Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 3 (2023)

Visual Inspection Checklist For Concrete Structures (As A Part Of Structural Health Assessment)

[1*]Sangeeta Pandey, [2]Ajay Kumar Sinha

[1]Research Scholar, National Institute of Technology Patna, Patna, Bihar, India
[2]Professor, National Institute of Technology Patna, Patna, Bihar, India

Abstract: Visual inspection of deteriorating reinforced concrete structures is an integral aspect of routine assessment practices. Data collected through visual inspection is primarily qualitative and subjective because it rarely involves. This article provides structural inspectors and facility engineers the methodology for visually inspecting any civil structure in a systematic way. The subject article is not prescribing any repair, retrofitting and rehabilitation methodologies. With help of basic design, technical and geographical information, inspectors can add value to the evaluation of deteriorated condition of structures. It is primarily for evaluating general civil structures, like buildings, retaining walls, transmission line towers, this study includes all the civil concrete structures, steel structures and pre-fabricated structures.
Keywords: Visual Inspection, Visual Inspection Checklist, Structural Health Assessment

1. Introduction

1.1 Structural Health Assessment-Visual Inspection-Checklist

Structural Health Assessment is method of damage detection and categorization of civil structures after construction. It is necessary for every civil structure that after a fix time interval and after some natural and artificial hazards it should be structurally audited. The category in which structures to be categorized are: Firstly, Structure is completely safe, as per latest IS codes [1] and free from any damages or minor aesthetic repair is sufficient and it satisfy all safety and serviceability requirements, Secondly, Structure is having structural damages or structure is deficient, not as per latest IS codes or codal safety requirements, which can be rectified by retrofitting, rehabilitation etc. to satisfy the performance set by the user , Structure is badly damaged and no further repair is either economical or safe hence to demolish and rebuild or build back later. The processes involved are Visual inspection [2], Non-Destructive Test [3], Destructive Test etc. and further evaluation and recommendations.

1.2 Visual Inspection

Visual inspection to be carried with prior survey of locality, nearby structures, soil conditions, drawing details. If drawings are not available then first drawings need to be developed first. Standard checklist is required for carrying visual inspection. The checklist to be so prepared in that way that almost all the required information related to structures to audit have been covered. To fill all the checklist detail, experiences and knowledge of structural inspector is need to the most, apart from that, the tools and equipment and documents like drawings [4-5].

2. Why to perform Visual Inspection with checklist

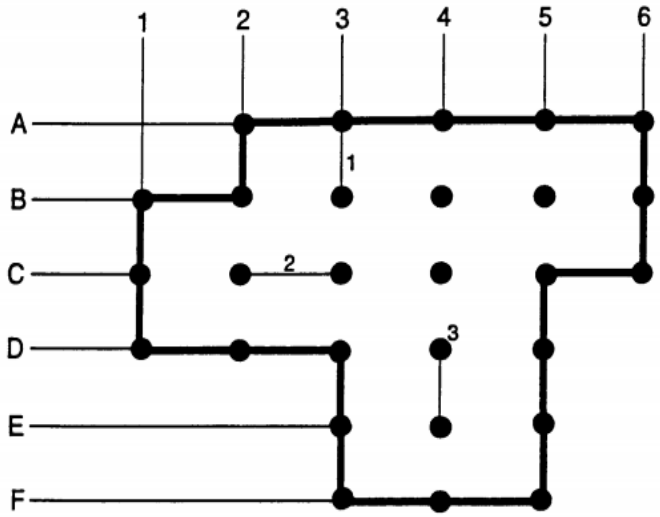
Visual Inspection is the first step towards performance of Structural Health Assessment and all the further decisions regarding Modelling, Nondestructive tests or destructive test, repair, retrofitting, rehabilitation, demolition etc. lies on the results of visual inspection only [6]. If standard checklist is developed for every nature of civil structure, then the errors will get reduced, consistency will be ensured and completeness will be achieved, systematic way will be adopted for inspection part. It is necessary that a systematic approach is to be adopted for visual inspection so that without missing any component or part the inspection has happened and step by step all components and factors have been covered while inspecting [7]. For all these requirements to cover a proper and standard checklist is to be prepared.

