Visual Defect Survey: Case Study of RCC Structure

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Abstract- Visual defect survey is generally a partial evauation of the present condition of the structure and helps detect its servisibility condition. Thus it is the pre-requisite procedure before the structural modification or renovation of any structure is carried out. It aims to determine how extensive the defects are and the probable cause of defects [2]. The results of the same are confirmed by performing various tests on the structure and assessing its present residual strength. These inspection results are directly related to the structure's insitu strength therefore it has to be carried out by technically sound and experienced professionals. Professionals qualified in the field of structural design, concrete technology & construction methods with field experience would give maximum effectiveness to the audit. Prior to the structural audit, it is essential to collect certain documents and information about the structure such as the floor plans of the building, the intended design and misuse, the repairs, renovations or extentions made, natural disasters if any etc. Visual defect survey, the initial step of structural audit helps pass a judgment on building elements that do not reach an acceptable standard of quality, level of building practice, or have not been built with proper workmanship in relation to the Building Acts of the country. Model bye-law no. 77 specifies Structural Audit as a mandatory requirement and stipulates that if the age of a building is 15 to 30 years.

Keywords: Visual Inspection, Structural Audit, Structural damage, Cracks, Leakages.

I. INTRODUCTION

"As many as 593 buildings in the city of Mumbai have been classified lying in C1 category i.e. in a 'very dangerous condition' and need to be demolished. A total of 817 buildings in the city are classified C2, meaning they require major structural repairs; 267 have been given permission for repairs. The civic body has classified106 buildings as C3, or needing minor repairs. Buildings are classified based on a two-step inspection process by the civic body's engineers and a structural audit report. The engineers look for cracks in the columns and beams, condition of the concrete and slabs, shrinkages or foundation settlement. Diagonal cracks are considered most dangerous to the structural integrity of a building" and "There are 32,429 buildings older than 30 years in the city and the BMC has sent notices to 13,779 of these under section 353 (B) of the MMC Act to conduct structural audits" [3]. "There are 55 buildings that cannot be repaired and we have no option but to demolish them. There are 219 buildings that can be strengthened with major repairs," said Sudhir Kadam, executive engineer of building department of Pune Municipal Corporation (PMC), while speaking to TOI [4]

A. Practical Necessity

Checking the building's performance from time to time will enable us detect any structural distress well within time and call for immediate measures will save a heavy economical loss over the long run [1]. Practical site work helps us get an insight of the various realistic problems and difficulties of which we only read in books, which may be far more serious than just our imagination. We as civil engineers get all our information from site visit and keen observations.

1) Government in Action: Safety of human life is given due priority, therefore even the government enforces laws to safeguard and protect lives and property. Carrying out a Structural Audit of a building is made complusory beyond 30 years of its service life, which can be prepond if left necessary. Design for durability is now highlighted in IS: 456-2000 under a specific section. The code emphasizes the perceived concern about the durability of concrete structures in India with specific design recommendations to deal with corrosion of reinforcement besides dealing with other types of durability problems.

2) Technical Aspect: In the codes, the requirements on durability are expressed in terms of minimum cement content, maximum water/cement ratio, minimum grade of concrete and minimum cover to reinforcement. These design parameters are related to specific exposure conditions. The general approach is to demand impermeability of concrete as the first line of defense against any of the deterioration process.

B. Challenges and Limitations Faced

Practicality is way different than what we plan to do, the feasibility of this project was far too difficult to achieve than expected.

1) Getting Reports: Getting reports of tested building is always an issue because of the customer-consultancy confidentiality.

2) Desired Case Study: Finding structures beyond 15 years with owners willing to permit survey was next to impossible.

3) Inaccessibility: Sometimes there are certain places in a building which are inaccessible due to the structural defects, architectural aesthetics or locked apartments which becomes a setback in the auditing

II. CASE STUDY

A. Building designed as Commercial Complex (Parking + 4 Floors)

1) Building History: Column Foundation Laid in: Feb 2011
Feb 2011 to Mar 2012 – Court Stay
Parking Constructed in: Mar 2012
2) Present Condition: Mar 2012 to Jun 2014 - Court Stay
3) Cause of Structural Audit: Connected shopkeepers' concern taking into account the continuous leakage of parking slab, Exposed reinforcement and visible honey combing.
4) Beyond its Scope: This report is based only on visual health survey of the building & the following are beyond its scope:

a) Assessment of structural stability
b) Non-destructive testing
c) Inspection of foundations
d) Seismic assessment
e) Assessment of any repair/ renovation work in progress in the building or the apartments/ offices/ shops etc during the survey period.

