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Evaluation studies on condition ranking of existing RCC ESRs in Amravati region using non-destructive modules

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Abstract
To properly maintain our public infrastructure, engineers and designers must learn different methods of inspection. An exhaustive review has been carried out for different aspects of non- destructive testing (NDT) adopted for RCC structures. NDT evaluates the remaining operation life of different components of structure. It provides an accurate diagnosis which allows prediction of extended life operation beyond the designed life. Different aspects are considered which includes condition assessment, durability, corrosion, condition ranking and service life of structures. In this work, several non-destructive inspection methods are evaluated, with the aim of identifying those, which are practical for detecting defects at early in the production sequence as possible. The methods used for carrying out non-destructive analysis used by different investigators are also discussed. Merits and demerits of each method are also stated. RCC structures considered are reinforced buildings ESRs, recently developed NDT techniques which are useful for prediction of performance of structure are also included.

Keywords: RCC ESRs, non-destructive modules, ranking of existing

1. Introduction

Reinforced cement concrete (RCC) as a construction material had come into use for the last one century. In India, RCC had been used extensively in the last 50-60 years. During this period, large number of infrastructure created in terms of buildings, bridges, water tanks, sports stadium, etc., which are lifeline for the civilized society. These were created with huge investment of resources. It is hard to even dream of recreating such assets out of limited national resources. It is therefore, essential to maintain them in functional condition. Since, deterioration of RCC is a natural phenomenon and has started exhibiting in large number of structures. It had been learnt from past experiences that concrete structures requires a closer inspection, not only immediately after construction but also periodically at a regular interval.

A long service life is considered synonymous with durability. Since durability under one set of conditions does not necessarily mean durability under another, it is customary to include a general reference to the environment when defining durability. Durability is the ability of the structure to maintain its level of reliability and serviceability during its lifetime. That is, durable concrete will retain its original form, quality, and serviceability when exposed to its environment [4].

ESR's are large elevated water storage containers constructed for the purpose of holding water at a height sufficient to pressurize a water distribution system. The materials used for construction of ESR's are cement concrete, steel etc. Generally RCC is used for constructing ESR's as it is more economical than steel ESR's. It had been observed that the deterioration phenomenon of RCC is not realized by majority of practicing civil engineers. As a result, the factors considered necessary for durability of RCC ESR's are many times not given due importance. RCC ESR's undergoes deterioration due to corrosion of reinforcement, chloride diffusion, carbonation, sulphate attack, alkali aggregate reaction, freezing and thawing etc. Which may lead failure of RCC ESR's. It affects directly and indirectly to the national economy.

2. Literature Review

2.1 General

Non-Destructive Testing (NDT) has been identified as include methods used to study objects, materials or systems without impairing their future usefulness, i.e.

inspect or measure no damage. NDT methods are now regarded as powerful tools to assess the existing concrete structures taking into account their strength and durability. Methods of non-destructive testing have been more and more attention, in terms of reliability and efficiency. It is important to be able to check in place has been recognized, and this trend is increasing compared to traditional random concrete sampling for the material. Non-destructive testing methods can be classified as: penetration tests, rebound tests, pull tests, dynamic tests and radioactive methods.

2.2 Durability
The study concludes that GBFS, with 30% replacement, improves high temperatures and sulphate resistance solutions due to its pozzolanic, chemical and thermal properties. In addition, all GBFS solutions are durable against high temperatures and sulfate sulfate due to its lower or similar losses in compression are strong compared to the reference series. The emergence of ettringite also improves sulfate resistance for 90 d, but it is reported in literatures that after 6 months this positive effect disappears due to cracking and increased weight loss (Baroghel-Bouny, *et al*., 2009) [7].
One can produce durable solutions using GBFS as a mineral additive at 30% replacement. This means that GBFS can be used at the maximum amount, and its quantity can be reduced. Thus, this study helps the concrete industry to develop technology with technical, economic and environmental benefits, useful for resource efficiency and sustainable development (TOPÇU İlker Bekir, 2007) [24].

2.3 Condition Rating
This paper presents the development of a status assessment system for assessing the condition of concrete marine structures in Malaysia. The assessment system is based on the status indicator (CI) method developed on the Corps of U.S. Army engineers. The evaluation considers the level of deterioration that is observed during the inspection works. The approach to the functional State Index (FCI) was used to compute CI structures. Data fields were collected through visual inspection on the concrete structure of the berth. Three types of impairment are considered in the assessment: (1) Corrosion of Fittings, (2) cracking, and (3) stretching the concrete surface. The results show that the calculated CI values based on the suggested method are comparatively close to the values of the expert opinions. The state assessment system based on the CI method is reliable and efficient, therefore, can be used to observe the implementation of maritime structures in Malaysia (Ayop, *et al*., 2006) [5].

