A Case Study – Blast Damaged Industrial Building – Insurance claim settlement

By - Er. Ravi Ranade
Structural Auditor, NDT, Structural Restoration Consultant
Managing Director -Construction Diagnostic Centre Pvt. Ltd., India
E-mail – info@concretepune.com website – www.ndtconcrete.com

Abstract : -

In one of the chemical manufacturing Industry in Maharashtra, the chemical vessel exploded damaging the RCC structure of the building. Insurance company wanted to assess the extent of damage caused by this blast. Hence a detail investigation was carried out by CDCPL. The owner company had claimed for a total damage of the building; but the investigation revealed only a localised damage.

Blast Damage Assessment Audit : -

This case study reveals the facts about blast damage assessment. The assessment work involved structural audit, collection of data / information from site and from client, conducting various Non-destructive tests, and finding out the extent of damage in RCC building

The detail activities carried out under all above scope of work were as below -

A) Structural Audit

1. Detail inspection of the entire structure
2. Photographic survey
3. Noting various observations such as load transfer system, Structural framing system, Structural deficiencies, settlement if any, Cracks in RCC members, Cracks in masonry / plaster, Leakages, Loads on structure, corrosion, defects in non structural elements etc.
4. Identification of broad areas / locations in the structure requiring further detail investigation and for conducting various ND Tests

B) Conducting various Non Destructive Tests

1. Ultrasonic Pulse Velocity test – Direct & Semi- direct Methods
2. Rebound Hammer Test
3. Core Test
4. Carbonation Test
5. Half-Cell Potential Test
6. Chloride & Sulphate Content test

Details of Structures : -

No. of floors	: Partly Ground + upper two floors, Partly Ground + upper Six floors Partly Ground + upper seven floors
Year of construction	: Old plant – 1989 & New plant - 2006
Type of construction -	: RCC & Steel frame structure
Walls - Superstructure	: BBM – 230 mm. thk
Roofing	: RCC slab & MS rafter with A.C. sheets
Use of Structure	: Industrial – Chemical Manufacturing

History of past Repairs / Modifications : -

1. The structure was constructed in two stages. The first building was constructed in 1989 and an extension to this building on west side was done in in 2006.

2. Some of the RCC members (Columns) were strengthened (Jacketed) in 2011-12.

3. In the past, some changes in machinery / vessels were carried out, but no data / record was available to know whether the structural members were checked for its capacity for this new / additional loads

Data / Information	Changes	Remarks
Details / Records of any repairs , modifications	No	----
Roof waterproofing	No	Original waterproofing, cracked at many places, needs replacement
Architectural / plan changes	Partly	Horizontal & vertical extension of building. Construction of steel towers and shed over RCC terrace
Structural changes	Partly	Horizontal & vertical extension of building was carried out, but no information available, whether the lower RCC structure was designed / checked to take load of upper steel tower structures
Structural / Corrosion repairs / strengthening	Yes	Some of the RCC members (Columns) were strengthened (Jacketed) in 2011-12, as vertical cracks were noticed in these columns. But probably no anti-corrosive treatment was given to these members, reinforcement. The columns are jacketed with micro-concrete of about 25 to 75 mm thickness. In some of the jacketed portion of columns additional bars were provided, but some of the columns were jacketed without any new bars. The additional bars are not extended in bottom and top slab, beams
Changes in Machinery Layout	Yes	But details / records of old and new machinery layout and loads not available

Observations : -

1. One of the vessel resting on first floor beams was blasted. The roof slab over the blasted vessel was totally damaged, the adjoining slab near staircase was also totally damaged.

2. Other than this slab no other RCC members at other locations and on other lower floors were having any visible crack / deflection caused due to the said blast.

3. Due this blast, the plaster over some RCC slabs, beams, columns and walls had de-bonded. The RCC jali around the blast area was damaged at almost places.

4. Majority of the RCC members were noticed to have moderate to severe corrosion cracks and spalling of cover concrete.

5. Foundations could not be inspected, but the superstructure was not having any visible signs indicating possibility of the settlement of foundations.

