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RECONNAISSANCE SURVEY OF TOWER A, B, C OF ARMY WELFARE HOUSING ORGANISATION "CHANDERKUNJ ARMY TOWERS" AT SILVER SAND ISLAND, VYTILLA, KOCHI, KERALA

APRIL 2021

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RECONNAISSANCE SURVEY OF TOWER A,B & C OF ARMY WELFARE HOUSING ORGANISATION "CHANDERKUNJ ARMY TOWERS" AT SILVER SAND ISLAND, VYTILLA, KOCHI, KERALA

APRIL 2021

Report on	:	Reconnaissance Survey Of Tower A, B & C Of Army Welfare Housing Organization "Chanderkunj Army Towers" At Silver Sand Island, Vytilla, Kochi, Kerala
Report for	:	M/s Army Welfare Housing Organization (AWHO) Vytilla, Kochi, Kerala.
Reference	:	Ref: SPI/621/2020-21 dated 15th October 2020 and Mail dated 24/09/2020 by Col. Venugopalan V K, Secretary, Managing Committee, Chanderkunj Army Towers
Period of Investigation	:	2nd to 6th March 2021 & 7th to 12th April 2021
Investigation carried out under the guidance of	:	Mr. Mohankumar Head-South Asia Region-NDT & RR Services Dr. Shantharaju Technical Advisor- Design review, NDT & RR M/s Bureau Veritas (India) Pvt Ltd,
Investigation carried out by	:	Mr. Ravishankar R N Manager–BD, Mumbai. Mr. Avinash J Technical Manager-NDT & RR Mr. Shivakumar M S Manager-NDT Mr. Girish R Manager-NDT Mr. Sreenivasa MT Senior Executive Mr. Bommanna Senior Technician-NDT Mr. Sebin Thomas Das Engineer-NDT

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Investigation carried out in the presence of	**:**	Maj Gen Rajagopal, AVSM,VSM (retd) President, Chanderkunj Army Towers Col. Venugopalan V K, Secretary, Ex-Managing Committee. Col. Jayaraman Technical Coordinator Col. Anil Raj Technical Coordinator Smt. Bindiya Suthan Technical Coordinator Mr. Jaya Kumar Velloor Manager M/s Army Welfare Housing Organization (AWHO) Residential Welfare Association (RWA) Managing committee, Chanderkunj Army towers Kochi
Date of submission of Pre-final report	**:**	15th May 2021

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Disclaimer:

The technical information furnished in this report is based on the inspection carried out by M/s. Bureau Veritas India Pvt Ltd. The responsibility of M/s. BVIPL is only to the technical content of this report. M/s. BVIPL shall not in any way be responsible for any consequential matters.

A. INTRODUCTION

The existing **Army Welfare Housing Organization "Chanderkunj Army Towers"** residential apartment building located at Silver Sand Island, Vytilla, Kochi, Kerala is a conventional RC framed structure with infilled masonry walls. The residential complex consists of three towers namely A, B & C.

Tower A comprises of Stilt plus fourteen upper floors & Tower B & C comprises of common basement, stilt floor plus twenty-eight upper floors with Helipad in Terrace. The residential blocks were reported to be constructed about 4 years back and since then most of the flats were occupied.

At present, concerned authorities of M/s. Army Welfare Housing Organization referred M/s. Bureau Veritas India Pvt. Ltd., Mumbai to conduct a reconnaissance survey of the external & common areas of all three towers namely A, B & C inaccessible regions through a detailed visual inspection for identification of distress features if any.

In response to this, a detailed visual inspection was carried out on **2nd to 6th** March **2021 & 7th to 12th April 2021** inaccessible regions of the buildings. This report in brief, summarizes the outcome of the inspection carried out.

B. PHYSICAL OBSERVATIONS

Following are the physical observations made consequent to the detailed inspection of Tower A, B & C.

Tower A : Common area & External

- Minor dampness/damp patches were observed in the staircase beam at 6th floor.
- De-bonding of marble cladding for lift wall of Lift NO.02 was observed at 7th floor.
- Minor cracks were observed in the exterior surface of peripheral RC Column at 7th, 11th, 12th floor at few locations.
- Peeling of paint & dampness/damp patches were observed on the mid landing slab of the staircase between 12th & 13th floor & 13th & 14th floor at few locations.
- Cracks were observed on the exterior surface of Cut lintel at few locations in 13th & 14th floor.

- Peeling of paint & damp patches was observed in RC beam of fire exit staircase at 14th floor.
- Patch-up repair works were observed on the staircase RC column/beam at few locations in 14th floor.

Terrace

- Stagnation of water was observed over the roof slab at few locations.
- Leakages of water were observed from leaky pipelines.

Water tank

- Cracks & patch-up repair works were observed in the exterior surface of the wall at few locations.
- Damp patches/black patches & growth of algae were observed over the exterior surface of the wall & RC beam at few locations.
- Peeling of the paint, dampness/damp patches were observed in RC beam at few locations.

Tower B : External

- Cracks were observed in the exterior surface of the masonry wall at few locations. Patch-up repair works were observed on masonry walls at various locations.
- Cracks were observed in chhejja & fins at various locations.
- Patch-up repair works were observed in chhejja & fins at various locations.
- Separation cracks between RC members & masonry wall at few locations.