5) Mode of Survey: Visual inspection using light tapping hammer, damp detector, spirit level etc.

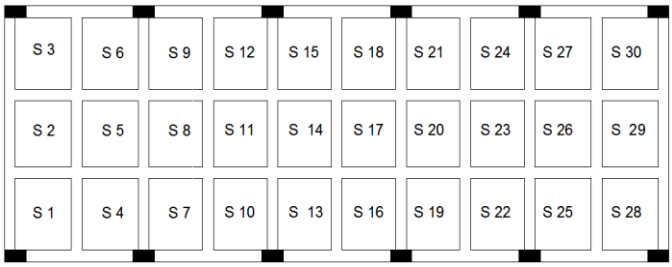

Fig. 1. Slab numbering as per inspection

TABLE I
SLAB DETAILING OF TEST BUILDING

ELEMENT NO.	VISUAL DEFECT
SLAB 1	Water leakage found Shuttering wood leftovers visible
SLAB 2	Shuttering wood leftovers visible Water leakage found
SLAB 3	Shuttering wood leftovers visible Water leakage found-severe
SLAB 4	Water leakage found-very severe Slab blackened due to moss/water
SLAB 5	Water leakage found Distorted shape due to bad shuttering
SLAB 6	Shuttering wood leftovers visible Water leakage found
SLAB 7	Shuttering wood leftovers visible Water leakage found Rust on surface due to leakage Distorted shape due to bad shuttering
SLAB 8	Water leakage found Slab blackened due to moss/water
SLAB 9	Water leakage found Slab blackened due to moss/water Spalling of concrete under slab Distorted shape due to bad shuttering
SLAB 10	Water leakage found-very severe Slab blackened due to moss/water
SLAB 11	Honey Combing Shuttering wood leftovers visible Water leakage found-very severe
SLAB 12	Honey Combing Shuttering wood leftovers visible Water leakage found-very severe Spalling of concrete under slab
SLAB 13	Shuttering wood leftovers visible Water leakage found-very severe Rust on surface due to leakage
SLAB 14	Honey Combing Shuttering wood leftovers visible Water leakage found-very severe Rust on surface due to leakage-bad
SLAB 15	Shuttering wood leftovers visible Water leakage found-very severe Rust on surface due to leakage
SLAB 16	Shuttering wood leftovers visible Water leakage found Rust on surface due to leakage
SLAB 17	Honey Combing Water leakage found
SLAB 18	Honey Combing Water leakage found
SLAB 19	Water leakage found Rust on surface due to leakage Distorted shape due to bad shuttering
SLAB 20	Shuttering wood leftovers visible Water leakage found Efflorescence found
SLAB 21	Shuttering wood leftovers visible Water leakage found Rust on surface due to leakage Distorted shape due to bad shuttering
SLAB 22	Water leakage found Efflorescence found Distorted shape due to bad shuttering
SLAB 23	Shuttering wood leftovers visible Water leakage found Efflorescence found Honey Combing
SLAB 24	Shuttering wood leftovers visible Water leakage found

	Efflorescence found Distorted shape due to bad shuttering Slab Blackened by Fire
SLAB 25	Honey Combing Water leakage found-very severe Rust on surface due to leakage-very severe Efflorescence found
SLAB 26	Shuttering wood leftovers visible Rust on surface due to leakage
SLAB 27	Water leakage found Efflorescence found
SLAB 28	Honey Combing-severe
SLAB 29	Shuttering wood leftovers visible Water leakage found Distorted shape due to bad shuttering
SLAB 30	Honey Combing Water leakage found Rust on surface due to leakage Efflorescence found Distorted shape due to bad shuttering

Fig. 2. Excessive leakage with rust stains visible at slab bottom

Fig. 3. Honey combing hidden with cement paste, slab leakage, uneven slab surface with rust stains clearly visible

