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Structural stability analysis of structure by destructive and NDT: a case study of Ladies hostel, Vallabh Vidyanagar, AnandGuj

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Abstract

It is important to analyze the old structures for structural integration to understand the type and extent of damage the structure has sustained and what type of retrofitting is further required. The case study involves a 55 years old building that has suffered extensive weathering damage. Rigorous analysis for functionality and durability of the structure was done using non-destructive testing methods (NDT) and core cutting. Two NDT methods employed were ultrasonic pulse velocity (UPV) and rebound hammer (RH) along with core cutting at a critical location. A damage contour map was drawn for a better understanding of the extent and intensity of damage sustained by the structure and appropriate retrofitting and repairs were advised.

Keyword – *Core cutting, Damage contour, Rebound hammer, Ultrasonic pulse velocity.*

I. INTRODUCTION

Concrete is a widely used construction material. Its properties change right from the time of casting to the end of its lifetime. The structure would undergo damage because of many reasons including the damage to concrete, rusting of steel. Damage sustained by the structural system could be because of changes in loading conditions (including earthquake loading) and because of exposure to materials. NDT methods such as rebound hammer, ultrasonic pulse velocity, acoustic wave emission, and many more are employed throughout the world to understand the damage sustained by various structures.

Out of many available methods, UPV and RH are the most predominant and widely used methods employed around the world and in India. They are preferred because of the accuracy and ease with which they can be employed in the laboratory as well as on-site. Proper testing can help in understanding the damage sustained by structure and can be very helpful in exploring the best options for repair and retrofitting.

For this case study, UPV and RH were performed along with core cutting at some critical locations.

A. Rebound Hammer test

It is an NDT method of concrete that provides a convenient and rapid indication of the compressive strength of the concrete surface. IS: 1311-2(1992) is followed as a guide handbook.

Calibration can be done by placing a 15X30 cm cylinder (given the same proportion of coarse and fine aggregate are used in casting them as on job) in a compression testing machine to obtain compressive strength. Several readings, well-distributed and reproducible, will help in obtaining the average rebound number.

Advantages:

The Schmidt hammer provides an inexpensive, simple, and quick method of obtaining an indication of concrete strength, but the accuracy of ±15 to ±20 percent is possible only for specimens cast cured and tested under conditions for which calibration curves have been established.

Disadvantages:

The results are affected by factors such as smoothness of surface, size and shape of the specimen, moisture condition of the concrete, type of cement and coarse aggregate, and extent of carbonation of surface.

B. Ultra-Pulse Velocity test

It's a dynamic non-destructive test. It's an in-situ NDT test to check the quality of concrete. In this test, the strength and quality of concrete are assessed by measuring the velocity of an ultrasonic pulse passing through a concrete structure. In the portion where there is leakage or moisture UPV tests are ineffective. IS: 1311-2(1992) is followed as a guide handbook.

Fundamental features of all commercially available units are similar, consisting of the pulse generator and pulse receiver. Pulses are generated by shock-exciting piezoelectric crystals, with similar crystals used in the receiver. The time taken for the pulse to pass through the concrete is measured by electronic measuring circuits.

Factors affecting measurement are as follows.

1. There must be smooth contact of transmitter and receiver with the concrete surface for that a thin film of oil or grease or acoustic gel is used.
2. Distance (i.e. path length between transmitter and receiver) should be at least 30cm to avoid any errors by heterogeneity.
3. The presence of reinforcing steel in concrete has an appreciable effect on pulse velocity. It is therefore desirable and often mandatory to choose pulse paths that avoid the influence of reinforcing steel or to make corrections if the steel is in the pulse path.

Application:

A fairly good correlation can be obtained between cube compressive strength and pulse velocity. These relations enable the strength of structural concrete to be predicted within ±20 percent, provided the types of aggregate and mix proportions are constant.

The pulse velocity method has been used to study the effects on the concrete of freeze-thaw action, sulfate attack, and acidic waters. Generally, the degree of damage is related to a reduction in pulse velocity. Cracks can also be detected. The pulse velocity method can also be used to estimate the rate of hardening and strength development of concrete in the early stages to determine when to remove the formwork.

Ultrasonic pulse velocity tests have great potential for concrete control, particularly for establishing uniformity and detecting cracks or defects.