Common area: 1st floor

- Patch-up repair works were observed in the refuge area of the balcony ceiling slab between B0101 to B0102.
- Cracks were observed on the waist slab of the staircase between 1st floor & 2nd floor of the southside & the waist slab of the fire exit staircase at north side.

2nd floor

- De-bonding of marble/granite cladding was observed in lift walls at various locations.
- Cracks were observed on the waist slab of fire exit staircase & staircase between 2nd to 3rd floor.

- Cracks were observed on mid landing beam & slab of staircase between 2nd to 3rd floor.

3rd floor

- Cracks were observed in RC beam of balcony in refuge area between B0301 to B0302 & B0303 to B0304 (East side)
- De-bonding of marble/granite cladding was observed in lift walls at various locations.
- Cracks were observed on patch-up repair regions of staircase waist slab & also fire exit staircase between 3rd to 4thfloor.
- Cracks were observed in the mid landing slab of the staircase between 3rd to 4th floor.

4th floor

- Cracks were observed in the RC beam of the balcony in the refuge area between B0401 to B0402 & B0403 to B0404.
- De-bonding of marble/granite cladding was observed in lift walls at various locations.
- Cracks were observed on staircase waist slab between 4th to 5th floor at the south side near lift no.3
- Cracks were observed in the mid landing slab of staircase between 4th to 5th floor.

5th floor

- Cracks were observed in RC beam of the balcony in refuge area between B0503 to B0504.
- De-bonding of marble/granite cladding was observed in lift walls at various locations.
- Cracks & patch-up repairs were observed on staircase waist slab between 5th to 6th floor at south side near lift no.3.
- Cracks were observed on the waist slab of fire exit staircase between 5th to 6th floor.

6th floor

- Cracks were observed in RC beam of balcony in refuge area between B0601 to B0602 & B0603 to B0604
- De-bonding of marble/granite cladding was observed in lift walls at various locations.
- Cracks & patch-up repairs were observed in staircase waist slab between 6th to 7th floor.
- Cracks were observed on waist slab of fire exit staircase between 6th to 7th floor.

7th floor

- Cracks were observed in RC beam of balcony in refuge area between B0703 to B0704.
- De-bonding of marble/granite cladding was observed in lift walls at various locations. Further, cracks were observed in marble cladding for lift no.3 at staircase region.
- Cracks & Patch up repairs were observed on staircase waist slab between 7th to 8th floor. Further cracks were observed in patch-up repair region of waist slab.
- Minor patch-up repairs were observed on the waist slab of fire exit staircase between 7th to 8th floor.
- Separation cracks were observed between the junction of staircase wall & cladded marble/granite.

8th floor

- Cracks were observed in RC beam of balcony in refuge area between B0801 to B0802 & B0803 to B0804.
- De-bonding of marble cladding for lift columns/ walls was observed in lift area at various locations.
- Cracks & de-bonding of concrete were observed on waist slab of staircase between 8th to 9th floor.

9th floor

- Cracks were observed in RC beam of balcony in refuge area between B0903 to B0904 & B0901 to B0902.
- De-bonding of marble/granite cladding was observed in lift walls at various locations.
- Cracks, de-bonding of concrete & patch-up repair works were observed on waist slab of staircase between 9th to 10th floor. Further cracks were observed in patch-up repair region of waist slab.
- Corrosion cracks were observed in middle landing slab of staircase between 9th to 10th floor.
- Patch-up repair works were observed in RC column at bottom level opposite to Lift No.o3 at few locations.

10th floor

- Cracks were observed in RC beam of balcony in refuge area between B1003 to B1004 & B1001 to B1002.
- De-bonding of marble/granite cladding was observed in lift walls at various locations.
- Cracks were observed on waist slab, mid landing slab & landing beam of staircase between 10th to 11th floor.

11th floor

- Cracks were observed in patch-up region of RC beam of balcony in refuge area between B1103 to B1104.
- De-bonding of marble/granite cladding was observed in lift walls at various locations.
- Cracks were observed on waist slab of staircase between 11th to 12th floor.

12th floor

- Cracks were observed in RC beam of balcony in refuge area between B1203 to B1204.
- De-bonding of marble/granite cladding was observed in lift walls at various locations.
- Cracks were observed on patch-up repair region of waist slab of staircase & fire exit staircase between 12th to 13th floor.
- Severe cracks, spalling of concrete & exposure of corroded rebars were observed in staircase landing beam between 12th to 13th floor.
- Minor patch-up repairs were observed in ceiling slab of refuge area at few locations.

13th floor

- Cracks were observed in RC beam of balcony in refuge area between B1303 to B1304 & B1301 to B1302.
- Cracks & patch-up repair works were observed on waist slab of regular staircase & fire exit staircase between 13th to 14th floor.
- Cracks were observed in RC column at the duct region & peripheral RC Column.
- Separation cracks were observed between peripheral RC Column & masonry wall.

14th floor

- Cracks were observed in patch-up repair region of RC beam of balcony in refuge area between B1403 to B1404 (East side).
- Cracks were observed in fire exit staircase between 13th to 14th floor.

15th floor

- Cracks were observed in RC beam of balcony in refuge area between B1501 to B1502.
- Minor patch-up repair works were observed on waist slab of staircase between 15th to 16th floor.
- Cracks were observed in peripheral RC column & also in duct region.
- Separation cracks were observed between the junction of fins & chhejjas.