6. The other observations are as reported below.

Overall Observation	Severity	Location, Cause & Effect
Signs of foundation settlement	Nil	----
Structural Cracks in RCC members	Severe	Roof beam (+11 m Lvl) around vessel blast area
Corrosion Cracks in RCC members	Moderate to Severe	Majority of the RCC members
Corrosion of structural steel members Rusting / Scaling / Pitting	Moderate to severe	Some columns & Beams were having severe corrosion, with threat to safety of the structure, requiring an immediate intervention. While some other columns and beams were having minor to moderate corrosion
Spalling of cover concrete	Moderate to Severe	Majority of the RCC members were having moderate to severe corrosion cracks and spalling of cover concrete mainly due to corrosion.
Cracks in walls / Plaster	Minor to Severe	At some places (new building) ceiling plaster and at some places the plaster and cover concrete of beams and column had fallen due to blast impact. Probably this plaster / cover concrete had already cracked and de-bonded due to severe corrosion of reinforcement.
Deflections / Sag / Tilt in RCC / Steel members	Severe	Roof Slab (+11 m Lvl) near stair around vessel blast area had a huge deflection
Deflections / Sag / Tilt in Walls	Nil	----
Honeycombing in RCC members	Nil	----
Crushing , crumbling of concrete	--	Roof Slab over blasted vessel & near stair (+11 m Lvl) was totally
Leakages from roof slab / Roofing sheets	Moderate	Roof slab
Leakages from Toilet slabs	--	----
Leakages in Walls	Nil	----
Abnormal loading / Overloading -	--	---
Constructional defects	Minor to Moderate	Steel column of 4th floor, of east side tower buckled at joint. Some of the steel columns are placed eccentrically above lower level columns.
Structural Deficiencies	Nil	----
Condition of drainage / water lines, Gutters	----	----
Vegetation over walls , RCC members, Plumbing pipes	Nil	

Overall Observation	Severity	Location, Cause & Effect
Ground / Parking floor / Drainage chamber settlement	---	---
OH Tank / Ground Tank - Leakages from roof slab , bottom slab, tank walls	----	---
Structure / Members exposed to Aggressive Exposure Condition	Severe	The entire building is exposed severe corrosive fumes
Suspended loads - Stability of False Ceiling, Heavy hanging fixtures	Nil	----
Roof sheets / Cladding sheets cracked / damaged	Minor	
Other -	----	----

Front view of the buildings

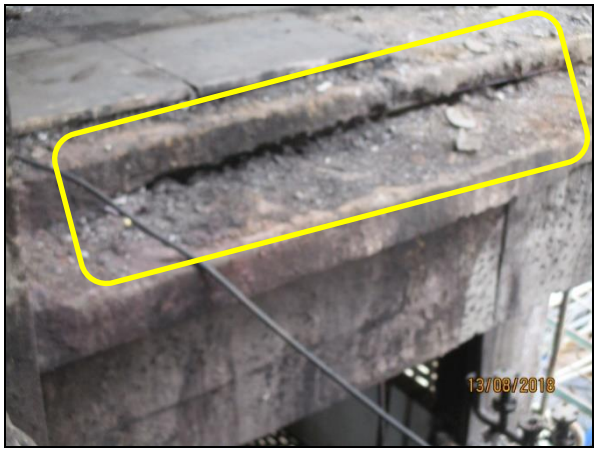
RCC members around blasted area – Ground floor

Apparently no structural cracks in any of members due to blast, but only corrosion cracks

RCC / Steel members around blasted area – First floor
Apparently no structural cracks in any of members due to blast, but only corrosion cracks

Totally damaged roof slab due to Blast (Two slab panels)

Totally damaged roof slab due to Blast

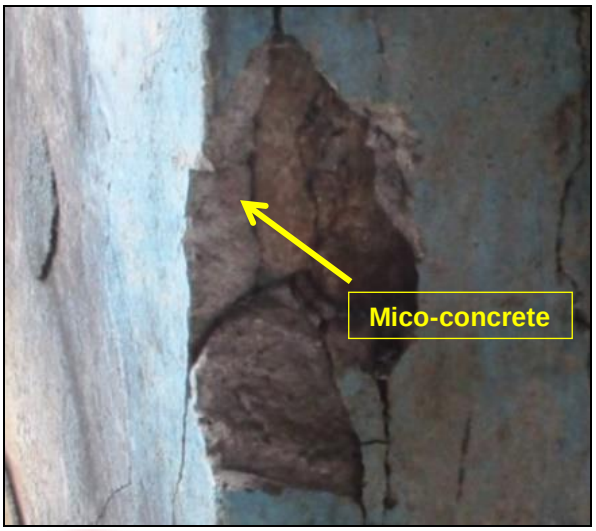


Roof slab adjacent to staircase – crackd and lifted up

Moderate to Severe corrosion of reeinforcement along with spalling of cover concrete

Ceiling plaster fallen due to blast

Plaster over RCC member fallen and parapet wall & RCC Grill collapsed due to blast