Limitation:

As concrete ages, the rate of increase of pulse velocity slows down much more rapidly than the rate of development of strength, so that beyond the strength of 13.6 to 20.4 MPa accuracy in determining the strength is less than ±20%.

Its use for predicting strength is much more limited, owing to the large number of variables affecting the relation between strength and pulse velocity.

C. Core cutting

It is destructive testing where a core sample is taken with the help of a drill and later it is tested in the laboratory. Many tests could be performed on such samples such as compression testing, RCPT (rapid chloride permeability test), split tensile test, etc.

The building is Four Storey load-bearing structure, constructed in 1965 as informed by the authority and is not well maintained as per appearance. The concrete has undergone heavy damage due to exposure. To get a proper understanding of the extent of damage and residual concrete strength rebound hammer tests, UPV tests, and if necessary core cutting was performed.

PLANS & LAYOUT:

As the building doesn't have its original plan so a line diagram was made for convenience. The hostel is a four-story structure with a reading room living quarters and dining hall on the ground story. Each other floor has 34 rooms for the student. Between each floor on both sides of the stairs landing, there are bathrooms and restrooms. On the terrace, there are 4 water tanks on the stair cabin.

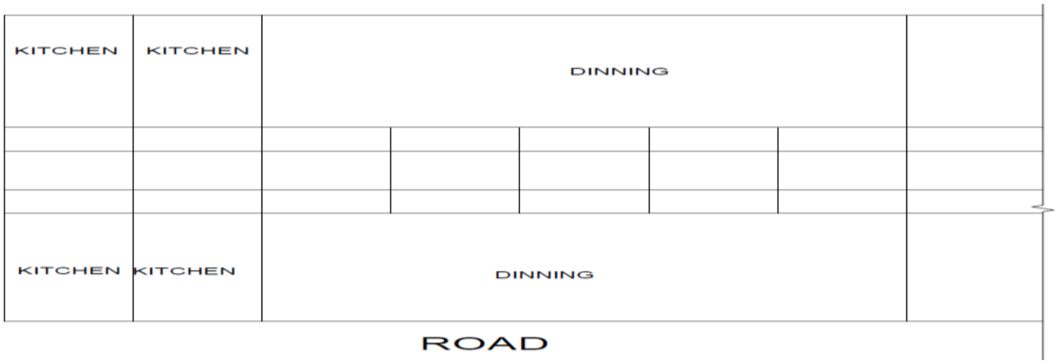

Fig. 1 Ground Floor Plan

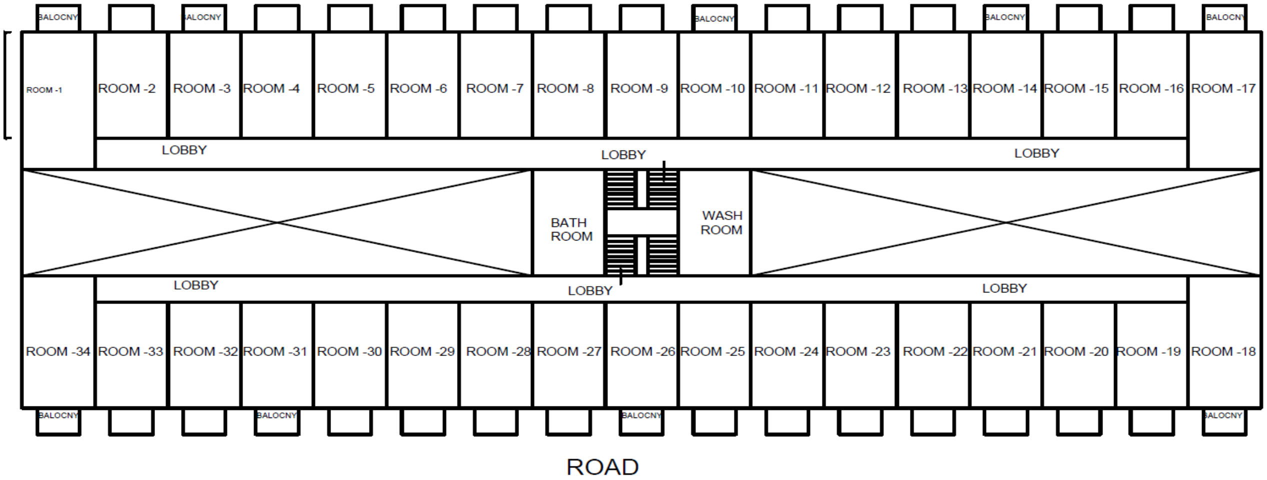

Fig. 2 First Floor Plan

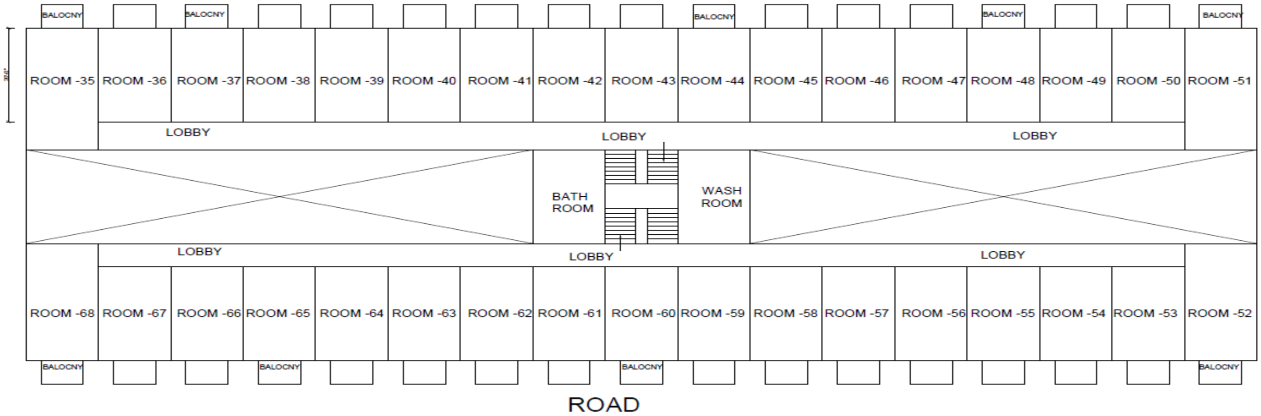

Fig. 3 Second Floor Plan

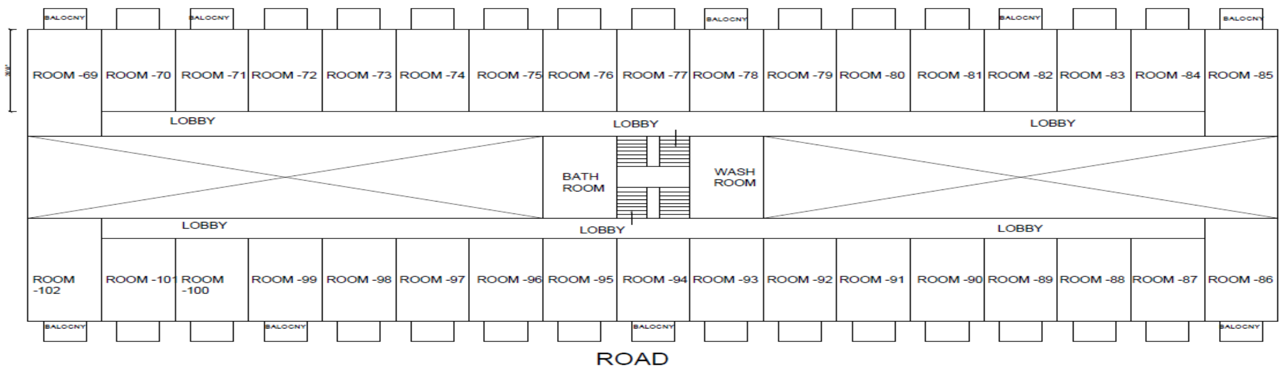

Fig. 4 Third Floor Plan

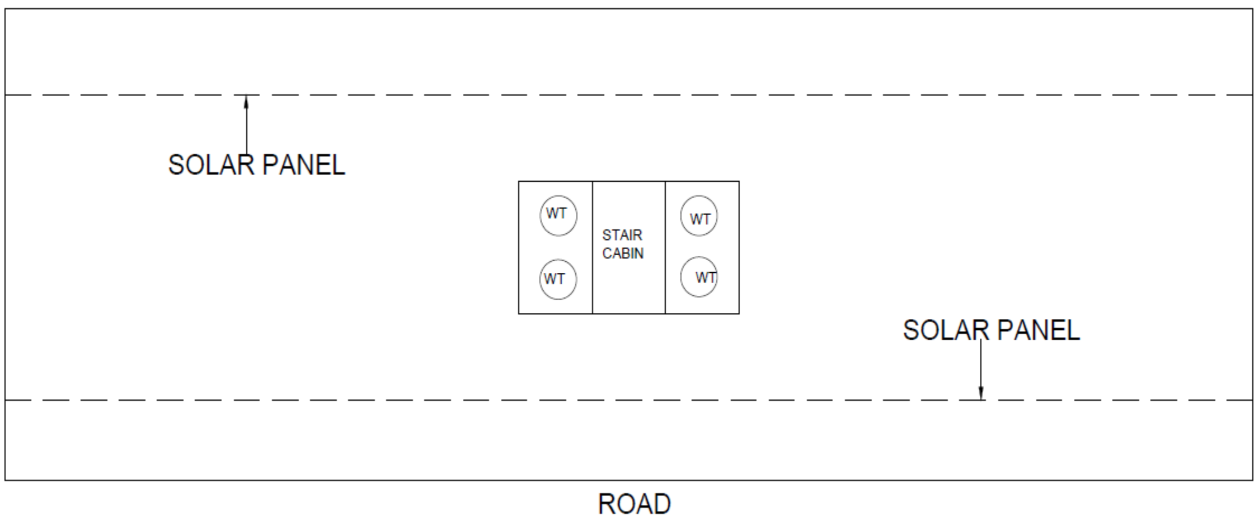

Fig. 5 Terrace Floor Plan

STRUCTURAL SYSTEM

Table: A Structure has the following components.

Material	Component	Size(mm)	
BRICK	Walls	350 thick 230 thick	Plastered
RCC	Slabs	150(assumed)	Plastered
	Beam (including slab thickness)	B1:350X450 B2:230X450	Plastered
	Parapet walls	75 thick	Without plaster

- The staircase is a combination of two half-pace stairs.
- The ground floor slab is open to the sky.
- Each other floor has a common lobby and each room has an individual standing balcony.

II. OBJECTIVE

To understand the extent of damage endured by concrete, draw a contour map of damage on the structure-based upon the NDT and core cutting results and to recommend remedies to ensure the structural and functional stability of the structure.

III. CRITICAL LITERATURE REVIEW

- Factors affecting the reliability of assessing the concrete strength by rebound hammer and core.

Author: Maitham Alwash, Denys Breysse, Zoubir Mehdi Sbartaï, Katalin Szilágyi, Adorján Borosnyói.

In this paper reliability of an assessment is studied based on the location, number of tests, and the true value of concrete strength variability, within test variability of rebound measurement, accepted uncertainty level, and selection of core locations.

- Embedding ultrasonic transducers in concrete: A lifelong monitoring technology.

Author: Arnaud Deraemaeker, CédricDumoulin.

A new technique called the Direct Wave Interferometry (DWI) is introduced which uses time stretching only on the early part of the recorded wave. Which is a good trade-off between the high resolution of the Coda Wave Interferometry (CWI) for low-velocity variations and the reliability of the measurement of the time of flight (TOF) for large velocity variations.