17th floor

- Cracks were observed in RC beam of balcony in refuge area between B1703 to B1704.

18th floor

- Cracks were observed in patch-up repair region of RC beam of balcony in refuge area between B1803 to B1804.
- Cracks were observed in waist slab of staircase between 18th to 19th floor.

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19th floor

- Cracks were observed in the patch-up region of RC beam of balcony in refuge area between B1901 to B1902 & B1903 to 1904.
- Cracks were observed on waist slab of staircase between 19th to 20th floor.

20th floor

- Minor patch-up repairs were observed in RC beam of balcony in refuge area between B2001 to B2002.

21st floor

- Minor patch-up repairs were observed in waist slab of staircase between 21st to 22nd floor.

22nd floor

- Cracks were observed in marble cladding for lift wall/column at few locations.

23rd floor

- Minor dampness/damp patches was observed in staircase wall at few locations.

24th floor

- Dampness/damp patches were observed in fire exit staircase wall at few locations.

25th floor

- Patch up repair works were observed in waist slab of staircase between 25th to 26th floor at few locations.

26th floor

- Separation cracks were observed between the junction of peripheral RC column & masonry wall at few locations.

27th floor

- Peeling of paint & damp patches were observed on interior surface of masonry wall at few locations.
- Patch-up repair works were observed in the ceiling slab at few locations.

Water Tank

- Peeling of paint & damp patches/black patches were observed in RC beams, RC wall & RC slab at few locations.
- Patch-up repair works was observed on RC beams, RC wall & slab at few locations.
- Cracks were observed in RC beams at few locations.

Fire lift/ Lift No 5- Internal side of Lift wall

- Cracks, spalling of concrete & de-bonding of concrete were observed on RC wall towards the fire duct of lift at 21st, 19th, 13th, 12th, 9th, 8th, 7th, 6th, 5th and down up to stilt floor.

Lift No 2 - Internal side of Lift wall

- separation cracks were observed near the lift door at few locations.
- Corrosion cracks were observed in RC wall of lift from the stilt floor to 9th floor at isolated locations.

Tower C- Common area: 1st floor

- Corrosion cracks were observed in RC column & beam at duct region.
- Cracks were observed in RC beam of balcony at refuge area.
- Separation crack was observed at the junction of RC beam & masonry wall at few locations.
- De-bonding of plaster was observed in exterior surface of masonry wall near House no.0102 at few locations.

2nd floor

- Corrosion cracks were observed in RC column & beam at duct region.
- Separation crack was observed between the junction of RC beam & masonry wall at few locations.
- Cracks, spalling of concrete & exposure of rebars were observed in waist slab of staircase between 2nd & 3rd floor.

3rd floor

- Corrosion cracks were observed in RC column & beam at duct region.
- Cracks were observed in RC beams of balcony in refuge area between C0303 to C0304 & C0301 to C0302.
- Cracks were observed in peripheral RC Column at few locations.
- Corrosion cracks, spalling of concrete & exposure of corroded rebars were observed in waist slab of staircase & fire exit staircase between 3rd to 4th floor.

4th floor

- Corrosion cracks were observed in RC column & beam at duct region.
- Cracks were observed in RC beams of balcony in refuge area between C0403 to C0404 (east side) & C0401 to C0402 (west side) of the refuge area.
- Cracks were observed in peripheral RC Column at few locations.

- Cracks were observed patch up repair region in waist slab of staircase between 4th to 5th floor.
- Cracks were observed in the patch-up repaired region of RC beam at fire exit staircase.

5th floor

- Corrosion cracks were observed in RC column & beam at duct region. Further, spalling of concrete & exposure of corroded rebars were observed in RC beam at duct region.
- Cracks were observed in RC beams of balcony in refuge area between C0503 to C0504 & C0501 to C0502.
- Cracks & spalling of concrete were observed in peripheral RC beam at few locations.
- Cracks were observed in RC column of fire exit staircase.
- Cracks were observed in the patch up repair region of waist slab of staircase between 5th to 6th floor.

6th floor

- Corrosion cracks were observed in RC column & beam at duct region.
- Cracks were observed in RC beams of balcony in refuge area between C0601 to C0602.
- Cracks were observed mid landing beam at few locations.
- Cracks were observed in patch-up repair region of waist slab of staircase & fire exit staircase between 6th to 7th floor.

7th floor

- Corrosion cracks were observed in RC columns & beam at duct region.
- Cracks were observed in RC beams of balcony in refuge area between C0703 to C0704 & C0701 to C0702.
- Cracks & patch-up repairs were observed in landing slab of staircase & patch-up repair works observed in waist slab of staircase.

8th floor

- Corrosion cracks were observed in RC columns & beam at duct region.
- Cracks were observed in RC beams of balcony in refuge area between C0803 to C0804 & C0801 to C0802. Further, severe cracks were observed in lath plaster of parapet wall of balcony at refuge area between C0801 to C0802.

- Cracks & patch-up repair works were observed in stair case RC column at few locations.
- Cracks & patch-up repair works were observed in waist slab of staircase between 8th to 9th floor.

9th floor

- Corrosion cracks were observed in RC columns & beam at duct region. Further, spalling of concrete was observed in RC column at few locations at duct region.
- Corrosion cracks were observed in RC beams of balcony in refuge area between C0903 to C0904 & C0901 to C0902.
- Cracks were observed in chhejjas at few locations.
- Cracks & patch-up repair works were observed in waist slab of staircase between 9th to 10th floor.