3. Considerations for Checklist development

To develop standard checklist all the observance which are to be considered while visually inspecting any civil structure need to be considered [8]. The factors like Seismic Zone, Wind zone, Flood Zone, Cyclone, Tsunami, landslides, Type of structure, Design and Drawing details, Type of damages (Architectural or Structural), are to be considered while checklist development. Checklist to be prepared in a very systematic way like first general detail then exterior envelope and lastly component inspection. The defects like Abrasion, Blistering, Chemical Deterioration, Cracking, Crazing, Discolouration, Dampness, Disintegration, Distortion, Efflorescence, Honeycombing, Pop-outs, Peeling, Spalling, Differential Settlements, Shrinkage, Stratification, Carbonation, Corrosion, ASR(Alkali Silica Reaction), AAR(Alkali Aggregate Reaction) Termite Effects and others are to be considered for all the places of frequent occurrences like exterior and interior walls, openings, foundations, columns, beams, slabs etc. Cracks Pattern considerations (plastic/ active/passive/longitudinal/transverse/diagonal/single etc.) are to be mentioned so that the severity of damages can be assessed. The severity of cracking is considered as function of crack width. (Hairline: upto 0.1mm; Minor: 0.1mm to 0.3mm; Moderate:0.3mm to 0.6mm; and Severe: Greater than 0.6mm) [9-10]. Colour considerations can be given like yellow, orange or red for safe, damage and repairable or severely damaged. Marking system may be developed to complete total assessment on summing up marks given to each section (0-no repair needed, 1-asthetic repair, 2-structural repair, 3- overall structural and architectural repair is needed). If the part has been opened up for examining (veener/ lamination /false ceilings) to be mentioned in checklist.
The details changed as per the civil structures. The requirements and defects vary as per civil structures.

4. Equipment required for checklist observance

Checklist is to be filled after or ongoing visual inspection. The equipment required are drawings, general details, notebook, checklist, camera, human eye and brain, measuring tape (computerized), vernier calipers, clipboard, pocket knife, magnifying glass, plumb bob, wire brush, inspection mirror, screw driver, pliers, marker, chalk crack comparator etc. All safety measures must to consider. It is normal to record date, time and weather conditions while doing the survey, the defects need to be photographed (with date and time mentioned).



PLAN (STRUCTURAL FRAME)
Floor Wise Sketch Plan to ease the location of particular segment.

Examples of Designation Usage:

1. Beam (A3-B3), if 2nd floor would be (A3-B3,2) etc.
2. Beam (C2-C3)
3. Column (D4)

Standard Format of checklist of visual inspection for Concrete structures has been developed considering majority of the factors.

Format of Detail Checklist:

VISUAL INSPECTION CHECKLIST				
DESCRIPTION		**YES**	**NO**	**OTHER DETAILS**
1	STRUCTURE NAME			
2	DATE OF INSPECTION			
3	WEATHER/TIME AT TIME OF INSPECTION			
4	NAME/DESIGNATION OF INSPECTOR			
5	NATURE/USAGE OF STRUCTURE			
6	TYPE OF STRUCTURE: RCC/LOAD BEARING/PRE-FABRICATED/CONCRETE/OTHERS.			
7	PREVIOUS INSPECTION DETAIL WITH INSPECTOR NAME/DESIGNATION.			
8	PREVIOUS FINDINGS AND REMEDIAL OPTED DETAIL			
BUILDING INFORMATION				
1	SEISMIC ZONE			
2	WIND ZONE			
3	SNOW FALL ZONE			
4	TSUNAMI/CYCLONE EFFECT (IF ANY)			
5	FLOOD ZONES			
6	ORIGINAL USE/PURPOSE			
7	CHANGED/PRESENT USE			
8	DAMAGES IN PAST DUE TO FIRE/FLOOD/EARTHQUAKE /SETTLEMENT/WATER TABLE CHANGE (IF ANY) WITH DETAILS OF DATES AND EXPENDITURES ETC.			
9	PREVIOUS REPAIR/ ALTERATIONS/RETROFITTING DETAILS (IF ANY)			
DETAILS AS PER DRAWINGS AND RECORDS				
1	DATE OF FINAL CONSTRUCTION/HANDING OVER OF STRUCTURE			