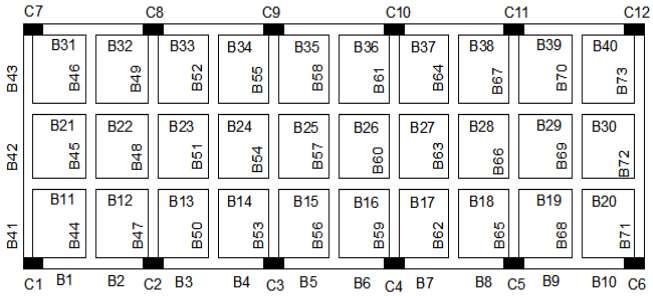

Fig. 4. Beam and column numbering as per inspection

TABLE II
BEAM DETAILING OF TEST BUILDING

ELEMENT NO.	VISUAL DEFECT
BEAM 1	Honey Combing Reinforcement bars visible Beam blackened due to water leakage
BEAM 2	Honey Combing Beam surface uneven - joints Spalling of Concrete-small patch
BEAM 3	Honey Combing Reinforcement bars visible Beam blackened due to water leakage
BEAM 4	Honey Combing – severe Reinforcement bars visible – severe
BEAM 5	Honey Combing Beam surface uneven – joints
BEAM 6	Honey Combing
BEAM 7	Honey Combing Shuttering wood leftovers visible
BEAM 8	Honey Combing
BEAM 9	Beam surface uneven – joints Shuttering wood leftovers visible
BEAM 10	Honey Combing
BEAM 11	Honey Combing Reinforcement bars visible
BEAM 12	Broken beam edges
BEAM 13	Honey Combing Broken beam edges
BEAM 14	Broken beam edges
BEAM 15	No Visible Defect
BEAM 16	Broken beam edges
BEAM 17	Broken beam edges
BEAM 18	No Visible defect
BEAM 19	Reinforcement bars visible Broken beam edges
BEAM 20	Honey Combing
BEAM 21	Honey Combing
BEAM 22	Broken beam edges
BEAM 23	Honey Combing
BEAM 24	No Visible defect

BEAM 25	Reinforcement bars visible Broken beam edges
BEAM 26	Honey Combing
BEAM 27	Honey Combing - Severe Reinforcement bars visible-severe
BEAM 28	Honey Combing Reinforcement bars visible
BEAM 29	Reinforcement bars visible Blackened by Fire Shuttering wood leftovers visible
BEAM 30	Shuttering wood leftovers visible Bulging due to bad shuttering
BEAM 31	Water leakage found Shuttering wood leftovers visible
BEAM 32	Water leakage found Shuttering wood leftovers visible
BEAM 33	Honey Combing
BEAM 34	Honey Combing Shuttering wood leftovers visible Reinforcement bars visible Beam blackened due to water
BEAM 35	Cover below requirement Reinforcement bars visible
BEAM 36	No visible defects
BEAM 37	Honey Combing Cover below requirement Reinforcement bars visible Shuttering wood leftovers visible
BEAM 38	Honey Combing Cover below requirement Reinforcement bars visible Blackened by Fire
BEAM 39	Traces of wood shuttering found
BEAM 40	Shuttering wood leftovers visible
BEAM 41	Honey Combing Cover below requirement Reinforcement bars visible Shuttering wood leftovers visible
BEAM 42	Honey Combing Cover below requirement Reinforcement bars visible Shuttering wood leftovers visible
BEAM 43	Honey Combing Reinforcement bars visible Shuttering wood leftovers visible Water leakage found
BEAM 44	Cover much below requirement Honey Combing-severe Reinforcement bars visible-severe
BEAM 45	Honey Combing Water leakage found
BEAM 46	Reinforcement bars visible
BEAM 47	Honey Combing Reinforcement bars visible Shuttering wood leftovers visible Beam surface uneven – joints
BEAM 48	Cover much below requirement Honey Combing-severe Reinforcement bars visible-severe
BEAM 49	Reinforcement bars visible Honey Combing Shuttering wood leftovers visible
BEAM 50	Water leakage found Honey Combing
BEAM 51	Honey Combing Shuttering wood leftovers visible
BEAM 52	Honey Combing Water leakage found
BEAM 53	Honey Combing Shuttering wood leftovers visible Reinforcement bars visible Water leakage found
BEAM 54	Honey Combing Water leakage found
BEAM 55	Honey Combing Shuttering wood leftovers visible Water leakage found Cover below requirement
BEAM 56	Honey Combing-Severe Shuttering wood leftovers visible Reinforcement bars visible-Severe
BEAM 57	Honey Combing Shuttering wood leftovers visible Reinforcement bars visible
BEAM 58	Honey Combing Reinforcement bars visible
BEAM 59	Honey Combing Shuttering wood leftovers visible
BEAM 60	Shuttering wood leftovers visible
BEAM 61	Honey Combing Bulging due to bad shuttering
BEAM 62	Honey Combing-very severe Cover much below requirement Shuttering wood leftovers visible Reinforcement bars visible-rusted
BEAM 63	Honey Combing Shuttering wood leftovers visible Reinforcement bars visible
BEAM 64	Reinforcement bars visible Blackened by Fire
BEAM 65	Honey Combing Water leakage found-severe

