Structural Strengthening of a Multiplex During Construction Stage in Chennai - A Case Study

[Edited from the archives of the case studies of CC Division of Pidilite Industries Limited, Mumbai]

1.0 Background

The project was located at IT express highway in Chennai on Rajiv Gandhi Salai, Karapakkam near to the riverside (Fig.1). The client was constructing a mall and multiplex complex with three tier basements in an area of 5 lakhs sqft in which total built-up space was 1.25 lakhs sqft. The structure was a G+ 10 storey structure with 3 basements having total area of 18.30 lakhs sqft, mall area of 10.44 lakhs sqft, office area of 2.70 lakhs sqft and a five star hotel of 5.17 lakhs sqft. area. As the site was very near to the river, a rise in water table created enormous water pressure and caused the upliftment of the newly built raft. The raft was 450 mm thick of M40 grade of concrete (Fig. 2). The situation further worsened due to drilling of holes for releasing the upward pressure at few places on the raft. Further the client had decided to increase the number of floors from four to eleven. All these factors were responsible for repair and rehabilitation of the damaged portions as well as strengthening and increasing the load carrying capacity of raft and columns.

Fig. 1: Site location of Multiplex besides the river

Fig. 2: Raft for structural strengthening

2.0 Distress Observed

After the raft was drilled with holes to release the uplift pressure, the floor got completely flooded with water. There were structural cracks in retaining walls, RCC raft and bulging of columns of basement at many places. The structural consultant redesigned the raft foundation and advised to increase the raft size to 1200 mm from existing 450 mm of M40 grade concrete by anchoring the new concrete with old concrete with the help of bonding agent and anchor fix grouts for rebars.

3.0 Repair Materials and Methodology

The flooded area was dewatered by pumping. A sump was created outside the raft from where pumping was done continuously (Fig. 3). Raft area was dried and all the locations of cracks were identified and marked for injection grouts.

Fig. 3: De-watering by pumping

3.1 Repair of Structural Cracks of Raft and Columns with Epoxy Injection

The holes were drilled and cleaned with high pressure vacuum cleaner. Injection packers were fixed with epoxy putties for facilitating epoxy injections. The viscosity of the resin was 200 cps and pressure exerted was 8-10 bars. The injection was carried out through those installed packers with a 2-component epoxy resin. After the injection the packers were removed and holes were sealed with epoxy putties. Thus all the structural cracks in raft and columns were strengthened with a 2-component epoxy resin injection. The various properties of epoxy injection grout are given in Table. 1.

Table 1: Properties of epoxy injection grouts

Properties	Values
Viscosity	200 cps at 30°C
Specific gravity	1.02
Compressive Strength at 7 days	80 Mpa
Tensile Strength at 7 days	45 Mpa
Bond Strength at 2 days moist cure	16 Mpa
Pot life at 30°C	45 minutes

3.2 Repair of Water Leakages in Rafts and Basement with PU Injection

Certain place of the raft and wall of basement where the leakage was high, PU (Polyurethane) foam injection was used. PU resin was based on MDI (Methylene Diphenyl Isocyanate) polyurethane pre-polymer & accelerator. It had low viscosity, high penetration and very quick setting properties. It could form tough and flexible polyurethane rubber after complete chemical reaction. The various properties of two-component PU foam injection are given in Table. 2. Figure 4 shows the view of basement wall after PU injection was done.

Table 2: Properties of two-component PU injection grouts

Properties	Values
Viscosity	180 cps for a Mix 1:1
Tensile strength at 28 days	4.5 Mpa
Shear strength	0.11 Mpa
Bond strength at 2 days moist cure	2 Mpa
Relative elongation	10-20 %
Maximum expansion	40 times
Pot life at 25°C	2 hours

Fig. 4: Basement wall after PU injection

3.3 Bonding of Old and New Concrete Layer of the Raft

The surface were rubbed and cleaned thoroughly. An epoxy based bonding agent was used to bond old with new concrete of the raft. It was a 2-component with base and hardener in proportion of 1 : 0.87. It had excellent bond strength and tensile strength was higher than its bond strength. The total surface area treated with epoxy bonding agent was around 20000 sq. ft. Since the area was quite large, the bonding agent was sprayed to the surface.

To have the structural integrity, anchor fix grouts were used by anchoring 12 mm, 16 mm and 25 mm diameter rebars of embedded length of 15 times the diameter of the bar (L_a) @ 500 mm c/c through out the raft slab as shear connectors. The holes were drilled of diameter 4 mm greater than the diameter of the rebar, cleaned and poured with modified grouts. The anchor fix grouts were polyester resin based grouts having strength more than pull out strength. Approximately 10000 numbers of holes were drilled for fixing anchor bars. The various properties of epoxy bonding agent and the anchor fix grouts are given in Table 3 and 4 respectively.

