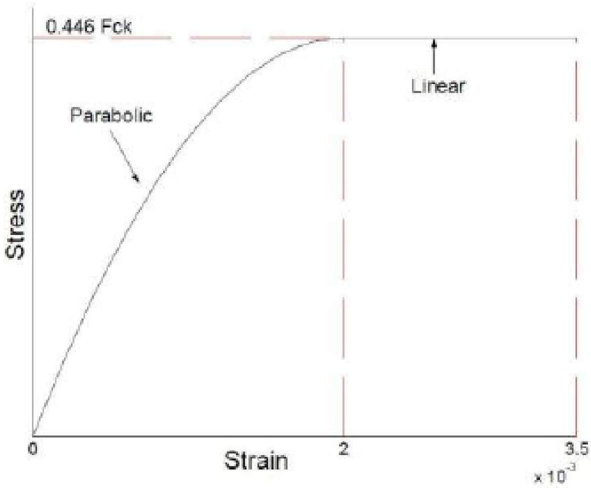


Fig. 4 (b) Concrete Stress Block

Since it is complicated to analysis this type of shear wall with arbitrary shape, Csicol software is used for finding out the capacity of shear wall.

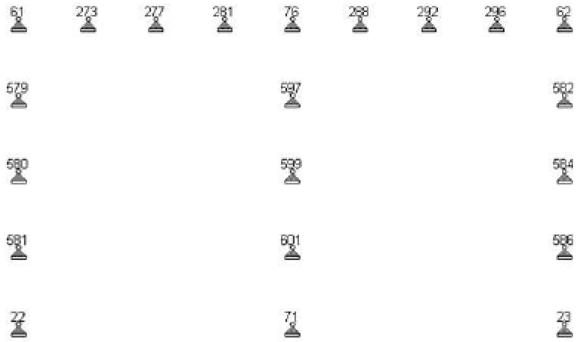


Fig. 5 Shear wall support Node numbers (STAAD).

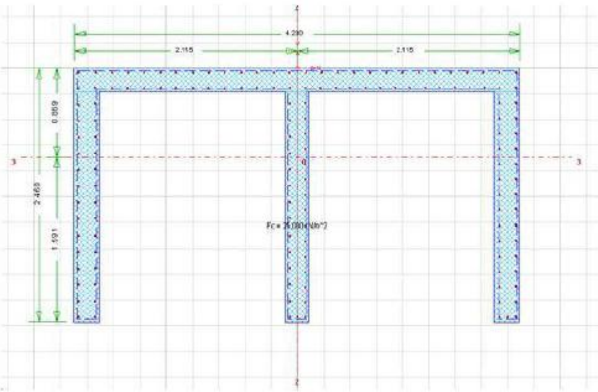


Fig. 6 Support Node numbers at the bottom of shear wall.

The support reaction computed from excel sheet are applied in Csicol software to get capacity, stress and strain behavior of shear wall under critical load combinations. The shear wall is failing under following load combination.