2.4 Corrosion
This article is a scheme of testing for steel corrosion in reinforced concrete, based on a near-field influence of the meter wave. Physical mechanism of near field method is introduced, detailed structure of measuring device is presented. The electromagnetic field near the steel bar, which was buried in the concrete structure, is simulated by a finite difference of the time domain of Metod. The simulated data show that the average radiation power decreases monorically with the increase in corrosion depth of the steel panel, and the peripheral area is promising to be photographed directly due to the localization in the near field. The results show that almost field appliances can act as a new non-destructive testing for detection and even images of corrosion of the area buried in concrete in the engineering structure (Zhao, *et al*., 2017) [29].
Methods and sensory technologies of non-destructive Testing (NDT) are evaluated in the context of ensuring input parameters for servicing models of life of reinforced concrete constructions. The appropriate methods and NDT sensors are defined, based on various technologies including mechanical impact, ultrasound waves, electromagnetic waves, nuclear and chemical and electrical methods. Degradation corrosion reinforcement scenarios, alkaline-silica reaction, and cracking are used to detect gaps in affordable NDT methods to maintain status scores and predict service life. Common gaps, as well as strategies for resolving these gaps (Snyder, *et al*., 2013) [21].
One of the main reasons for the failure of reinforced concrete (RC) structures is corrosion of structural rebars. As a result of premature corrosion of fittings, the service life of the structures is reduced and thus there is a need for indispensable repairs or replacement, so the huge state budget is held annually. On the other hand, the effective and early detection of the corrosion process helps to limit the degree of necessary repairs or replacement, which leads to a reduction in the cost associated with the rehabilitation work. Thus, effective methods of monitoring are necessary to assess the level of corrosion in these structures, so that the necessary maintenance and repair is carried out. It is therefore necessary to identify any possible problems with durability in structures before they become serious. For the same non-destructive methods have proved to be useful for on-site corrosion evaluation in structural rebars. This paper presents an overview of various non-destructive methods for monitoring the corrosion level in reinforced concrete structures (Singh & Singh, N.D.).

3. Methodology
3.1 Nondestructive testing methods
Nondestructive testing techniques can be defined as one that does not damage or impair the performance of the structural element or member being tested. The objective of non-destructive test are for quality control and monitoring of strength in long term development, latter are to establish structural adequacy, material deterioration against time or environment, condition evaluation of older concrete for rehabilitation purpose and quality assurance of concrete repair. Non-destructive techniques, which are less time consuming and relatively inexpensive, can be useful for the following purposes [8].
1. Test on actual structure rather than on a companion sample.
2. Test at several location.
3. Test at various ages.
4. Quality control of actual structures.
5. Assessment of uniformity of concrete.
6. Location and assessment of the extent cracks, voids, honey combing.

Following are the NDT methods used to determine corrosion status, rebar cover and strength of structures.
1. Half-cell potential method.
2. Ultrasonic Pulse Velocity.
3. Cover depth measure.
4. Surface hardness.

3.2 Analysis method for condition ranking

It is a numerical index of damage level of the element and the whole structure, on the basis of in-situ tests and visual observation of the intensity and extent of damage and judging the urgency of repair.

The assessment is based on physical deterioration as determined by measurable distress. The Condition Ranking / Condition Index (CI) are represented by a quantitative ranking between 0 and 100. 0 being the worst condition and 100 being the best condition. The index serves as guidelines for structures that require immediate repairs and further evaluation [2].

3.3 Purpose and significance of condition ranking/ condition rating

The purpose and significance of condition ranting evaluation work is generally performed for the following purposes:

1. To determine the feasibility of changing the use of structure or retrofitting the structure of accommodates a different use from the present one. The feasibility of enlarging the structure or changing appearance of the structure may also to be determined.
2. To determine the structure adequacy and integrity of a structure or selected elements.
3. To evaluate the structural problems or distresses which result from unusual loading, exposure condition, inadequate design or poor construction practices. To determine the feasibility of modifying the existing structure to conform with current codes and standards
4. To determine the service life of existing structures.
5. To evaluate or determine the cost effectiveness of repairing, replacing and strengthening the existing structural members elements.

The main significance of condition rating to verify the structural problems discovered and to determine whether or not corrective action is required to repair the existing conditions or to protect the existing structural system [3].

4. Results

There are total 50 water tanks and the data related to it is collected from the different 50 villages. The data collected includes, year of construction, capacity of water tank, staging height, shape of the column, number of columns, bracing level, structures geometry of the tank, structure of staging, exposure conditions, top dome, bottom dome, vertical / cylindrical wall, beam, columns and bracings. The visual inspections and the non-destructive testing has been incorporated on the water tank.

The data from the different villages and the results are mentioned as follows.