IV. RESULTS

Table: B NDT results

Sr. no	Location	Element	Rebound hammer		Ultrasonic pulse velocity
			R. no.	fck	Vel. (m/sec.)
1	1st floor room 2 lobby	Beam	29.7	24.6	2177
2	1st floor room 6 lobby	Beam	21.15	16.8	2650
3	1st floor room 12 lobby	Slab	39.8	38.6	1705
4	1st floor room 16 lobby	Beam	41	38.6	4185
5	1st floor room 20 lobby	Slab	34	28	2020
6	1st-floor room 20 lobby	Beam	42	37.8	-
7	1st floor room 23 lobby	Beam	48	42.7	4380
8	1st floor room 23 lobby	Slab	40	33.7	1550
9	1st floor room 25 lobby	Slab	36	35	2000
10	1st floor room 28 lobby	Beam	40.4	43.3	4190
11	1st floor room 32 lobby	Slab	42.7	47.3	2275
12	1st floor room 33	Beam	37.4	37.8	4370
13	2nd floor room 46	Slab	40	31.5	2900
14	2nd-floor room opp. 60	Stair slab	42.2	36	-
15	2nd floor between room 45 and 46	Beam	43.3	38	4190
16	2nd floor room 48 lobby	Slab	35.2	24.3	-
17	2nd-floor room 43	Beam	34.11	20	-
18	2nd-floor opp. Room 60	Stair slab	49.11	50.5	-
19	2nd floor room:43	Beam in lobby	34.11	35	-
20	2nd-floor opp. Room 42	Stair slab	37.22	29	-
21	2rd floor room 60	Inclined slab	49.11	52	1720
22	3rd floor room 77	Inclined stair slab	42.33	34.5	2110
23	3rd floor room 77-94	Slab (front of room 77-94)	39	32	-
24	3rd-floor room 77	Stair slab beam	40	34	1740
25	3rd-floor opp. Room 94	Stair slab	46.44	49	-
26	3rd-floor room 98	Slab	34	22.5	-
27	3rd-floor room 100	Slab	32.5	19	-
28	3rd-floor room 72 lobby	slab	36	26	-
29	3rd-floor room 82 lobby	beam	30.5	27	-
30	3rd-floor room 84 lobby	beam	31.4	19.5	-
31	3rd-floor room 90 lobby	slab	33	21	-

32	Between room 9, 10, 26 and 25	Straight stair slab	39	32	1230
33	The terrace above room 102	Parapet wall	35	32	-
34	The terrace above room 80	Slab	42	36.8	-
35	Terrace above room 85	Slab	35	38	1400
36	Terrace stair cabin washroom	Slab	29	12.5	-
37	Terrace stair cabin concrete w.t.	slab	44.1	50.3	-
38	Terrace stair cabin concrete w.t.	slab	45.1	52.3	-
39	Terrace stair cabin concrete w.t.	slab	48	58	-
40	Terrace stair cabin concrete w.t.	wall	55	62	1970
41	Terrace stair cabin bathroom	wall	27.9	21.6	-
42	Terrace stair cabin	slab	31	26.7	2290
43	Room 10	Inclined slab	37.11	29	-
44	B/w room:9,10 and room:25,26	Straight slab landing	39	32	1230
45	Kitchen	Beam pt:1	49.67	53	-
46	Kitchen	Beam pt:2	50.77	54	-
47	Dining	Beam pt:3	35.22	36	-
48	Dining	Beam pt:4	31.22	17	-
49	Dining	Beam pt:5	43.44	33	-
50	Entrance (opp. to reading room)	Main Beam	41	32.5	-

V. OBSERVATION

From the NDT results, it is inferred that the structural members have sufficient strength.

According to IS standards, the test results show that the quality of concrete is doubtful in most cases and at best they are good in some cases.

- **Masonry Walls:** The brick masonry walls are 350mm and 230mm thick and observed to be in a good condition with only a few shear cracks and Moisture-associated skin damage (MASD) especially on the walls corresponding to restrooms and bathrooms.
- **RCC Slabs:** It has been observed that the slab of the lobby on the 1st floor is moderately damaged because of the weathering effect. One of the reasons for such damage is also because of poor workmanship during the time of construction. River pebbles are used in the entire structure except for the terrace. Proper cover to the reinforcements was not provided and because of that, substantial corrosion in reinforcements is observed due to weathering. Reinforcements in the slab of the lobby are exposed especially on the 1st and 2nd floors and there is water leakage on the slab of the 3rd floor which is due to the installation of solar panel on the terrace above room no 86 to 102.
- **RCC Beams:** The main beams on each floor are in good condition. Beams supporting the slab of the lobby are overhanging and are severely damaged. Beams in the dining hall and kitchen are also in good condition.
- **RCC Parapet walls:** The parapet walls are damaged because of weathering. On the balcony because of the parapet wall, the cantilever slab is getting damaged.