Table 3: Properties of epoxy bonding agents

Properties	Values
Specific gravity	1.02
Compressive Strength at 7 days	35 Mpa
Tensile Strength at 28 days	6 Mpa
Flexural Strength	3.5 Mpa
Shear Strength	1.4 Mpa
Bond Strength at 2 days moist cure	2 Mpa
Pot life at 30°C	5 hours

Table 4: Properties of epoxy injection grouts

Properties	Values
Specific gravity	2.0
Compressive strength at 7 days	70 MPa
Tensile strength at 7days	17.5 MPa
Flexural strength at 7days	34 MPa
Pullout strength at 7 days	30 MPa
Gell time at 30°C	20 minutes

3.4 Enlarging Sizes of Columns

The sizes of existing columns (Fig. 5) are also proposed to be increased from 1000 mm x 1000 mm to the modified design size with self-compacting concrete.

Fig. 5: Columns for strengthening

3.5 Basement Waterproofing

As the site was very close to river, the basement raft and walls were required to be waterproofed properly. The box type waterproofing system was selected for which polyester APP (Atactic Poly Propylene) torch on membrane was used. This was a heavy duty bituminous based polyester reinforced membrane of 4 mm thick. The surface was thoroughly cleaned by a vacuum cleaner and dried. A bituminous based primer was applied over which the membrane was aligned and rolled on the surface. Thereafter it was torched on with an acetylene gas at a softening point of 115-150°C and tucked to the surface. The overlap between each successive adjacent roll was 100 mm. It could provide highly durable vapour barrier coating to the wall and raft of the basement. A screeding of cement sand mortar was provided above it for protecting the membrane from puncture or rupture at any point. The various properties of polyester APP membrane are given in Table. 5.

Table 5: Properties of APP membrane

Properties		Values
Tensile Strength in N per 5 cm width	In longitudinal direction	700
	In transverse direction	550
Elongation at Break (%)	In longitudinal direction	40
	In transverse direction	50
Tear Resistance (N)	In longitudinal direction	150
	In transverse direction	170
Resistance to water pressure		No leakage
Water absorption (%)		< 0.15

3.6 Pullout Test of Embedded Steel Bars

It was decided to do the pull out test of the 12 mm and 16mm embedded steel bars to check the proper bonding of anchor fix grouts with rebars. Results of pullout tests for design load is given in Table 6. Though the test results showed that it met the design load requirement but the client insisted to find out the failure load.

Table 6: Results of pullout tests of anchor fixed bars with grouts for design load

Diameter of the bar (d_b)	Diameter of the hole drilled for fixing the bar	Pull out test value(P) (KN)	Bond strength = $P / \pi . d_b . L_a$ (MPa)	Average bond strength (MPa)
16	20	51.71	4.28	4.13
		57.99	4.81	
		39.95	3.31	
12	16	43.88	6.47	4.66
		14.27	2.10	
		36.74	5.42	

L_a = Embedded length of the anchor bars (15 x d_b)

Average bond strength of embedded bars with anchor fix grouts are calculated and given in Table 6. A second pull out test was also carried out with modified sample of anchor fix grouts as per the site requirement. Results of pull out test on embedded steel bars of 12 and 16 mm diameter using anchor fix grouts and for failure load is given in Table 7. The test results were also satisfactory.

Table 7: Results of pullout tests of anchor fixed bars with grouts for failure load

Diameter of the bar	Diameter of the hole drilled for fixing the bar	Pull out test value (KN)	Remarks
16	20	36.41	Weld failure
		35.77	Weld failure
12	16	33.98	Welded bolt failure. Fracture occurred in the threaded portion of the bolt
		33.82	Weld failure

4.0 Conclusion

The site investigation of the project should be carried out thoroughly. The foundation design of the structures located near the river side area where the ground water table is high or adjacent to the catchment should be done properly. Special attention should be paid to the foundation details and design keeping in view the drainage system of the site and the upward pressure. The basement raft and walls should be properly waterproofed. The box type membrane waterproofing is the best system. Waterproofing should be done at both positive as well as negative side for such important multiplex structures. Additionally drainage system should be provided for structures which can ensure a fool proof waterproofing system. The structural strengthening of the members and waterproofing of the basement of this project was carried out successfully.

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