All columns of old building were jacketed with Micro-Concrete 25 to 75 mm thick

Structural steel members with minor to moderate corrosion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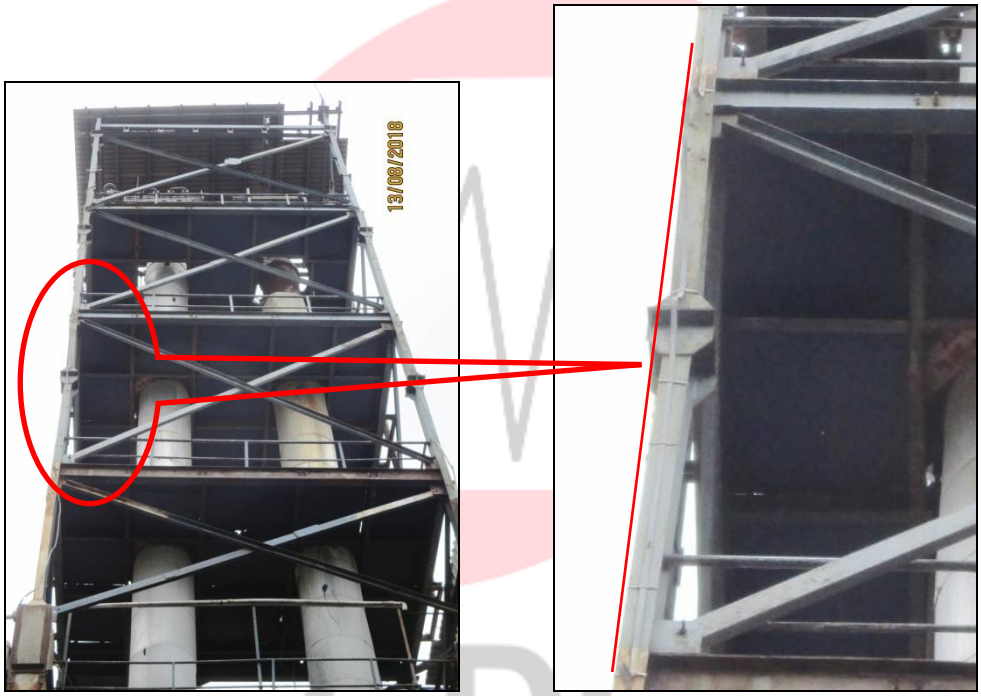
Structural steel members with Severe corrosion



Bend at column joint

Misaligned Structural Column of staircase of east side Steel tower

Non Destructive Testing observations : -

1) **The original grade of concrete of both the wings (old and new) was not known. Considering the year of construction, probably the grade of concrete of old building could be M-15 and that of new building being constructed in 2006, should be M-20. But as there was no data available to confirm this, we had assumed the grade of concrete of both the wings as M-15**

2) **The core test results indicated a very wide range in strength of concrete for both the wings as below –**
   a) **Old building - M – 09 to M - 32**
   b) **New building - M – 08 to M - 38**
   c) **New building (blasted area Grid A2-A3-B2-B3) - M – 14 to M - 30**

3) **The Rebound Hammer & Ultra Sonic Pulse velocity test results also indicated a very wide range in strength of concrete for both the wings as below –**
   a) **Old building - M – 17 to M - 32**
   b) **New building - M – 06 to M - 26**
   c) **New building (blasted area Grid A2-A3-B2-B3) - M – 06 to M - 27**

The strength of site concrete was predicted by carrying out a regression analysis on combined NDT methods – Rebound Hammer Test, UPV Test and Core test.

The qualitative assessment of concrete quality was done based on below table -

At CDC we have carried out extensive research on quality assessment and it has been observed that, the quality gradation as per IS – 13311 (part-1)- 1992 is valid ONLY for M – 15 grade concrete and only for direct probing method. For concrete with more than M – 20, we recommend to grade the quality of concrete as per below given table –

Gradation of Quality of concrete (as per CDC) Direct & Semi-Direct velocity Km/Sec.				
Quality of Concrete	**< 15 Mpa**	**20 to 25 Mpa**	**30 to 35 Mpa**	**> 40 Mpa**
Excellent	**More than 4.000**	**More than 4.400**	**More than 4.600**	**More than 4.900**
Good	**3.500 to 4.000**	**3.750 to 4.400**	**3.900 to 4.600**	**4.150 to 4.900**
Medium	**3.000 to 3.500**	**3.400 to 3.750**	**3.600 to 3.900**	**3.800 to 4.150**
Doubtful	**Less than 3.000**	**Less than 3.400**	**Less than 3.600**	**Less than 3.800**

Gradation of Quality of concrete (as per CDC) Indirect velocity Km/Sec.				
Quality of Concrete	**< 15 Mpa**	**20 to 25 Mpa**	**30 to 35 Mpa**	**> 40 Mpa**
Excellent	**More than 3.500**	**More than 3.900**	**More than 4.100**	**More than 4.400**
Good	**3.000 to 3.500**	**3.250 to 3.900**	**3.400 to 4.100**	**3.650 to 4.400**
Medium	**2.500 to 3.000**	**2.900 to 3.250**	**3.100 to 3.400**	**3.300 to 3.650**
Doubtful	**Less than 2.500**	**Less than 2.900**	**Less than 3.100**	**Less than 3.300**