CORE TESTING RESULTS

Correction: IS: 516-1959 (pg.: 13 fig: 1 correction factor vs length/dia. graph)

Uncorrected result: $\frac{(matric\ ton)\times 10^4}{\frac{\pi}{4}\times D^2}$ D (dia. of the sample): 68mm

Corrected result: uncorrected result$\times$1.25$\times$correction

A	LENGTH (mm)
B	L/D
C	CORRECTION
D	MT (Metric Ton)
E	uncorrected results
F	corrected results

Table: C Core testing results

SR. NO.	LOCATION	SAMPLE	DIMENSION			COMP. TEST RESULTS			REMARK
			A	B	C	D	E	F	
1	BRACKET	BK-2	128	1.882	0.989	4.2	11.563	14.292	unsatisfactory
2		BK-3	105	1.544	0.953	8.9	24.503	29.184	satisfactory
3		BK-1	130	1.912	0.992	6.4	17.620	21.847	satisfactory
4	LOBBY	FH-1	68	1.000	0.895	12.2	33.589	37.578	satisfactory
5		FH-2	148	2.176	1.020	9.8	26.981	34.401	satisfactory
6	BALCONY WALL		115	1.691	0.968	7.1	19.548	23.663	satisfactory
7	TERRACE		160	2.353	1.039	6.6	18.171	23.594	satisfactory

VI. CONCLUSIONS AND RECOMMENDATIONS

- From the observation itself, dampness and plenty of traces of water leakage were found. This kind of damage is predominant in the walls and slabs corresponding to the restroom and bathroom. Before making retrofitting for this issue it is very important to have a good drainage system and for that, the old system must be repaired and additional provisions must be made so that water doesn't get stagnated at a place.
- Some of the components of the building have not deteriorated but the walls, slabs, and beams corresponding to restrooms, bathrooms, and other leakage prone areas must be properly waterproofed.
- From tests and observations, it is clear that the building hasn't suffered any major damage because of loading conditions but most of the damage is because of weathering and inadequate maintenance. The moisture and leakage have led to severe corrosion in reinforcements.
- Mostly all the sub-locations of the ground floor are relatively undamaged but the balconies of all the room (wall and slab of balconies), slabs of the lobby, and terrace slab are damaged considerably and must be retrofitted or removed as early as possible.
- Few samples of core were tested after performing the core cutting of some doubtful locations to get an idea about the extent of deterioration and damage. These samples were taken on 1st October 2019 and were tested on 17th October 2019.

➢ From the tests and observations, the components of the building could be divided into three types.

Type A: severely damaged and needs immediate retrofitting. The reinforcement in this region is exposed and intensely corroded.

Type B: moderately damaged and needs proper retrofitting. Where the leaking of the slab and dampness involve affecting the overall structural system.

Type C: scarcely damaged and needs basic retrofitting.

Type A	All room balcony. Lobby slabs near the washrooms and bathrooms. The interior part of the kitchen. A slab of washrooms of stair cabin on the top floor.
Type B	All rooms at the top floor level. Stair slab and landing slab. Walls corresponding to restrooms and bathrooms.
Type C	All remaining rooms, dining and assembly area