2	COST AT THE TIME OF CONSTRUCTION	
3	TOTAL MAINTENANACE EXPENSES TILL DATE	
4	PLAN/ELEVATION/STRUCTURAL DRAWINGS	
5	NUMBER OF STOREY	
6	PER FLOOR AREA DETAIL	
7	MASS IRREGULARITY (IF ANY)	
8	SOFT STOREY/RCC STRUCTURAL WALL ETC.	
9	PLAN AND ELEVATION SYMMETRICAL OR NOT.	
10	TYPE OF BUILDING MATERIAL USED CONCRETE/STEEL/PRESTRESSED CONCRETE/REINFORCED CONCRETE/PREFABRICATED ETC.	
	GENERAL DETAIL	
1	DRAWING AVAILABLE	
2	PRELIMINARY SKETCHES PREPARED	
3	ALL NECESSARY INFORMATION GATHERED	
4	DEFICIENCIES AS PER LATEST CODAL PROVISIONS	
	SOIL/FOUNDATION DETAIL	
1	TYPE OF FOUNDATION(PILE/RAFT/ISOLATED)	
2	ANY SIGN OF EROSION OF SOIL	
3	SIGN OF DISTURBED SOIL DUE TO ANIMAL BURROW/VEHICULAR TRAFFIC EFFECT.	
4	IS SOIL BEING RETAINED BY STRUCTURE (RETAINING/BASEMENT WALL)	
5	EVIDENCE OF SETTLEMENT AROUND PERIMETER OF BUILDING.	
6	PAVEMENT HEAVE OCCURRENCE BY SOIL.	
7	WALL CONDITION WITH DAMPNESS/SEEPAGE/OUT OF ALIGNMENT/ LEANING IN OR OUT	

8	CRACKS IF ANY(PATTERN AND NATURE TO MENTION)	
9	VEGETATION /TREE ROOT DAMAGE TO STRUCCTURE.	
10	FOUNDATION WALL EXTENSION BEYOND NORMAL FROST DEPTH.	
	DRAINAGE	
1	INFILTRATION SYMPTONS IN BUILDING.	
2	ALGAE/FUNGI ON SURFACE OF BUILDING.	
3	ANY ACTIVE WATER BODY NEARBY STRUCTURE. (RIVER/POND/STREAM ETC.)	
4	DRAINANGE DETAIL AND DISTANCE FROM STRUCTURE.	
5	SEPTIC TANK, SOAK PIT, RAINWATER STORAGE AND RECHARGE STRUCTURE DETAIL AND EFFECT ON BUILDING.	
6	CONTOUR ELEVATION OF DRAINS.	
7	FLASHING JOINTS, WEEP HOLES ETC.	
	CHEMICAL EFFECTS	
1	CHEMICAL STORAGE TANKS NEARY BY.	
2	SEWER PIPE LINES OR OTHER INDICATION OF CHEMICAL LEAKAGE/SPILL.	
3	CHEMICAL CORROSION, SULPHATES ACIDS, BASES, CHLORIDE, GASES.	
	OTHER PHYSICAL EFFECTS	
1	HEAVY VEHICULAR TRAFFIC MOVEMENT	
2	COLLISION OR ANY COLLAPSES OR PART COLLAPSES.	
3	HEAVY VIBRATIONS DUE TO FACTORY OR OTHER SIMILAR STRUCTURES.	
	EXTERIOR ENVELOPE INSPECTION	
	WALL/PARAPETS ETC.	
	TYPE OF WALL (RCC FRAMED/LOAD BEARING/ SEMI FRAMED/SEMI LOAD BEARING/OTHER).	
	BUILDING MATERIAL USED.	