Members	Total Testing members	Total Testing Location	% Velocity below 2.5 km/Sec.	% Velocity 2.50 to 3.00 Km/Sec.	% Velocity 3.00 to 3.50 Km/Sec.	% Velocity 3.50 to 4.00 Km/Sec.	% Velocity Above 4.00 Km/ Sec.
New Building (Blasted Area)							
Columns	12	24	12.50%	45.83%	33.33%	8.33%	0.00%
Beams	13	26	26.92%	46.15%	19.23%	7.69%	0.00%
New Building							
Columns	36	72	25.00%	27.77%	40.27%	6.94%	0.00%
Beams	76	130	35.07%	20.89%	29.85%	12.68%	1.49%
Slabs	18	44	11.36%	22.72%	40.90%	25.00%	0.00%
Old Building							
Beams	31	62	17.74%	35.48%	33.87%	9.67%	3.22%
Slabs	12	34	0.00%	26.74%	44.11%	29.41%	0.00%
New Building (Slab Near Blasted Area)							
Slabs	6	12	16.66%	25.00%	25.00%	33.33%	0.00%

4) The Half-Cell Potential test indicated that at majority of the test locations, there was a more than 90 % possibility of corrosion

	% Half cell Potential < -200 (mV)	% Half cell Potential < -200 to -350 (mV)	% Half cell Potential < -350 to -500 (mV)	% Half cell Potential > -500 (mV)
Combined Report				
New Building				
Columns	**6.48%**	**50.00%**	**27.05%**	**16.5%**
Beams	**8.80%**	**37.60%**	**46.40%**	**7.2%**
Slabs	**9.10%**	**50.00%**	**30.30%**	**10.6%**
Tie Beams	**0.00%**	**0.00%**	**20.00%**	**80.0%**
Old Building				
Beams	**0.00%**	**40.00%**	**40.25%**	**19.0%**
Slabs	**0.00%**	**75.00%**	**0.00%**	**25.0%**
Tie Beams	**0.00%**	**0.00%**	**70.00%**	**30.0%**

Interpretation of Hal-Cell Potential test results -

- If potentials over an area are numerically less than – 200 mV Copper – Copper sulphate half cell, there is a greater than 90 % possibility that, no reinforcing steel corrosion is occurring in that area at the time of measurement.
- If potentials over an area are in the range of – 200 mV to – 350 mV Copper – Copper sulphate half cell, then the corrosion activity of reinforcing steel in that area is uncertain.
- If potentials over an area are numerically greater than – 350 mV Copper – Copper sulphate half cell, there is a greater than 90 % possibility that, reinforcing steel corrosion is occurring in that area at the time of measurement.

Conclusions : -

1) **The visual observation indicated that, except the damaged roof slab panel and adjoining slab panel, at no other locations any distresses in form of any structural cracks were observed due to the blast.**

2) **At some locations the plaster over slab ceiling & other RCC members had fallen due to impact of the blast.**

3) **At some locations the parapet walls and RCC grill had collapsed due to blast impact.**

4) **It is observed that, both the buildings had a very serious issue of corrosion of reinforcement. All visible cracks in RCC members were mainly due to corrosion of the reinforcement steel. The crack widths indicated that, the corrosion of reinforcement is probably of moderate to severe level.**

5) **The NDT results indicate that, there was a very vast variation in strength of concrete from M-06 to M- 38. But it was observed that even in blasted area Grid A2-A3-B2-B3, the strength of concrete was similar to that of other entire unaffected areas of both old and new building. Thus the reduction in strength of concrete was not due to blast and it was a probable original construction quality issue.**

6) **Thus, we concluded that, the blast dames was limited only to the two roof slab panels (as against the claim of, total damage of the building, made by the owner). Along with slab damages some other associated partial damages in walls, RCC grills, waterproofing and plaster can be certified for claim settlement -**

Description	**Damage – Extent – Full / Partial / Nil**	**Requires – Reconstruction / Repair**
Roof RCC slab panels (2 Nos) along with ceiling plaster & waterproofing	Full	Reconstruction
RCC Grill along with plaster touch-ups and painting, as marked in the sketch	Partial	Replacement of all fully damaged grills
Brick parapet walls along with plaster and painting, as marked in the sketch	Partial	Replacement of all fully damaged walls
Fallen plaster over ceiling of slabs, and RCC members	Partial	Replacement of all fully damaged plaster over RCC members