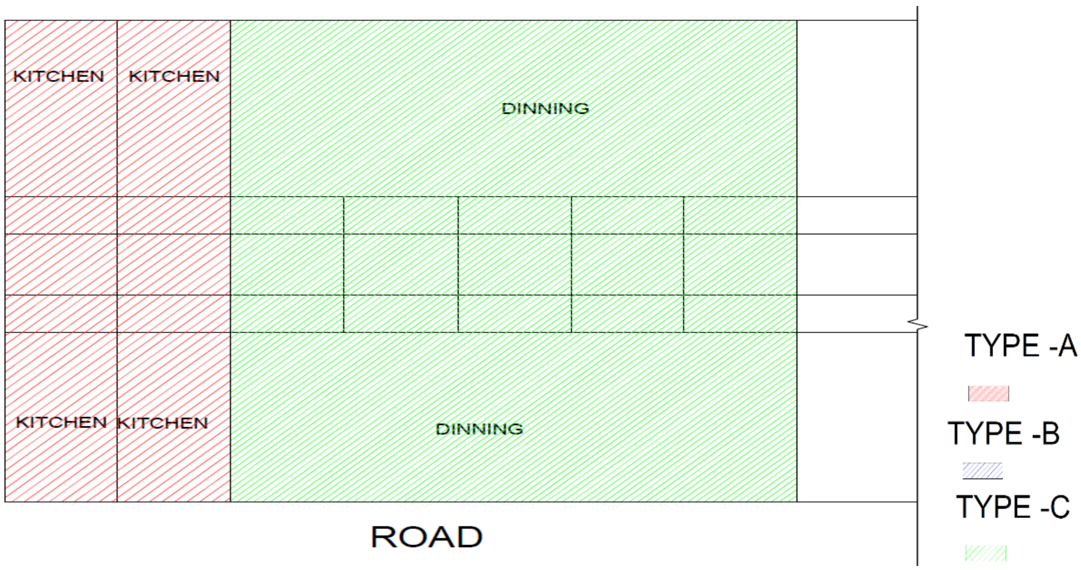

Fig. 6 Ground floor damage contour

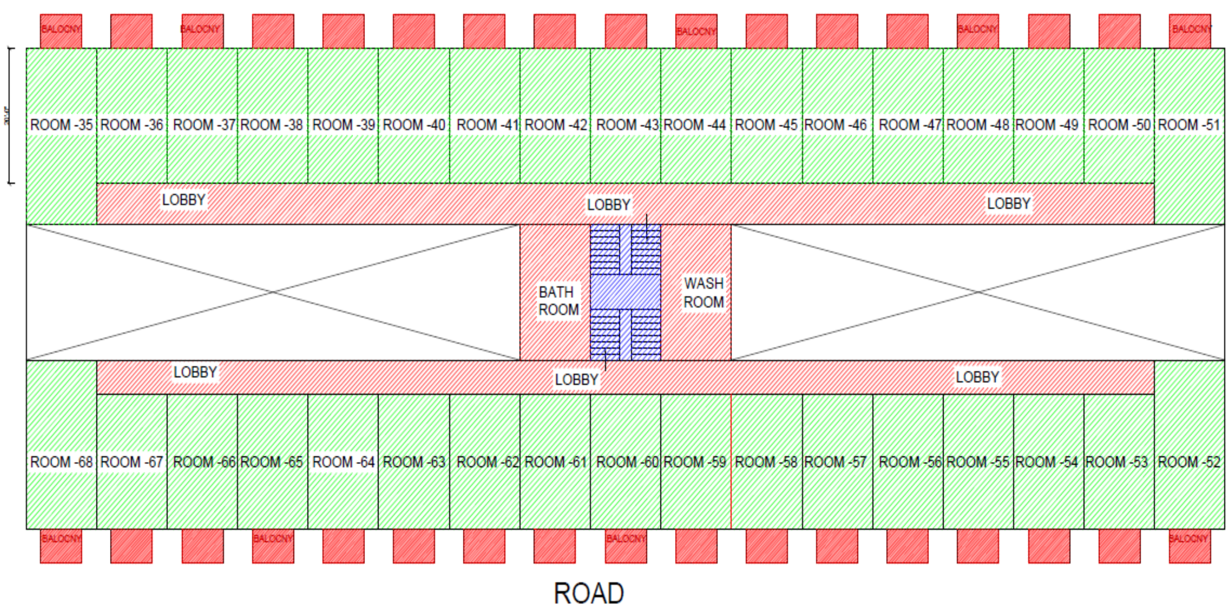

Fig. 7 1st and 2nd-floor damage contour (1st and 2nd floor have the same plan as far as damage contour drawing is concerned)