	ROLE OF WALL (MASONRY INFILL/LOAD CARRYING).	
	SURFACED WITH CLADDING/VENEER/LAMINATED ETC.	
	OUT OF PLUMB OR IN LINE/ BULGING/UNEVENNESS IN WALL.	
	DEFLECTION, CRACKS (LOCATION TYPE, WIDTH AND DEPTH OF CRACK)	
	ANY SURFACE DEFECTS (IF AVAILABLE)	
	DAMAGES TO PARAPETS AND CHAJJAS.	
	SIGN OF WATER INFILTRATION AROUND OPENINGS AND OTHER PARTS.	
	CONTINUOUS LINTEL BAND IS THERE OR NOT.	
	ARE CRACKS ON JOINING OF MASONRY AND RCC. (WIRE MESH ON JOINTS PROVIDED OR NOT).	
	OPENINGS DETAIL	
	DEFLECTION/SAGGING OF WALL ABOVE OR BELOW THE OPENINGS.	
	DIAGONAL CRACKS AT THE CORNER OF OPENINGS.	
	DISTORTION OF OPENINGS.	
	WATER INFILTRATION SYMPTONS	
	EVIDENCE OF ABRASION AND IMPACT.	
	EVIDENCE OF TERMITE EFFECTS ON DOORS AND WINDOWS	
	CONDITION OF MATERIAL USED FOR DOORS, WINDOWS ETC.	
	ROOF	
	WATERPROOFING DONE OR NOT.	
	WATER STAGNANCY ON ROOF.	
	CONDITION OF ROOF SLOPES, RAIN WATER PIPE, CLOGGING ETC.	
	SAGGING OF ROOF	
	WATER INFILTRATION AT OPENINGS OR JOINTS ETC.	
	DO THE ROOF CONSIDERED RAIN WATER HARVESTING.	

	ANY STRUCTURAL DEFECTS ON ROOF SURFACE.	
	FOUNDATION	
	METHOD USED TO ACCESS CONDITION OF FOUNDATION (RADIATION, GPR METHOD OR ACTUAL EXCAVATION OF SOME PART)	
	CRACKS IN FOUNDATION WALL.	
	LOCATION OF CRACKS (NEAR TO STRUCTURAL JOINTS OR ANYWHERE ELSE) (PROPER LOCATION TO MENTIONED)	
	PIER ALIGNMENT OR OUT OF PLUMB.	
	DIFFERENTIAL SETTLEMENT OF FOUNDATION.	
	CONDITION OF PLINTH PROTECTION (CRACKED/ SETTLED/DISRUPTED/RUPTURED ETC.)	
	COVERING CONDITION OF FOUNDATION WITH SOIL.	
	FLOORS, CEILINGS AND PARTITIONS	
	DIFFERENTIAL SETTLEMENTS OF FLOOR	
	CRACKS ON FLOOR	
	TYPE OF FLOORING(TILE/MOSAIC/OTHERS).	
	SAGGING/BULGING/DISCOLOURING	
	CONDITION OF FLOORING	
	ARE PARTITION SUFFERS SAGGING/BULGING/OUT OF PLUMB.	
	PARTITION MATERIAL AND CONDITION DETAIL	
	CEILING MATERIAL AND CONDITION DETAIL	
	COMPONENT INSPECTION	
	WALLS(INTERIOR)	
	CLADDING /VENEER DETAIL IF ANY.	
	SIGN OF WATER PENETRATION	
	ROLE OF WALL (STRUCTURAL SUPPORT/MASONRY INFILL)	
	PLUMB DETAIL OF WALL.	
	SURFACE DEFECTS OF WALL.	
	COLUMNS	