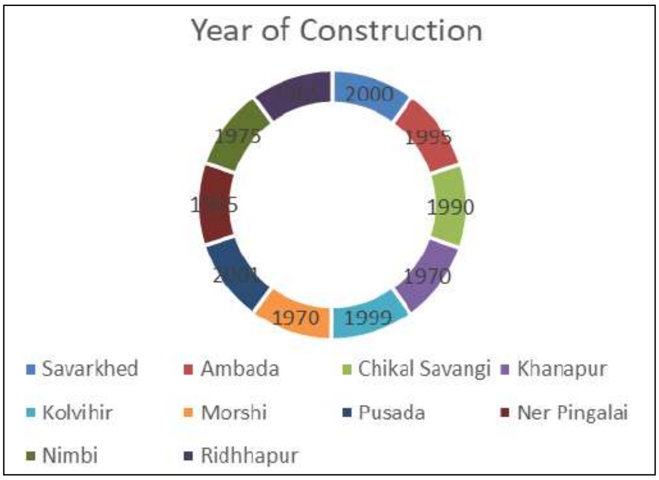

Fig 1: Year of construction of water tank in the different villages

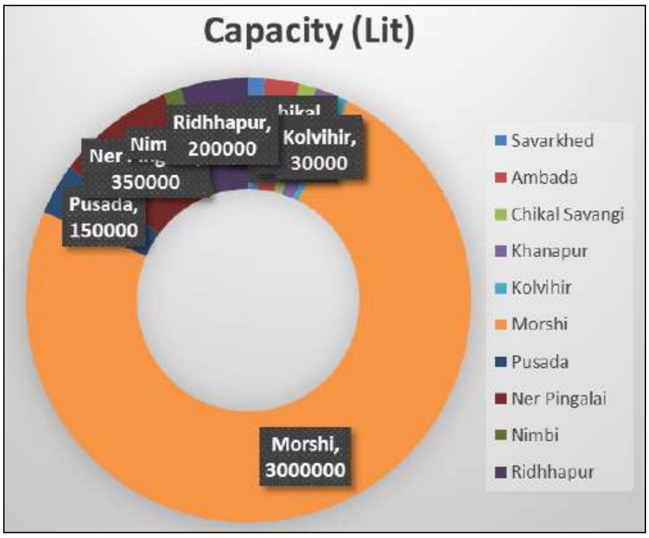

Fig 2: Capacity of water tank in the different villages

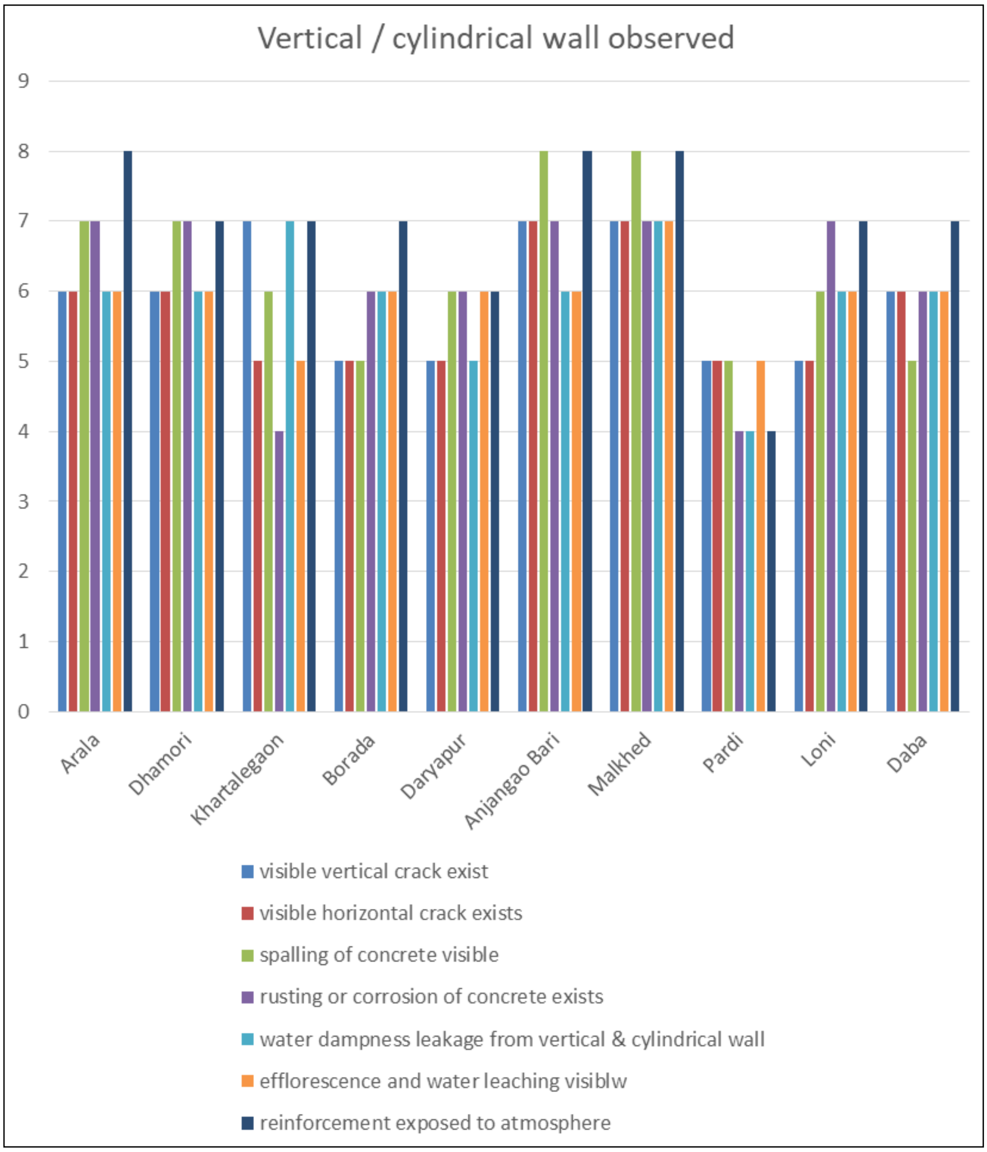

Fig 3: Vertical / cylindrical wall observed on the water tank in the different villages

The condition index/condition ranking (CI) of RCC ESR at Adgaon is presented as follows.