10th floor

- Corrosion cracks were observed in RC columns & beam at duct region.
- Cracks & spalling of concrete were observed in RC beam of balcony in refuge area between C1003 to C1004.Further, spalling of plaster/concrete & de-bonding of plaster was observed in parapet wall of balcony at refuge area.
- Cracks were observed in chhejjas at few locations.
- Corrosion cracks were observed in patch-up region of waist slab of staircase between 10th to 11th floor. After chipping off the concrete at the cracked region/patch up region it was observed that the repair work carried out was up to 100 mm to 120 mm thick for waist slab of staircase.

11th floor

- Corrosion cracks were observed in waist slab of staircase & fire exit staircase between 11th to 12th floor.

12th floor

- Corrosion cracks were observed in waist slab of staircase between 12th to 13th floor near lift 3 at north side.
- Separation cracks were observed at the junction of peripheral RC beam & exterior surface of masonry wall.

- Cracks were observed in chhejjas & fins.

13th floor

- Corrosion cracks were observed in RC column of staircase.
- Cracks were observed in RC beams of balcony in refuge area between C1303 to C1304.
- Separation cracks was observed between the junction of RC Peripheral beam & masonry wall in refuge area between C1303 to C1304 (East side).
- Corrosion cracks were observed in waist slab of staircase between 13th to 14th floor.

14th floor

- Cracks were observed in RC beam of balcony in refuge area between C1401 to C1402.
- Corrosion cracks were observed in the Peripheral RC column.
- Cracks were observed in exterior surface of masonry wall.
- Corrosion cracks & patch-up repairs were observed in waist slab of staircase between 14th to 15th floor.
- Patch-up repair works in waist slab of fire exit staircase.
- Cracks & patch-up repair works were observed in staircase column/wall.

15th floor

- Cracks were observed in chhejjas & fins.
- Patch-up repair works were observed in waist slab of staircase between 15th to 16th floor.
- Cracks were observed in waist slab of fire exit staircase between 15th to 16th floor.

16th floor

- Cracks were observed in Chhejjas & fins.
- Cracks & patch-up repairs were observed in waist slab of staircase & fire exit staircase between 16th to 17th floor.
- Cracks & spalling of concrete was observed in RC column at fire exit staircase.

17th floor

- Cracks were observed in chhejjas & fins.

- De-bonding of marble cladding for lift columns/ walls was observed in lift area at various locations.

18th floor

- Cracks were observed in chhejjas & fins.
- Damp patches & black patches were observed on exterior surface of masonry wall.
- Separation cracks were observed at the junction of peripheral RC beam & masonry wall at exterior surface.

19th floor

- Cracks were observed in chhejjas & fins.
- Cracks were observed in waist slab of fire exit staircase between 19th to 20th floor.
- Damp patches/black patches were observed on exterior surface of masonry wall at few locations.
- Separation cracks were observed between the junction of peripheral RC beam & masonry wall at exterior surface.
- Patch-up repair works were observed in staircase wall/column.

20th floor

- Cracks were observed in chhejjas & fins.
- Cracks were observed in waist slab of fire exit staircase & staircase between to 20th to 21st floor. Patch-up works were observed in waist slab of staircase.
- Separation crack between the junction of peripheral RC beam & masonry wall at exterior surface.

22nd floor

- Cracks were observed in RC beam of balcony in refuge area between C2201 to C2202.

23rd floor

- De-bonding of marble/granite cladding for Lift column/ wall at few locations in Lift no.03.

24th floor

- De-bonding of marble/granite cladding for lift columns/ walls was observed in lift area at various locations.

- Minor patch-up repairs were observed in waist slab of fire exit staircase.

25th floor

- De-bonding of marble/granite cladded for lift columns/ walls was observed in lift area at various locations.
- Patch-up repairs were observed in waist slab of staircase at few locations.

26th floor

- Separation crack between the junction of RC column/ beam & masonry wall at exterior surface.
- De-bonding of marble/granite cladding for lift columns/ walls was observed in lift area at various locations.

27th floor

- The steel plates provided over RC column (grid C19) was observed to be corroded.
- Peeling of paint & damp patches/black patches were observed on Parapet wall at various locations.
- Stagnation of rainwater was observed over roof slab at various locations.

Water tank- SW corner

- Separation crack between the junction of RC beam & RC wall at exterior surface at various locations.
- Cracks were observed in RC beams at few locations.
- Peeling of paint, dampness/damp patches & growth of fungus were observed on exterior surface of RC wall &beams at various locations.
- Peeling of paint & dampness/damp patches were observed on RC slab at few locations.
- The beam concrete was observed to be abruptly chipped off for the provision of fire pipe lines.

28th floor

- Cracks were observed on wall surface of duct & masonry wall at few locations.
- Patch up repair works were observed on ceiling slab at few locations.

29th floor

- Separation cracks were observed at the junction of RC beam & masonry wall at few locations.
- Peeling of paint & damp patches were observed on RC beams & ceiling slab at few locations.
- Cracks were observed in ceiling slab at few locations.

Helipad

- Cracks were observed on top surface of the WPC at various locations.
- Damp patches/black patches were observed on WPC over landing slab at few locations.