	PROPER ALIGNMNET OF COLUMNS	
	PLUMB OF COLUMN	
	CRACKS (IN COLUMN) PATTERN OF CRACKS WIDTH /DEPTH OF CRACKS.	
	SAGGING / VERTICALITY CHANGE.	
	MID SECTION/END SECTION SIZES OF COLUMN	
	BEAMS AND GIRDERS	
	DEFLECTION	
	CRACKING (WIDTH/DEPTH)(DIAGONAL/LONGITUDINAL/ TRANSVERSE/OTHERS)	
	CHANGE IN SECTION SIZES (MID AND END SPAN).	
	CORROSION CONDITION	
	CONDITION OF LATERAL SUPPORT OF FRAMING STRUCTURE.	
	EVIDENCE OF ABRASION IF ANY.	
	ABRASION DUE TO SLIDING OR CRACKS DUE TO STRESS CONCENTRATIONS AT CONNECTIONS	
	LOCATION OF CRACKS/DEFLECTION (END SPAN, JOINTS, MID SPAN).	
	INTERSECTIONS/CONNECTIONS	
	CRACKS/DEFLECTION AT INTERSECTION OF BEAMS AND COLUMNS, BEAMS AND SLABS, COLUMNS AND FOUNDATIONS ETC.	
	STEEL/OTHER CONNECTION CONDITION	
	SURFACE DEFECTS AT CONNECTIONS OR INTERSECTING AREAS.	
	CORROSION CONDITION OF STEEL-TO-STEEL CONNECTIONS	
	SLABS/	
	CRACKING AT COLUMN BASE.	
	SIGN OF SETTLEMENTS.	
	FLOOR/WALL SETTLEMENTS/SEPERATIONS OR SETTLEMENTS.	
	CONDITION OF WATER PROOFING.	

	CIRCUMFERENTIAL CRACKING IF ANY.	
	FLOORING	
	CRACKING	
	SIGN OF SETTLEMENTS.	
	FLOOR/WALL SETTLEMENTS/SEPERATIONS OR SETTLEMENTS.	
	CIRCUMFERENTIAL CRACKING.	
	STAIRCASE	
	DAMAGES ON STAIRS.	
	CRACKING/CORROSION	
	REINFORCEMENT EXPOSURE IF ANY.	
	CONDITION OF HAND RAILS , RISE, TREADS, LANDING, PLATFORM ETC.	
	LIGHT CONDITION FOR THE STAIR AREA.	
	CONNECTION/ANCHORAGE OF HAND RAILS.	
	LIFTS	
	CONDITION OF CHORD, GRILLS, DOORS, BUTTONS, SWITCHES, FAN, LIGHTS ETC.	
	LIFT DUCT (CRACKS/DAMAGES) ETC.	
	SANITARY FITTINGS AND PLUMBING	
	LEAKAGES/SEEPAGES DUE TO PIPES/ FITTINGS ETC.	
	CONDITION OF ALL THE PIPES (SEWER/RAIN WATER/WATER SUPPLY) WITH FITTINGS AND ACCESSORIES.	
	CONDITION OF SEPTIC TANK, SOAK PIT, WATER TANK, FIRE FIGHTING WATER TANK, RAIN WATER HARVESTING RECHARGE AND STORAGE SYSTEM.	
	DAMAGES WATER TREATMENT PLANT IF ANY.	
	DAMAGES OF SEWERAGE TREATMENT PLANT IF ANY.	
	ELECTRICAL INSTALLATION	
	CONDITION OF WIRES, SWITCHBOARDS AND OTHER EQUIPMENTS.	

	FIRE SYSTEM	
	WALL WITH ELECTRICAL CONDUITS/EQUIPMENTS IF HAVING SEEPAGE	
	SOLAR PANELS/ BATTERIES/SWITCHES ETC. AND THEIR CONNECTION TO STRUCTURES.	
	PREFABRICATED STRUCTURES	
	TYPE OF MATERIAL USED	
	THE SANDWICHED PANEL LOCATION(HORIZONTAL/VERTICAL/PARTITION)	
	CONDITION OF PREFABRICATED STRUCTURE.	
	COMMON SURFACE DEFECTS FOR ALL THE COMPONENTS. (This should be common observance for each component mentioned above).	
	BEAM/COLUMN/OPENINGS/SLABS/FLOORS/GIRDERS/WALLS/FOUNDATIONS ETC.	
	ABRASION	
	BLISTERING	
	CHEMICAL DETERIORATION	
	CRACKING	
	LONGITUDINAL	
	TRANSVERSE	
	DIAGONAL	
	PATTERN	
	SINGLE	
	CRAZING	
	DISCOLORATION	
	DISINTEGRATION	
	DISTORTION	
	EFFLORESCENCE	
	HONEYCOMBING	
	PEELING	
	PITTING	
	POP-OUTS	
	REINFORCEMENT CORROSION	
	SCALING	
	SPALLING	
	STRATIFICATION	
	ASR/AAR (ALKALI SILICA REACTION/ ALKALI AGGREGATE REACTION)	
	OTHER	