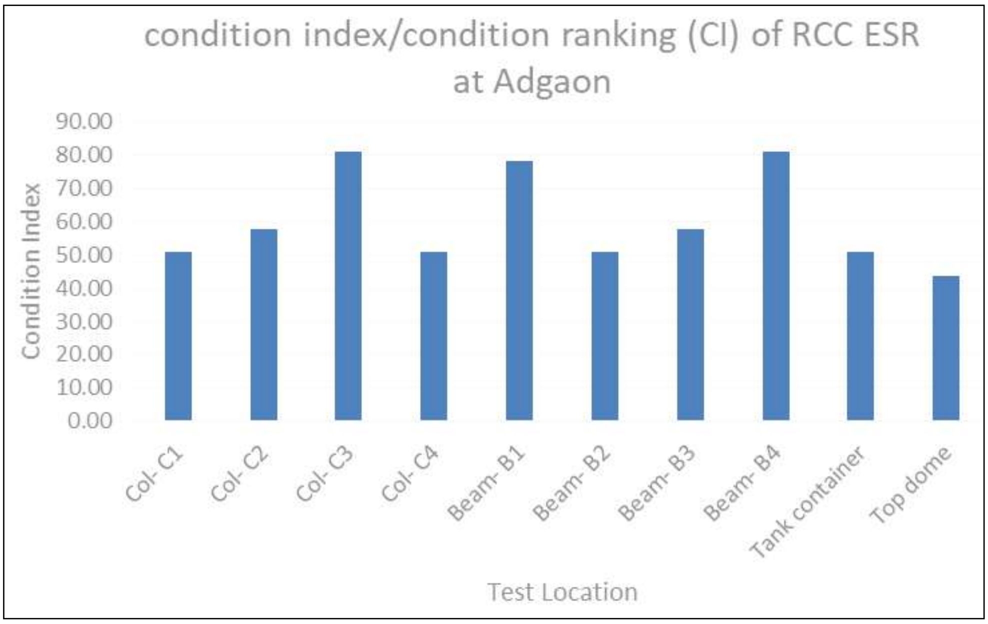

Fig 4: Condition index of RCC ESR at Adgaon

The maximum value of condition index is found to be on column C3 and beam B4.

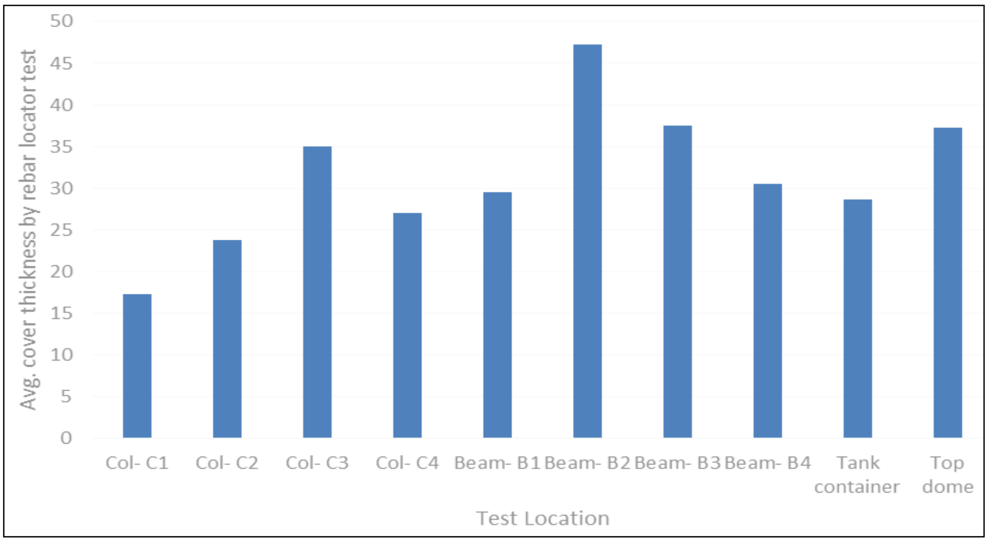

Fig 5: Avg cover thickness for rebar locator test

The average cover thickness for rebar locator test is found to be at Beam B2.

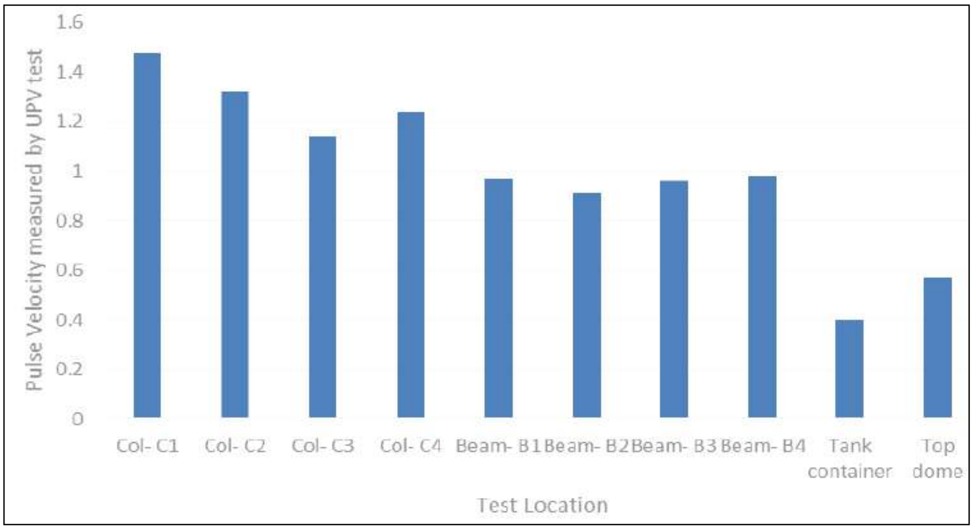

Fig 6: Pulse velocity measured by UPV test of RCC ESR at Adgaon

The pulse velocity measured by UPV test is found to be at column C1 and the minimum value at tank container.