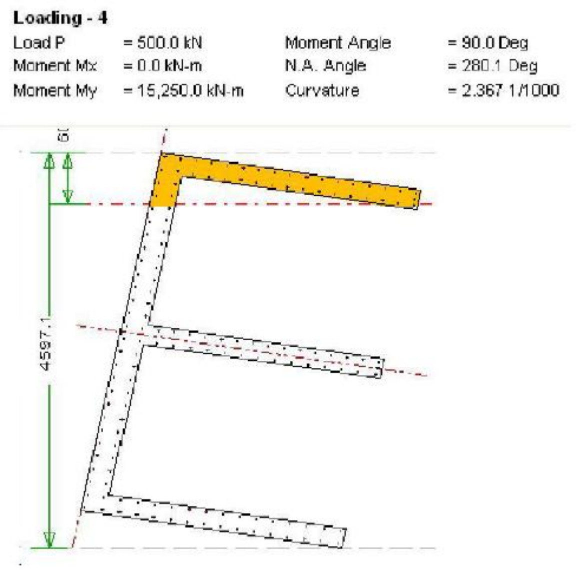


Fig.7 (a) Section under critical load combination

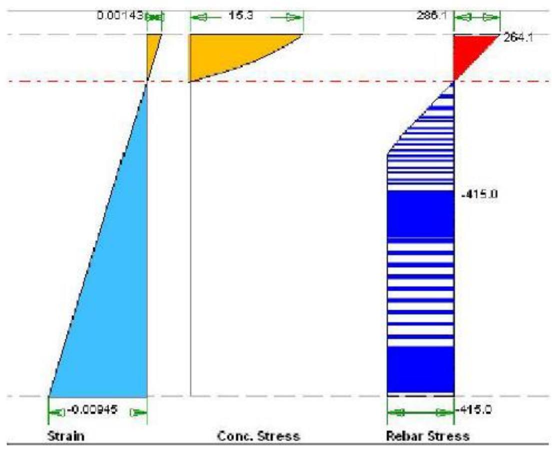


Fig.7 (b) Strain and stress diagram

We can see here that, reinforcement reaches its limiting stresses before concrete. Bending moment at the bottom of shear wall is predominant here. The Neutral axis shifts towards top due to predominant bending over axial force.

Table III

Sr. No	Load Comb	Load-Pu (kN)	Mux (kN-m)	Muy (kN-m)	Muxy (kN-m)	Mx-My Angle (Deg)
1	Combination1	400.0	558.0	3732.0	3773.5	81.5
2	Combination 2	400.0	0.0	5000.0	5000.0	90.0
3	combination 3	400.0	0.0	10000.0	10000.0	90.0
4	combination 4	500.0	0.0	15250.0	15250.0	90.0

Load Vector	Capacity Vector	Capacity Ratio	N/A Angle (deg)	N/A Depth (mm)	Capacity Method	Remarks
3773.5	12103.8	0.31	294.6	741.4	2	OK
5000.0	12470.1	0.40	280.0	510.6	2	OK
10000.0	12470.1	0.80	280.0	510.6	2	OK
15250.0	12653.8	1.21	280.1	518.8	2	<Not OK>

As we can see in table III, for load combination 4, the capacity ratio exceeds 1.0. Our main aim now is to apply some techniques by means to shift the capacity ratio below 1.0 value. The shear wall can be made safe at this condition is by applying external post tensioning force.

By applying external axial load, we can stabilize the excessive tension caused in reinforcement due to bending moment. The external post tensioning can be achieved by placing the steel section at the top of shear wall. The post tensioning cables will connect to top girder and bottom shear wall foundation. After application of post-tensioning force in combination 5 (see Fig 8a & 8b), we can see that the capacity becomes 0.99(see Table IV).