Some Considerations

	DESCRIPTION	**REMARKS**
	OVERALL APPARENT ALIGNMENT OF STRUCTURE SETTLEMENT/DEFLECTION/EXPANSION/CONTRACTION	
	GENERAL CONDITION OF CONCRETE SURFACE GOOD/SATISFACTORY/POOR	
	FORMED AND FINISHED CONCRETE SURFACE	
	EXISTING USAGE AND LOADING CONDITION OF STRUCTURE IS COMPATIBLE WITH INTENDED PURPOSE.	
	EXPOSURE TO AGGRESSIVE ENVIRONMENT (PRESENCE OF COLUMN(S) IMMERSED IN WATER). (PRESENCE OF EXCESSIVE CHEMICALS ESPECIALLY IN INDUSTRIAL BUILDINGS).	
	RETAINING WALLS/SLOPE PROTECTION (GROUND ANCHORS/SOIL NAILS ETC.)	
	WALL MOVEMENT/INTENDED IMPOSED LOADING BEHIND WALL/TENSION CRACKS ETC.	

Major Findings (with location details)
Further Recommendations …….
Repairs required.

Signature of Inspector **Signature of Owner**
DATE:……...
PLACE:…….

5. Conclusion:

- The checklist must be feasible; the quality of the health assessment of structure can be managed only if inspector sincerely fill each and every section of checklist.
- The checklist is to be accompanied with photographs and drawing details.
- The standard checklist is to be developed for every type of civil structures to ease and differentiate the assessment process based on structure type.
- The time limit to perform visual inspection is one to two hours and checklist filling is another one hour per structure.
- Each and all parameters and factors right from building details, site survey, exterior envelope components and internal components need to be considered for each part of structure. Their type of defects will only vary.
- Each sheet of checklist is to be signed by inspector along with date.
- The comprehensive checklist filling relies on professional engineering assessment, judgement and advice of structural engineer.
- Covered part with work like veneer, lamination, cladding, false ceiling etc. are to be removed to audit the part.
- The checklist must be unambiguous, component must be marked clearly, numbers to each column, beams, floors, slabs, openings should be provided in order so that particular part must be clearly located and identified.
- While inspecting the portion/part of structure which are not accessible to be mentioned on checklist remarks.

References:

[1] *IS 456:2000* Plain and Reinforced Concrete - Code of Practice. *Bureau of Indian Standard, India*.

[2] R. T. Chin and C. A. Harlow, "Automated Visual Inspection: A Survey," in *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. PAMI-4, no. 6, pp. 557-573, Nov. 1982, doi: 10.1109/TPAMI.1982.4767309.

[3] J. Helal, M. Sofi and Mendis, P. (2015) "Non-Destructive Testing of Concrete: A Review of Methods", *Electronic Journal of Structural Engineering*, 14(1), pp. 97–105. doi: 10.56748/ejse.141931.

[4] ACI 201.1R-08 Guide for conducting a visual inspection of concrete in service, *American Concrete Institute, July 2008.*

[5] Construction Inspection Report, Texas department of Transportation. TxDOT Internal Audit Division.

[6] The Inspection and maintenance of Civil engineering assets, *Heritage Railway association, Version 1.1 July 2014.*

[7] Structural Inspection Manual, Part 3, *Structural Inspection procedures, September 2016, Queensland Government.*

[8] Model Building Bye Laws, Town and country planning organization, *Ministry of urban development, India, 2016.*

[9] National Building Code, *Volume1 and Volume 2, Bureau of Indian Standard, India, 2016.*

[10] *IS 13935:2004* Seismic evaluation, repair and strengthening of masonry buildings guidelines, *Bureau of Indian Standard, India.*