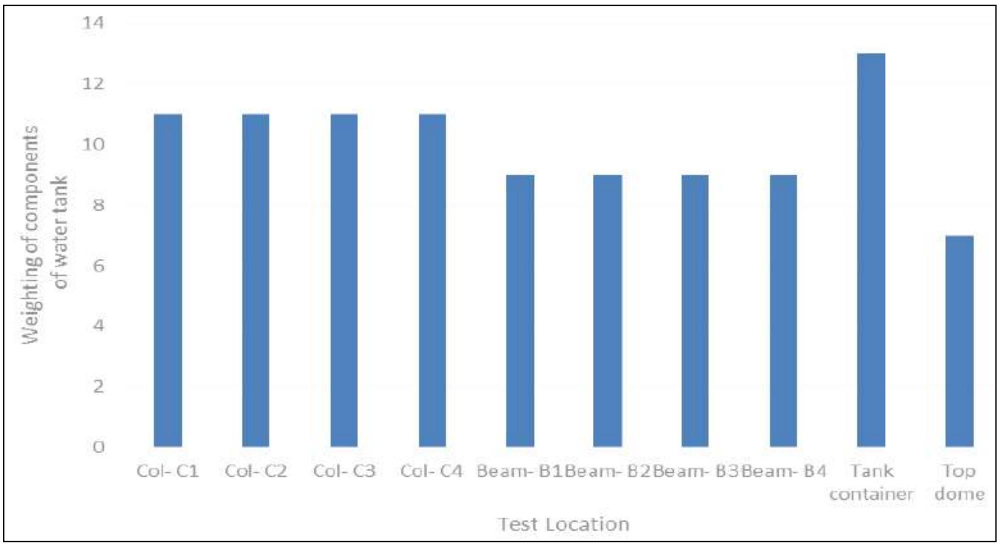

Fig 7: Weightage of components of water tank of RCC ESR at Adgaon

The weightage of components of water tank is found to be maximum at tank container and minimum at top dome.

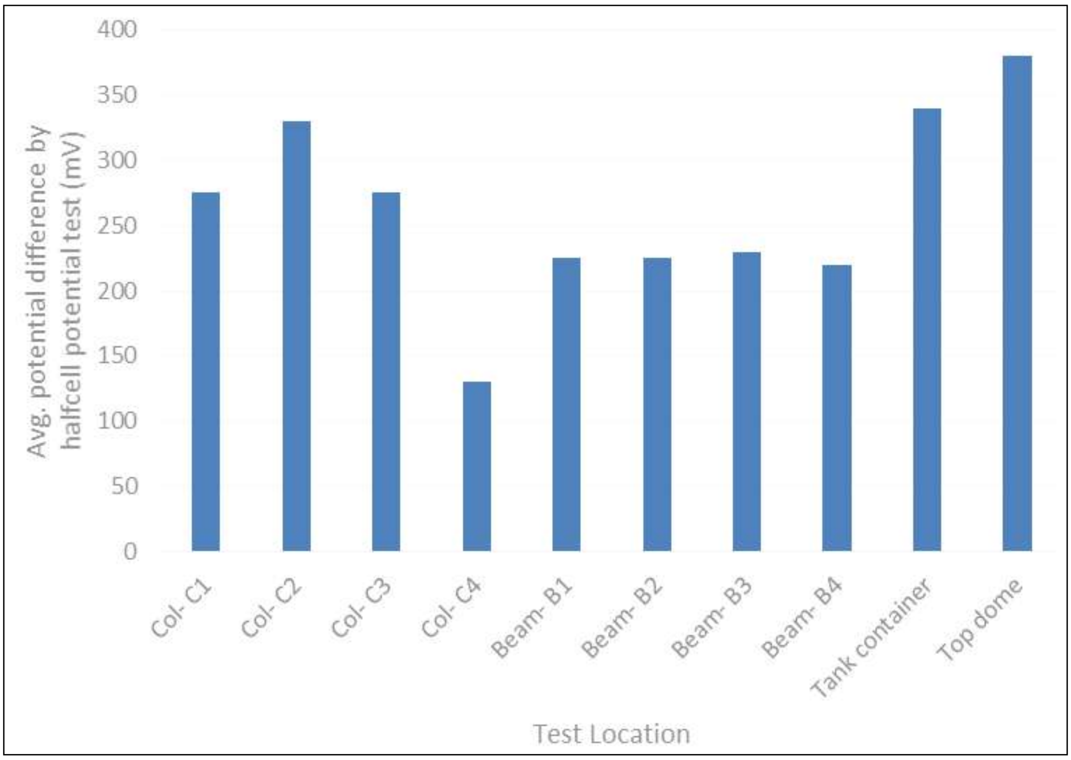

Fig 8: Average potential difference by half-cell potential test of RCC ESR at Adgaon

The average potential difference by half-cell potential test is found to be maximum at top dome and minimum at the column C4.