Lift No.05- Internal side of Lift wall

- Cracks, spalling of concrete & exposure of rebars were observed in RC wall of lift at stilt floor.
- Cracks & spalling of concrete were observed in RC wall of lift at 3rd,4th ,5th ,7th,8th, 9th & 12th floor.
- Patch-up repairs, peeling of paint & dampness/damp patches were observed on the RC wall of lift at 13th, 14th,15th & 16th floor.
- Minor patch up repair works were observed on RC wall of lift at 21st,22nd & 25th floor.
- Cracks were observed on RC wall of lift at 26th floor.

Lift No.03-Internal side of lift wall

- Cracks, spalling of concrete & de-bonding of concrete were observed on RC wall of lift at stilt floor & 3rd, 5th, 7th, 10th, 11th, 15th, 20th, 25th floor.
- Cracks were observed on RC wall of lift at 1st & 2nd, 4th, 8th, 9th floor.
- Minor spalling of concrete was observed on RC wall of lift at 21st floor.
- The concrete in the lift wall was observed to abruptly be chipped off for clearance of the door in most of the floors.
- Minor patch-up repair works were observed on RC wall of lift at 21st, 22nd & 25th floor.
- Cracks were observed on RC wall of lift at 26th floor.

Note: At most of the locations patch-up repair works were observed to be carried out. The material & methodology adopted to repair the distressed regions were not shared with us.

C. PROBING TESTS.

In order to assess the extent of distress & to assess the quality/strength of concrete in RC members random in identified floors of common area following probing tests/studies were resorted to.

1. **Non-destructive tests to assess the quality/strength of concrete in RC members.**
   a. **Ultrasonic Pulse Velocity test on RC members.**
   b. **Rebound Hammer test on RC members.**
2. **Half-cell potential measurement test on RC members to assess the probability of corrosion.**
3. **Carbonation test on RC members to assess the loss of alkalinity in concrete.**
4. **Chemical Analysis on concrete samples to assess.**
   a. **Chloride content.**
   b. **Sulphate content**
   c. **Determination of pH value.**

1. Non-destructive tests to assess the quality/strength of concrete in RC members.

a. Ultrasonic Pulse Velocity test on RC members.

Ultrasonic Pulse Velocity test was conducted on RC members at random to assess the quality of concrete in the identified floors of common area at Tower A ,B & C. The test was conducted using "PUNDIT Lab+" (Portable Ultrasonic Non-destructive Digital Indicating Tester) equipment from M/s. Proceq, Switzerland as per the guidelines in Indian Standard **IS: 516 (Part 5/Sec1)-2018(Amendment –November 2019**). Direct & Indirect method of test was adopted at the site for scanning.

The results of the test are tabulated in **Table-1** along with **reference-quality grading chart**.

The Ultrasonic Pulse Velocity test results indicate that the quality of concrete in the tested RC members as per **clause 2.5.2 of IS: 516(Part 5/Sec1)-2018(Amendment –November 2019)** are as follows.

Following are the Tower wise/member-wise results.

Tower-A

- RC Beams fall under the category of **"Good"** concrete.

Tower-B

RC Beams fall under the category of **"Doubtful to Good"** concrete.

Tower – C

- RC Columns fall under the category of **"Doubtful to Good"** concrete.
- RC Beams fall under the category of **"Doubtful to Good"** concrete.

b. Rebound Hammer test on RC slab.

Rebound Hammer Test was carried out on RC slab at random in the identified floors of common area of Tower A,B & C to assess the surface hardness/strength of concrete nearer to surface. The test was conducted using Schmidt Rebound Hammer from M/s. Proceq Switzerland as per the guidelines in Indian Standard **IS: 516 (Part5/Sec4)-2020**. The position of the hammer was vertically upwards during the test.

The results of the test are tabulated in **Table-2** the corresponding reference strength chart is tabulated in **Table-2A.**

From the results of the Rebound Hammer test, it is indicated that the estimated compressive strength of concrete nearer to surface in the tested RC slab is found to be as detailed below.

Following are the Tower wise/member-wise results.

Tower-A

RC Slab – Found to be in the range of **26.0 N/mm^2** to **30.0 N/mm^2**

Tower-B

RC Slab –Found to be in the range of **24.0 N/mm^2 to 30.0 N/mm^2.**

Tower -C

. RC Slab –Found to be in the range of **24.0 N/mm^2** to **30.0 N/mm^2**

2. Half-cell potential measurement test on RC members to assess the probability of corrosion.

Half-Cell Potential Measurement Test was carried out on RC members at random in identified floors at common area of Tower B & C by using Copper-Copper Sulphate Half-Cell to assess the probability of corrosion in reinforcing bars. The test was conducted

using **CANIN** equipment from **M/s. Proceq, Switzerland** as per the guidelines in **ASTM C876-15** &furnished by the manufacturer's manual.

The results of the test are tabulated in **Table-3 &** the corresponding reference chart is tabulated in **Table-3A.**

Following are the Tower wise/member-wise results.

