A Review on the Report by Bureau Veritas on

Investigation of distress in basement floor and terrace level overhead tanks of Army Welfare Housing Organisation "Chanderkunj Army Towers" at Silver Sand Island, Vytilla, Kochi, Kerala (November 2020)

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The results of the chloride tests conducted at IIT Madras

Prepared by

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Submitted to

Brigadier Sunil Kumar

ARMY WELFARE HOUSING ORGANIZATION (AWHO)
New Delhi

December 14, 2020

Review of the report by Bureau Veritas (dated Dec 3, 2020) for Chander Kunj Apartments, Silver Sand Island, Vytilla, Kochi

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Results of the chloride tests conducted at IIT Madras

References:

(i) email from Brig. Sunil Kumar, President RWA addressed to Prof. Manu Santhanam dated September 23, 2020
(ii) my email to Brig. Sunil Kumar, President RWA, CKAOT dated December 6, 2020; and
(iii) email from you dated December 5, 2020 with the BV Report (dated Dec 3, 2020)
(iv) email from you dated December 13, 2020.

We have reviewed the report on the Chander Kunj Apartments by Bureau Veritas (BV). Based on earlier submitted photographs, videos, and inputs from the site visits by Prof. Elson John and Mr. Naveen Krishnan, it was found that the beams and columns are also severely corroded/cracked/spalled and patch repairs were also failing at fast rate. This raised concerns about the chloride conditions of the concrete used. Later, all the tests done by IIT Madras and some tests done by BV indicate more than allowable amounts of chlorides (as per Table 7 of IS 456) in the concrete used in the about 5-year old structure. This indicates the presence of admixed chlorides in the concrete; either through mixing water, curing water, aggregates, and/or admixtures used.

The report from BV is based on the tests on basement floor, stilt floor, retaining wall and overhead water tank; and does not provide sufficient data on the corrosion and chloride conditions of the beams and columns of the buildings. Without the test results and inferences on the severely corroded/patch-repaired and distressed members, **the BV Report is incomplete and inadequate to make necessary inferences and recommendations** to achieve durable repair/rehabilitation work for the three buildings.

Table 1 provides my responses/suggestions against all the inferences in the BV Report. Also, the recommendations made in the BV Report are inadequate to achieve a service life of multiple decades with minimal maintenance and without major/repeated repairs. **Please arrange to conduct more tests and data analysis as suggested in Table 1 and revise the Sections D, E, F, and G of the BV Report.** Also, the collected data should be assessed in a quantitative manner, wherever possible. The submitted BV report do not comment on the corrosion and chloride conditions of the members that exhibited and are exhibiting corrosion/cracking. The revised report must reflect these. Note that Item 6 in Table 1 shows that the chloride contents (from the tests conducted at IIT Madras) in the concrete samples supplied is higher than the allowable chloride content of 0.6 kg/m^3 (as per IS 456).

As mentioned in my previous communications, these three towers need IMMEDIATE attention. Hence, I request you to avoid further delays due to bureaucratic and other reasons; because such delays will lead the building to a more unsafe situation for the residents. Hence, **we strongly suggest to prioritize, obtain the revised report in two weeks, and complete the suitable repairs before the upcoming monsoon season**. If a revised BV Report cannot be obtained in two weeks or a reasonable time, then it is suggested to

engage other agencies and expedite the corrosion/chloride condition assessment of the representative/critical elements of the buildings and proceed.

We both are available for an online meetings with the various stakeholders for any technical discussions. Prof. Elson John is available for site visits also.

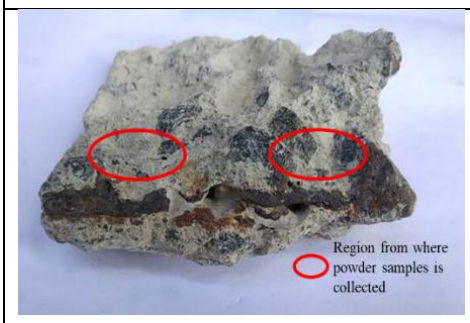
Table 1: Specific comments on inferences in BV Report

#	**Inferences as given in the BV report**	**Response from IIT Madras**
1	From the observations of extracted concrete core samples, it is evident that the extracted Samples are uniform, homogeneous, and free from voids / honeycombs. From the concrete core test results, it is inferred that the strength of concrete in the tested basement floor RC retaining walls were found to be satisfactory.	Inference is reasonable
2	From the results of Non-destructive ultrasonic pulse velocity & rebound hammer tests, it inferred that the quality of concrete in the tested RC members were found to be **satisfactory**	About 50% of the test results presented are in 'Doubtful' category. Hence, BV's inference that the quality of concrete is 'satisfactory' is not reasonable.
3	From the results of Cover meter studies, it is inferred that the cover concrete provided to the rebar were **adequate** in most of the tested RC members except at isolated locations where cover concrete was observed to be less.	As per BV report, the range of cover depth measured are: Columns - 45 to 60 mm Retaining walls – 25 to 65 mm Beams – 25 to 35 mm Slabs – 25 to 40 mm These values must be compared with the structural specifications/drawings before making an inference that it is 'adequate'. Hence, the BV's inference that cover depth is 'adequate' is not reasonable. ***R3a****: Please include a comparative table with information on specified cover depth and observed cover depth.*
4	From the results of Half-Cell Potential Measurement test, it is inferred that the probability of corrosion fall in the category of **"High probability of no corrosion to Uncertainty of corrosion"** (i.e., **Initial stage to Moderate** stage) in the tested RC members.	No data from the corroded/patch-repaired beams and columns are provided. ***R4a****: Provide photos of measurements **being taken** at all the 16 locations; at least for representative locations.* ***R4b****: Provide data from beams and columns that are/were experiencing corrosion/cracks etc. Also, include photographs and grid size of measurement points. Consider Appendix X1 in the ASTM C876-15 while making inferences.*