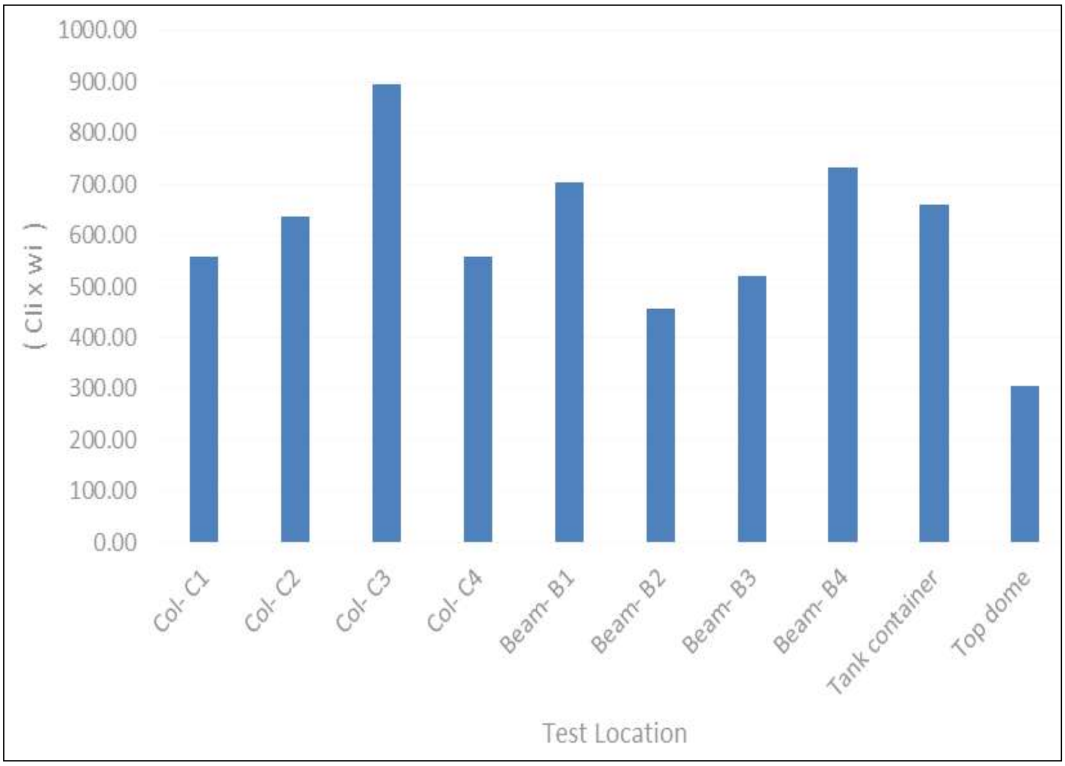

Fig 9: CII for the different test locations of RCC ESR at Adgaon

From the above graph it can be observed that the column C3 has the maximum value of CII while top dome has the minimum value.

The condition index/condition ranking (CI) of RCC ESR at Varha is as follows.

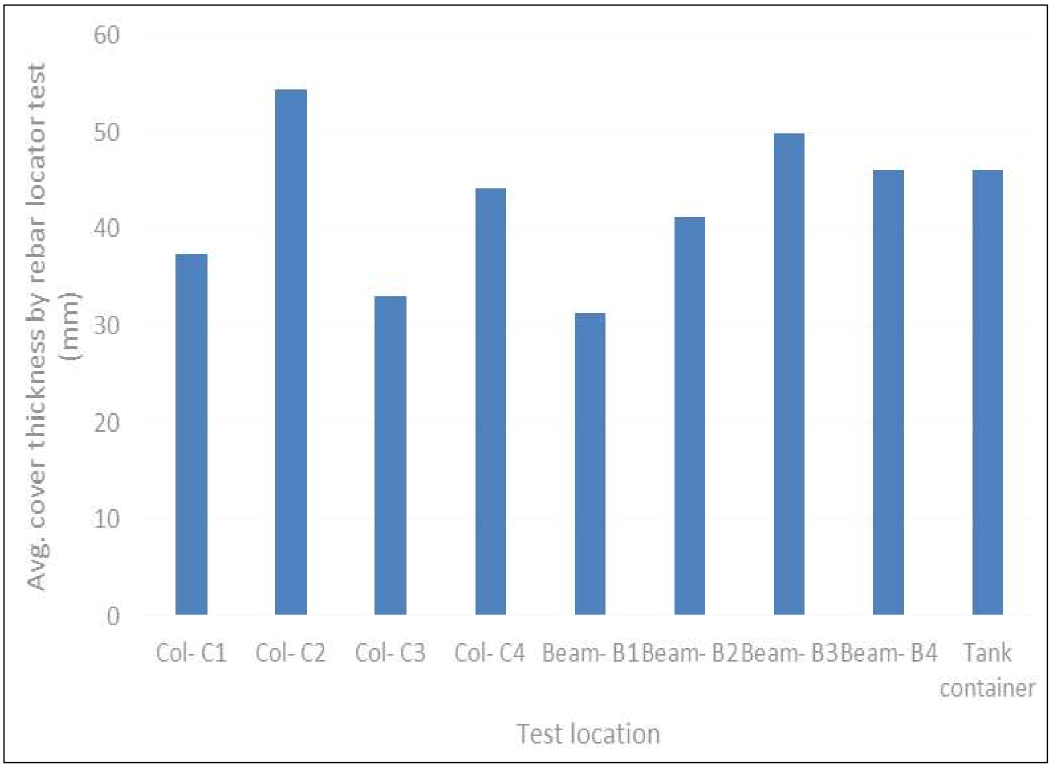

Fig 10: Average cover thickness by rebar locator test of RCC ESR at Varha

From the above graph the average cover thickness by rebar locator test is found to be maximum for column C-2 while it is minimum for the beam B-1.