TOWER-B

- RC Beam **- Uncertainty of Corrosion to High Probability of corrosion**
- RC slab **- Uncertainty of Corrosion to High Probability of corrosion**

TOWER-C

- RC Columns **-Uncertainty of Corrosion to High Probability of corrosion.**
- RC Beam **-Uncertainty of Corrosion to High Probability of corrosion**
- RC slab**-Uncertainty of Corrosion to High Probability of corrosion**

3. Carbonation test on RC members to assess the loss of alkalinity in concrete.

Carbonation test was carried out on RC members at random in identified floors at common area of Tower B & C using **phenolphthalein indicator of 1gm dissolved in 70 ml ethyl alcohol & diluted to 100ml with distilled or deionized water** to assess the loss of alkalinity in cover concrete. The test was conducted as per the guidelines in **BSEN-14630-2006.** The results of the test are tabulated in **Table-4.**

Note: New IS code ie., **IS: 516 (Part 5/Sec 3) : 2021** for carbonation depth of hardened concrete is available to evaluating. Since we are not accredited under NABL scope to use this new code, we are furnishing results as per **BSEN-14630-2006.**

Following are the Tower/member wise results.

TOWER-B

- RC Beam- **20 mm**
- RC Slab - **15 mm to 25 mm**

TOWER-C

- RC Column - **10 mm to 30 mm**
- RC Beams - **10 mm to 25mm**
- RC Slab - **20 mm to 45mm**

The results of the test indicate that the carbonation front in concrete has reached up to **reinforcement level** in most of the tested RC members indicating that the cover concrete has already lost its alkalinity which is essential to protect the reinforcing bars against potential corrosion.

4. Chemical Analysis on collected concrete samples to assess.

a. Chloride content.

Chloride determination test was carried out on concrete samples collected from the RC members at random at identified floors of the Tower B & C to estimate the level of chlorides in the concrete as per the guidelines in **IS: 14959(Part 2)-2001.**

The presence of higher amount of chlorides in the concrete surrounding the reinforcement will result in corrosion of rebars. The quantity of chlorides in concrete is determined generally by chemical analysis. The results of the test are tabulated in **Table.**

The results of the chloride content test in concrete indicate that the level of chlorides in the tested RC members is found to be as detailed below.

Following are the Tower/member-wise results.

Tower-B

- RC Lift wall – **2.59 Kg/m^3**
- RC Beam - **2.61 Kg/m^3**
- RC Slab - **2.61 Kg/m^{3}to 2.82 Kg/m^3**

Tower-C

- RC Column- **2.80 Kg/m^3**
- RC Slab **- 2.59 Kg/m^{3}to 2.80 Kg/m^3**

From the above test results, it is found that the level of Chloride content in the tested RC members of Tower B & C is found to be **exceeded the permissible limit of 0.6 Kg/m^3**in all the tested samples.

b. Sulphate content

Sulphate determination test in concrete is carried out on concrete samples collected from RC members at random at identified floors of Tower B & C to estimate the level of Sulphate in the concrete.

The presence of higher amount of Sulphates in concrete will result in reaction of calcium

present in cement with Sulphates, resulting in the deterioration of concrete. The quantity of Sulphates in concrete is determined generally by chemical analysis and is expressed in terms of percentage of Sulphates by weight of concrete. The results of the test are tabulated in **Table.**

The results of the Sulphate content test on concrete indicates that the level of Sulphate in the tested RC member was found to be as detailed below.

Following are the Tower/member-wise results.

Tower - B

- RC Lift wall - **0.36 %**
- RC Beam **- 0.69 %**
- RC Slab **- 0.26% to 0.60 %**

Tower - C

- RC Column**- 0.42%**
- RC Slab **- 0.22 % to 0.26 %**

From the above test results, it is found that the level of Sulphate content in the tested RC members of Tower B & C are found to be **within the permissible limit of 4%.**

c. Level of pH

The level of pH value is carried out on concrete samples collected from RC members at random at identified floors of Tower B & C & tested as per the guidelines in **NCB 9th International Seminar Vol.3 Page 500 / IS: 2720 (Part 26): 1987 (Reaffirmed 2016).**

The level of pH in fresh concrete is generally in the range of 12 to 14. Due to carbonation, the pH value of concrete will be reduced considerably. When the pH value fall below about 10, the alkalinity of the concrete will not be adequate to protect the rebars against corrosion. The results of the test are tabulated in **Table-5.**

The pH value of the interior concrete in the tested RC members is found to be as detailed below.

Following are the Tower/member-wise results.

Tower - B

- RC Lift wall – **11.71**
- RC Beam **- 11.10**

- RC Slab - **11.63 to 12.13**

Tower - C

- RC Column- **11.59**
- RC Slab - **11.93 to 12.13**

From the above test results, it is found that the level of pH content in most of the tested RC members of Tower B & C are found to be **marginally less than the desired value**.

D. INFERENCES.

Following are the inferences drawn, based on the detailed observations & results of probing tests.

1. From the results of Ultrasonic pulse velocity test, it is inferred that the quality of concrete in the tested RC beams of identified floors of Tower B & C fall under the category of **" Doubtful to Good concrete". However, the tested RC beams in Tower- A fall under the category of "Good concrete".**

2. From the results of Rebound Hammer test, it is inferred that the quality /surface hardness of tested RC Slab of identified floors of Tower A, B & C is found to be satisfactory.

3. From the results of the Half-Cell Potential Measurement Test, it is inferred that the probability of corrosion fall in the category of **"Moderate to Advance"** stage of corrosion in the tested RC members of identified floors of Tower B & C.