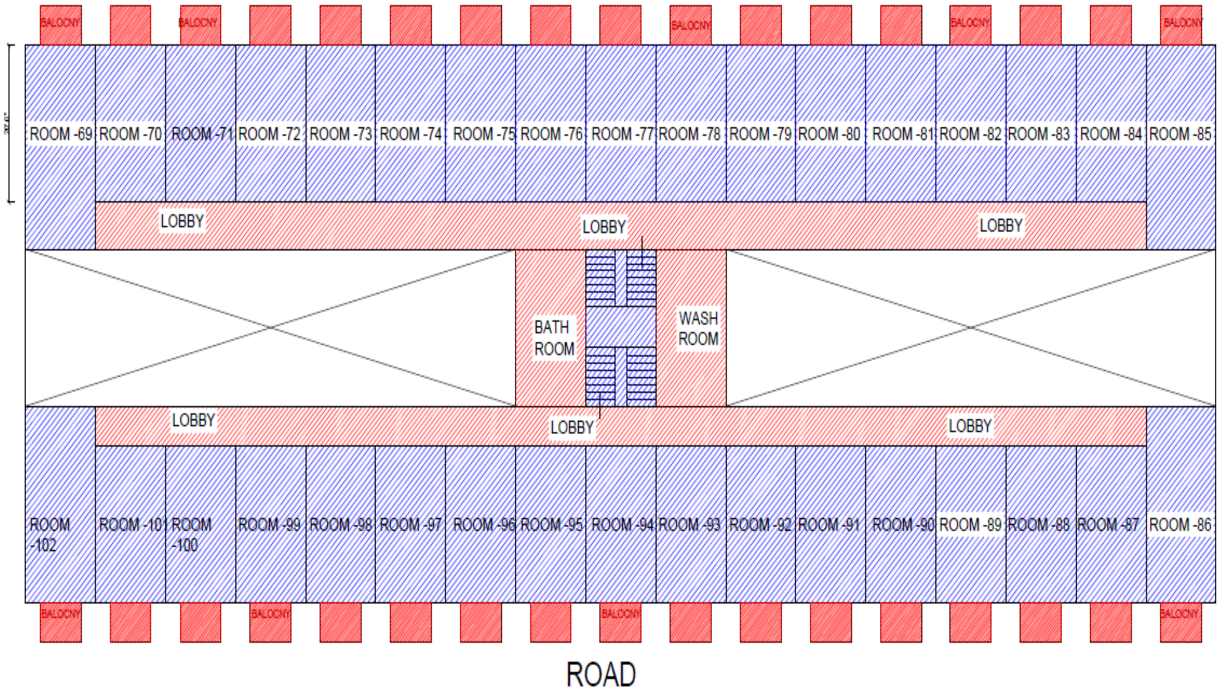

Fig. 8 3rd floor damage contour

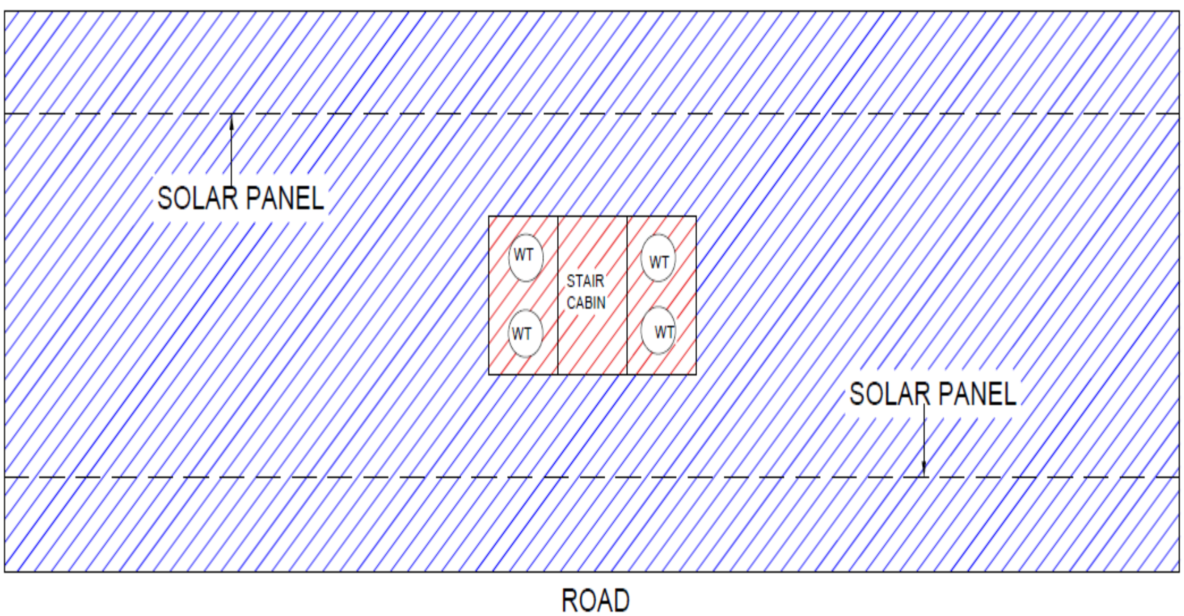

Fig. 9 terrace floor damage contour


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