BEAM 66	Honey Combing Shuttering wood leftovers visible-B Reinforcement bars visible
BEAM 67	Reinforcement bars visible
BEAM 68	Honey Combing Water leakage found
BEAM 69	Shuttering wood leftovers visible Water leakage found
BEAM 70	Bulging due to bad shuttering
BEAM 71	Honey Combing Reinforcement bars visible Shuttering wood leftovers visible Water leakage found
BEAM 72	Honey Combing Shuttering wood leftovers visible Bulging due to bad shuttering
BEAM 73	Honey Combing Reinforcement bars visible Bulging due to bad shuttering

Fig. 5. Beam-beam junction badly affected by loss of cover, honey combing and exposed reinforcement

Fig. 6. Beam affected by broken edges and exposed reinforcement

Fig. 7. Beam bottom found with traces of moss formation

Fig. 8. Beam bottom found with piece of wood and honey combing

TABLE II
COLUMN DETAILING OF TEST BUILDING

ELEMENT NO.	VISUAL DEFECT
COLUMN 1	Honey Combing Blackened by Fire Column projection bars rusted*
COLUMN 2	Honey Combing Column projection bars rusted*
COLUMN 3	Honey Combing Columns blackened due to water Column projection bars rusted*
COLUMN 4	Honey Combing Column projection bars rusted*
COLUMN 5	Honey Combing Columns blackened due to water Column projection bars rusted*
COLUMN 6	Honey Combing Column projection bars rusted*
COLUMN 7	Honey Combing Column surface uneven – joints Column projection bars rusted*
COLUMN 8	Honey Combing Column surface uneven – joints Column projection bars rusted*
COLUMN 9	Honey Combing Reinforcement bars visible Column surface uneven – joints Column projection bars rusted*
COLUMN 10	Honey Combing Column surface uneven – joints Reinforcement bars visible Column projection bars rusted*
COLUMN 11	Blackened by Fire Column surface uneven - joints Column projection bars rusted*
COLUMN 12	Unapproachable Column projection bars rusted*

*Seen from exterior

Fig. 9: Column affected by severe honey combing, hidden by cement paste
Fig. 10: Column with stains of moss due to moisture and exposed reinforcement bars completely corroded

III. CRITICAL OBSERVATIONS

- Honey combing is found in most of the elements
- Inadequate concrete cover is found in most of the beams and few slabs
- Reinforcement is visible for many elements with severe rust formation to few.
- Severe leakage problems through nearly every slab is observed
- Water accumulates under the slab in the parking during monsoon as reported
- External beams and columns reportedly show dampness during monsoon
- Efflorescence was observed in nearly every slab most with white powdery salts but few with rust travelled with water to slab surface
- Several members have wooden shuttering pieces or leftovers causing bad aesthetics and future threat of termite
- Spalling of concrete is found in few structural members

IV. PROBABLE CAUSES

- Bad quality supervision and workmanship found throughout structural survey
- Bad quality of original concrete
- Corrosion of reinforcement
- Inadequate cover to reinforcement
- Honeycombing of concrete
- Thin RCC sections, fully open to weather
- Poor quality of cement and lack of adequate compaction during construction of the building
- Seepage of water through concrete slabs
- Flooding during monsoon
- Lack of immediate attendance to seepage

CONCLUSIONS [1]

- Follow specifications: IS 456 -2000
- Start with exposure conditions and select grade of concrete and cover of concrete accordingly.
- Minimum water cement ratio
- Shape and size of structure should allow quick drainage of water
- Don’t use rusted steel or coated steel
- Prepare quality assurance plan and ensure it is followed
- Use good quality cement, graded aggregates and potable water
- Avoid, nominal mix, volume batch and hand compaction
- Use Mixer Machine & vibrator for compaction of concreting.
- Use rigid and water tight form work, as far as possible avoid wooden pieces loose formwork.
- Conduct simple permeability tests like ponding slab with water & checking for leakage and repairs.

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REFERENCES

[1] Merilyn J. Monteiro, (2011), “Study of Structural Soundness of buildings”. Dissertation report, University of Pune.
[2] Darren Love, (2013), Report - Building Consultants And Quality Inspectors, Darbeccs Pty. Ltd.
[3] Linah Baliga (2014), Report - "424 of 593 ‘dangerous’ buildings in Mumbai still occupied" The Times of India, TNN dated Mar 20, 2014 05.57 AM IST
[4] Prasad Kulkarni (2013), Report - "Pune Municipal Corporation to evacuate residents from 274 'highly dangerous' buildings" The Times of India TNN dated May 28, 2013, 05.44AM IST