4. From the results of carbonation test, it is inferred that the carbonation front **has reached up to reinforcement level** from the surface in most of the tested RC members of identified floors of Tower B & C.

5. From the results of Chloride content test, it is inferred that the level of chloride content in all the tested samples of RC members of identified floors of Tower B & C are **beyond the permissible limit of 0.6 Kg/m^3**.

6. From the results of Sulphate content test, it is inferred that the level of sulphate content in the tested samples of RC members of identified floors of Tower B & C are **within the permissible limit of 4%.**

7. From the results of pH value, it is evident that the pH value is found to be **marginally less than the desired value** in most of the tested samples of identified floors of Tower B & C.

8. Cracks, spalling of concrete and exposure of rebar are essentially due to corrosion of embedded rebars. The reasons for corrosion in RC members may be due any one or combination of reasons listed below.

- **Less cover provided for RC members.**

  As per clause 8.2.2.1 (Environmental Exposure Condition) and 26.4.2 (Nominal Cover to Meet Durability Requirement) of IS 456: 2000 minimum cover to be maintained in **"Severe"** (Coastal Environmental Exposure Condition) is 45mm.

  The cover concrete specified as per sketch ST-WD-REB.117C-018 are as follows:

  Column -35mm, beam-30mm and slab-30mm.

- **Presence of inbuilt high chloride content in concrete due to**

a. Use of high chloride content water during construction i.e. Mixing and as well as curing.
b. Use of adulterated aggregates

- **Ingress of moisture into RC members.**

  This is due to leakage of water from roof slabs, stagnation of water and inadequate slope in RC members.

- **Carbonation of concrete.**

  Considering the age of the concrete the depth of carbonation in the affected members is more than expected.

9. Repairs carried for distress regions of RC members to arrest corrosion were observed to be executed without providing shear connector, mechanical anchors and weld mesh which may lead to de-bonding of concrete/cracks over a prolonged period. This needs appropriate corrective action to enhance the durability and serviceability of the structure.

10. The existing cracks between masonry walls and RC members are essentially separation cracks due to differences in material properties and thermal expansion/contraction.

11. Stagnation of water over roof slab is essentially due to improper/inadequate slope provided towards disposal of rainwater & also due to leakages from pipelines at roof slab.

12. Dampness/damp patches/peeling of paint in the ceiling slab may be due to leakage of water

from the roof slab.

13. Inclined cracks at window sill level's is mainly due minor stress concentration.

14. Inclined cracks at lintels is aminly due non –provision of continuous lintels.

15. Corrosion in parapets are mainly due to corrosion of rebars embedded in concrete.

16. De-bonding of granite cladding in the lift areas is mainly due improper workmanship/improper filling of mortar/grout behind the granite.

Based on the type of distress observed and results of probing tests, it is inferred that the distress in RC members at the common area of identified floors is mainly due to the presence of inbuilt/inherent high chlorides content in the concrete samples and leakages from the roof slab over a period of time. The distressed RC members of identified floors call for appropriate restoration /corrective measures to render it normal/minimize the extent of distress and to enhance the life/durability of the structure.

E. RESTORATION/CORRECTIVE MEASURES

Based on the above-detailed studies & inferences drawn, appropriate recommendations are recommended.

1. Treatment for moderate to severly corrosion distressed RC members with cracks patch up repairs such as RC columns, staircase waist slab, landing slab, landing beam & lift wall.

Sequence of operations:

a. The existing plaster and loose concrete in beams shall be thoroughly removed by gentle chipping and cleaned using a mechanical wire brush and water jet.
b. Temporary support shall be provided to the adjoining slab around the beam using appropriate props for effective transfer of load.
c. The exposed reinforcement shall be cleaned thoroughly using the mechanical wire brush/ buffing wheel followed by a water jet to remove corrosion scales, loose particles, etc.
d. Severely corroded rebar, if any shall be replaced by the same diameter rebar through welding.
e. Exposed concrete surface shall be provided with corrosion inhibitor solution using a pneumatic sprayer as per manufacturer's specification.

f. The cleaned surface of the exposed reinforcement shall be provided with two coats of anticorrosive chemical, as per the manufacturer's specification.

g. A layer of 50 x 50 x 3 mm shall be placed and fixed to concrete using 'U' nails as per standard practice.

h. 20 mm thick polymer modified mortar plaster to specification shall be provided and finished in flush with the adjacent surface over a coat of primer as per manufacturer's specification and cured.

(Refer sketch DWG. REF. No.04)

c. Treatment for minorly damaged RC members with cracks & patch up regions in (Chhejjas & fins, RC columns, beams, slab, staircase waist slab, landing slab, landing beam & lift wall).

a. All loose plaster, cover concrete & patch-up regions in the RC members shall be completely removed by gentle chipping to expose hard/sound concrete surface.

b. Exposed reinforcing bars shall be thoroughly cleaned with wire brush and emery cloth or by mechanical buffing wheel to remove rust, scales etc.

c. Exposed concrete surface shall be thoroughly cleaned with wire brush followed by air and water jet to remove dust particles.

d. Two coats of anti-corrosive chemical shall be provided on the exposed and cleaned reinforcing bars as per the manufacturer's specification.

e. A coat of corrosion inhibitor coating to be provided on the cleaned concrete surface as per the manufacturer's specification.

f. 20 mm thick polymer modified mortar plaster (with chicken mesh fixed with 'U'nails to the concrete surface) to specification shall be provided (suitable to site condition) and finished in flush with the adjacent surface over a coat of primer as per manufacturer's specification and cured.