<table>
<tr>
<td>5</td>
<td>From the results of Carbonation test, it is inferred that the carbonation is limited to surface concrete only in the tested RC members.</td>
<td>5 to 10 mm carbonation depth in 5 years is reported. Based on Tutti's model, corrosion due to carbonation can initiate at about 30 and 100 years at locations with carbonation depths of 10 and 5 mm, respectively.

<u>R5a</u>: No further carbonation test is recommended.</td>
</tr>
<tr>
<td>6</td>
<td>From the results of chemical tests on concrete samples collected from RC members it is Inferred that the Chloride content in most of the tested samples is found to be with in the Permissible limit except for the concrete sample of column & slab of Basement floor at Tower —B , where the chloride content exceeds the permissible limit & Sulphate content is found to be with in the permissible limit. Further, the pH value of the tested concrete is found to be satisfactory.</td>
<td>The chloride data in BV report are given in the Table 6a.

Table 6a Data reproduced from BV report
<table>
<tr><th>Location</th><th>Chloride content reported (kg/cm3)</th></tr>
<tr><td rowspan="4">Retaining wall - Basement floor</td><td>0.045</td></tr>
<tr><td>0.04</td></tr>
<tr><td>0.028</td></tr>
<tr><td>0.096</td></tr>
<tr><td rowspan="2">Tower-B basement floor</td><td>1.12</td></tr>
<tr><td>1.12</td></tr>
<tr><td rowspan="2">Tower-C basement floor</td><td>0.34</td></tr>
<tr><td>0.26</td></tr>
<tr><td rowspan="2">Parking area</td><td>0.37</td></tr>
<tr><td>0.04</td></tr>
<tr><td>Tower A - stilt floor</td><td>0.4</td></tr>
<tr><td rowspan="3">Water tank</td><td>0.045</td></tr>
<tr><td>0.045</td></tr>
<tr><td>0.079</td></tr>
</table>
IIT Madras conducted experiments on samples collected from the exterior elements of the building. See Table 6b.

Table 6b Photo of the samples collected and acid soluble chloride content (kg/m^3 of concrete)
<table>
<tr><th>Photo of the sample collected</th><th>Acid soluble chloride content (kg/m^3 of concrete)</th></tr>
<tr><td> 
</td><td>2.46</td></tr>
<tr><td>  </td><td>4.94</td></tr>
</table>
</td>
</tr>
</table>

		Some of the obtained chloride contents are above the allowable chloride concentration as per Table 7 in IS 456 (see below). **Table 7 Limits of Chloride Content of Concrete** (*Clause* 8.2.5.2) **Sl No.** / **Type or Use of Concrete** / **Maximum Total Acid Soluble Chloride Content Expressed as kg/m³ of Concrete** (1) / (2) / (3) i) Concrete containing metal and steam cured at elevated temperature and pre-stressed concrete / 0.4 ii) Reinforced concrete or plain concrete containing embedded metal / 0.6 iii) Concrete not containing embedded metal or any material requiring protection from chloride / 3.0 The discrepancy in the results from BV and IITM raises some confusions. Also, the samples collected from basement and water tank elements alone are not representative of the entire building. **Chloride contents in corroded/corroding beams and columns are essential to make useful inferences towards making good recommendations.** ***R6a:*** *Perform chloride tests at 20 locations on the beams and columns that are/were corroding. Photos of sample locations are also needed.* ***R6b:*** *Provide the calculations used for expressing the results in kg/m^3 of concrete.* ***R6c:*** *Provide the chloride concentration of the water in the surrounding river.*
7	Seepage of water in basement roof slab & retaining wall is essentially due to very high-water table in the vicinity of the area	Inference is reasonable.
8	Leakage & damp patches in peripheral retaining walls in basement floor are essentially due to in-effective waterproof treatment at the junctions of the wall, the construction joint regions of the wall leading to ingress of water into the basement through retaining walls. (Further, it is reported that, during rains leakage from retaining wall is severe)	Inference is reasonable

9	Stagnation of water over roof slab is essentially due to improper slope provided towards disposal of rainwater.	Inference is reasonable
10	Dampness/damp patches in basement ceiling slab is essentially due to continuous leakage of water from the roof slab.	Inference is reasonable
11	Peeling of paint may be due to dripping of water from ceiling slab at few locations.	Inference is reasonable
12	Cracks in RC members of overhead water tanks may be due to corrosion of rebars. Corrosion of rebars is essentially due to carbonation of cover concrete & ingress of moisture into RC members	Inference is not reasonable. Carbonation depth reported is 5 mm. Also, pH reported in water tank elements are 12.15, 12.17, and 12.30. These do not support the reasoning that corrosion is due to carbonation and moisture. ***R12a****: Provide information on the locations of corroding rebars and chemical analysis of adjacent concrete.*

If you have any queries or need clarifications, please feel free to contact us.

Regards,

Radhakrishna G Pillai Elson John