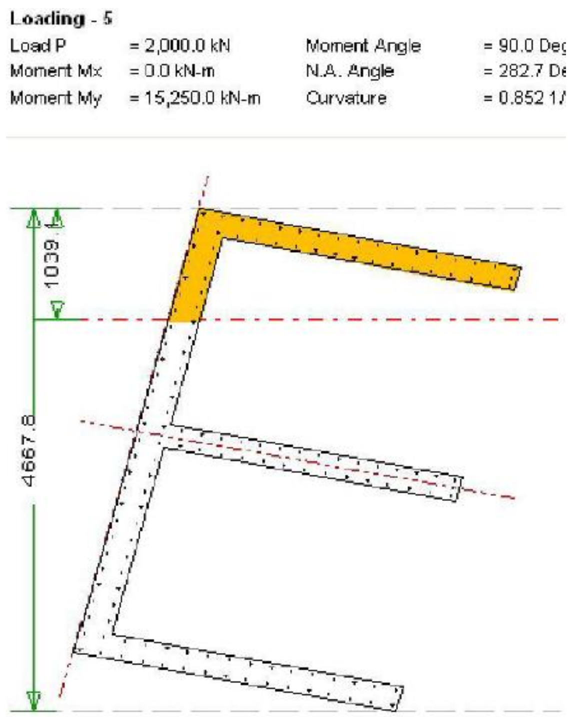


Fig. 8 (a) Section under critical load combination

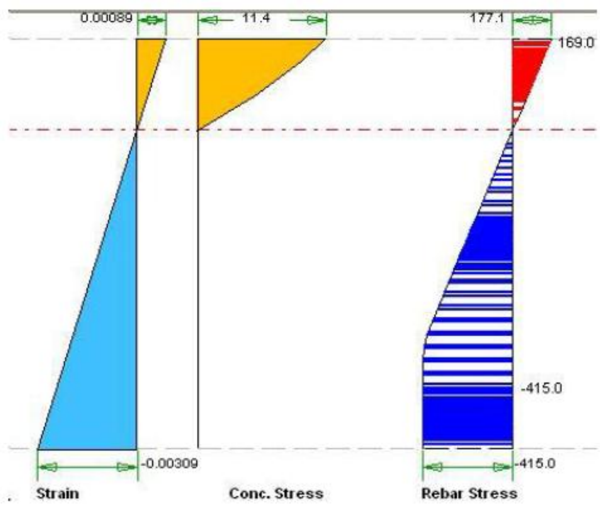


Fig.8 (b) Strain and stress diagram

Table IV

Sr. No	Load Comb	Load Pu (kN)	Mux (kN-m)	Muy (kN-m)	Muxy (kN-m)	Mx-My Angle (Deg)
1	Combination1	400.0	558.0	3732.0	3773.5	81.5
2	Combination 2	400.0	0.0	5000.0	5000.0	90.0
3	combination 3	400.0	0.0	10000.0	10000.0	90.0
4	combination 4	500.0	0.0	15250.0	15250.0	90.0
5	combination 5	2000.0	0.0	15250.0	15250.0	90.0

Load Vector	Capacity Vector	Capacity Ratio	N/A Angle (deg)	N/A Depth (mm)	Capacity Method	Remarks
3773.5	12103.8	0.31	294.6	741.4	2	OK
5000.0	12470.1	0.40	280.0	510.6	2	OK
10000.0	12470.1	0.80	280.0	510.6	2	OK
15250.0	12653.8	1.21	280.1	518.8	2	<Not OK>
15250.0	15405.6	0.99	282.7	655.9	2	OK

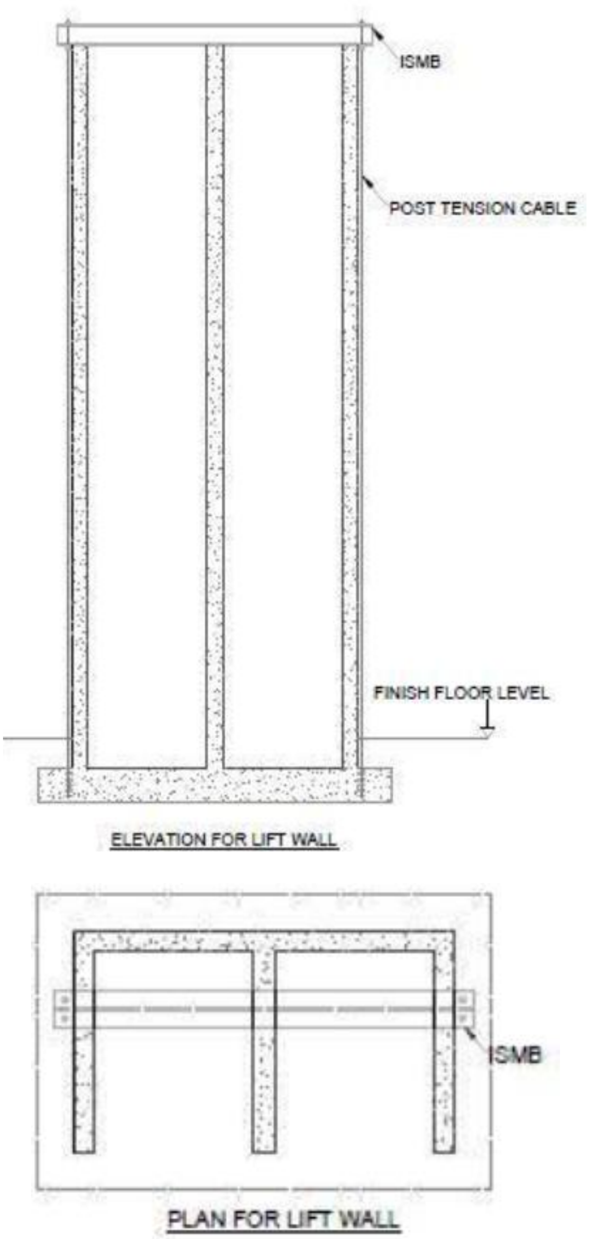


Fig. 9 Proposed solutions for post-tensioning of shear wall

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