(Refer sketch DWG.REF.No.05)

Note:

a) If the thickness of the structural grade polymer/latex modified mortar layer exceeds 20mm, a layer of weld mesh 50 x 50 x 3 mm shall be placed and fixed to concrete using U nails.

b) It is advisable to apply corrosion inhibitor solution to the entire external surface of RC members which are affected. The measures are recommended to avoid ingress of moisture

during rains since the chloride in concrete will be active in the presence of moisture environment.

c) *During any maintenance, it is recommended to use moisture-resistant paints to RC members.*

3. Treatment for separation crack between the junction of RC member & masonry wall.

a. ' U' groove of 12 mm wide 6 mm deep shall be made all along the crack at the interface of masonry wall and RC member junction and cleaned.

b. Groove shall be filled with a flexible sealant like Tacksel/Polysulphuide sealant /silicon sealant or any other equivalent.

(Refer sketch DWG.REF.No.06)

4. Treatment for cracks in the Masonry wall.

a. Existing plaster along the crack shall be removed on either side of the crack for a width of about 300 mm (on either side of the wall) and cleaned.

b. Mortar joints along the crack shall be deep raked and filled with cement mortar.

c. Weld-mesh of size 50 x 50 x 3 mm shall be fabricated and fixed across the crack using 'U' nails.

d. Re-plastering the region with CM 1:4 as per standard practice.

(Refer sketch DWG.REF.No.07)

5. Treatment for dampness region of the masonry wall.

a. The deteriorated plaster on masonry walls shall be removed by gentle chipping.

b. The mortar joints in walls shall be deep racked and re-pointed with CM 1:4 as per the standard practice followed by re-plastering in CM 1:3 mixed with waterproofing plasticizers.

6. Anti-Carbonation treatment to all RC members of Basement & stilt floor.

Considering the corrosion environment and presence of high chloride content in RC members it is recommended to provide anti-carbonation protective coating to identified /exposed RC members of Towers A, B & C to protect RC members from carbonation and to enhance the life of the structure.

(This has to be carried out after completing all proposed restorations measures to RC members)

7. **All leaky down take pipes in the shaft/duct region shall be removed and replaced with the new ones by using PVC pipes as per standard practice ensuring leak-proof joints.**

8. **Adequate slope shall be provided at terrace for easy disposal of water and avoid water stagnation.**

Note: *Since the inbuilt/inherent chloride content in the concrete is excess than the permissible limit, the restoration schemes are worked out in order to* ***reduce/ minimize*** *the corrosion by providing polymer modified mortar treatment to locally damaged regions.*
Additional protective measures such as anti-carbonation coating have been proposed which acts as a barrier against the corrosive environment and protects the concrete to maintain its alkalinity & rebar's from corrosion.
The above-recommended restoration /corrective measures is to render distress regions normal and minimize the extent of distress & to enhance the life/durability of the structure.

F. GENERAL RECOMMENDATIONS

In addition to the above-mentioned recommended measures, the following are the general recommendations.

- Corrosion activities shall be monitored in RC members periodically (i.e., at least three years once).

- Leakages/corrosion in any RC member shall be treated immediately without delay.

- Water stagnation on floor/roof slab shall be avoided.

- Stagnation of water around the flower pots shall be avoided by providing a plastic plate/bowl for collecting excess water.

- Washing of floor in common area by splashing water shall be avoided. Mopping can be adopted instead of washing to avoid moisture ingress into RC members (waist slabs/beams/columns).

- Leaky water lines at terrace level shall be attended immediately.

- Water stagnation due to inadequate slope/choking of rainwater outlets shall be attended at the earliest.

- Periodic maintenance of the building shall be strictly adhered to for effective functioning and enhancing the life of the structure.

G. CONCLUDING REMARKS

Based on the detailed assessment study carried out on the basement floor of Tower B & C, stilt floor of Tower A, B, C of the existing **"CHANDERKUNJ" Army Towers of Army Welfare Housing Organisation (AWHO) Residential Apartment Building"** located at Silver Sand Island, Vytilla, Kochi, Kerala India as it stands is found to be distressed mainly due to corrosion, minor leakages and seepages. However, the quality & strength of concrete in the tested RC members are found to be by and large satisfactory.

The more distress features were observed in Tower B & C of identified floors compared to Tower A in the form of corrosion cracks, severe spalling of concrete, exposure of rebar in RC members at common areas such as waist slab, landing slab, landing beams of staircase, RC members (columns & beams) at duct region, cracks in parapets, chhejjas & fins.

However, these distress features call for appropriate treatment to avoid further deterioration and to improve the durability and longevity of the structure.

On carrying out the recommended remedial measures effectively under the guidance of experienced technical personnel by an experienced agency, the distress regions of the building will be minimized.

After carrying out the recommended remedial measures effectively it is mandatory to carry out periodic maintenance of the building as per standard practice. Negligence in Periodic maintenance may/will lead to reoccurrence of distress.

From the detailed study, it is evident that the life of the structures will be relatively reduced compared to actual designed life due to inherent chloride content in RC members, present rate of carbonation and aggressive coastal environment.

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