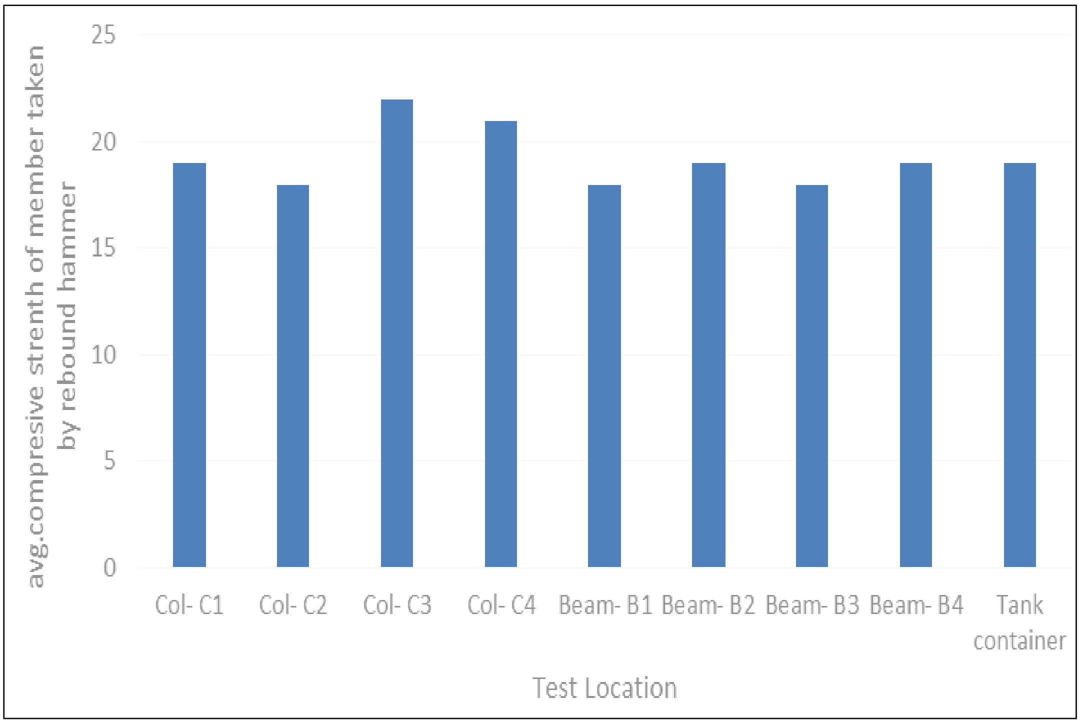

Fig 11: Average compressive strength of members taken by rebound hammer test of RCC ESR at Varha

The average compressive strength of the members taken by rebound hammer test is found to be maximum at the column C-3 while it is minimum at the beam B-1.

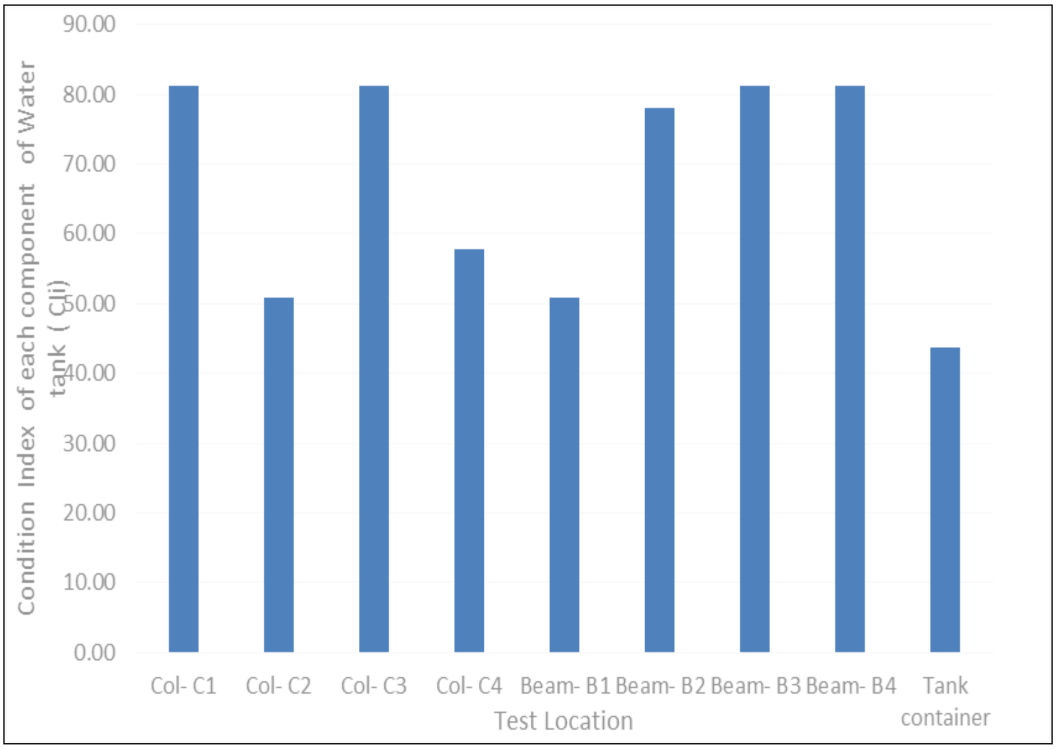

Fig 12: Condition index of each component of water tank of RCC ESR at Varha

The condition index of each component of water tank is found to be maximum at the beam B-4 while it minimum at the tank container.

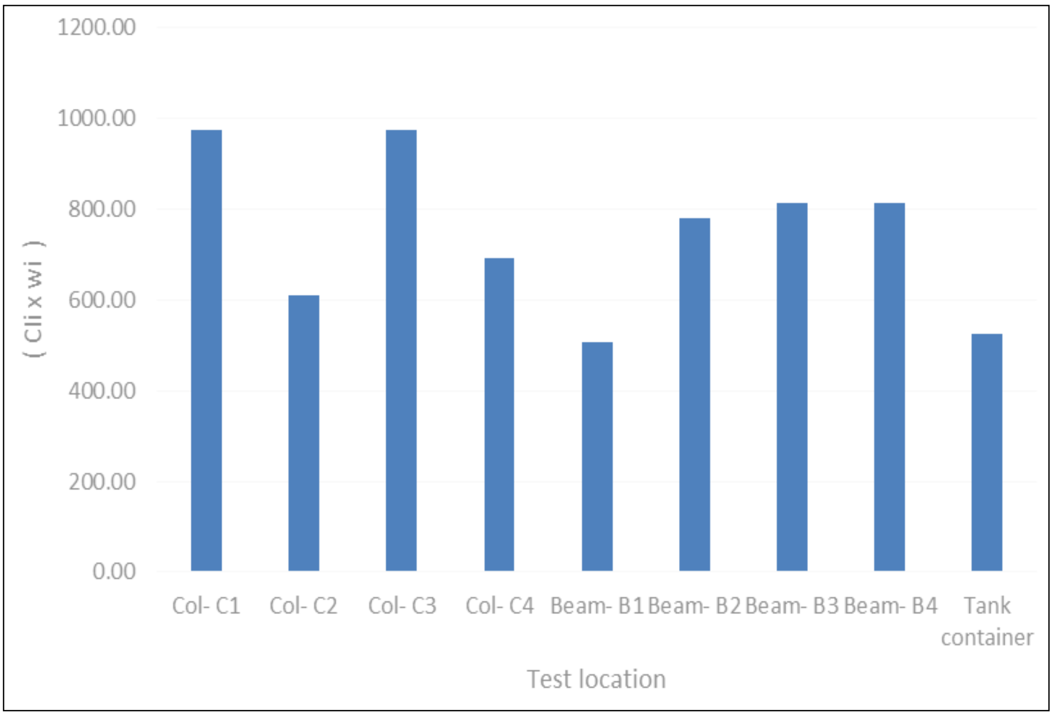

Fig 13: CII for the tank at different location of test of RCC ESR at Varha

The maximum value for the CII is found to be at the column C1 and it is minimum at the beam B-1.

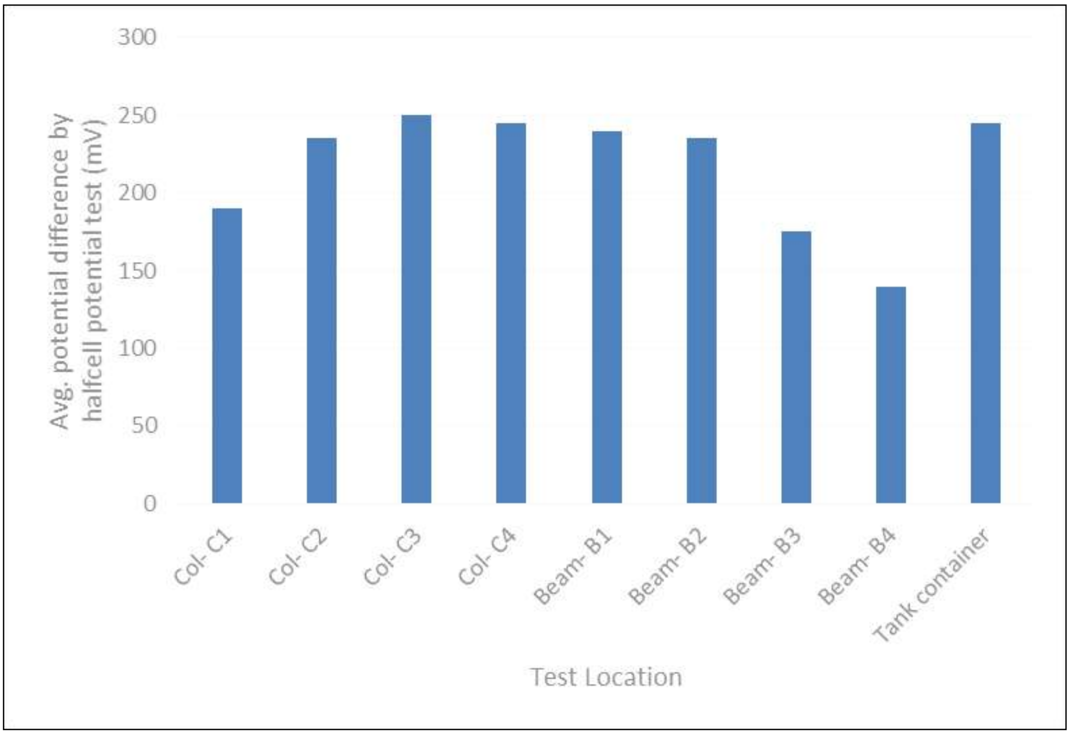

Fig 14: Average potential different by half-cell potential test of RCC ESR at Varha

From the above graph it can be observed that the average potential difference by half-cell potential test is maximum at the column C3 while it is minimum at the beam B4.

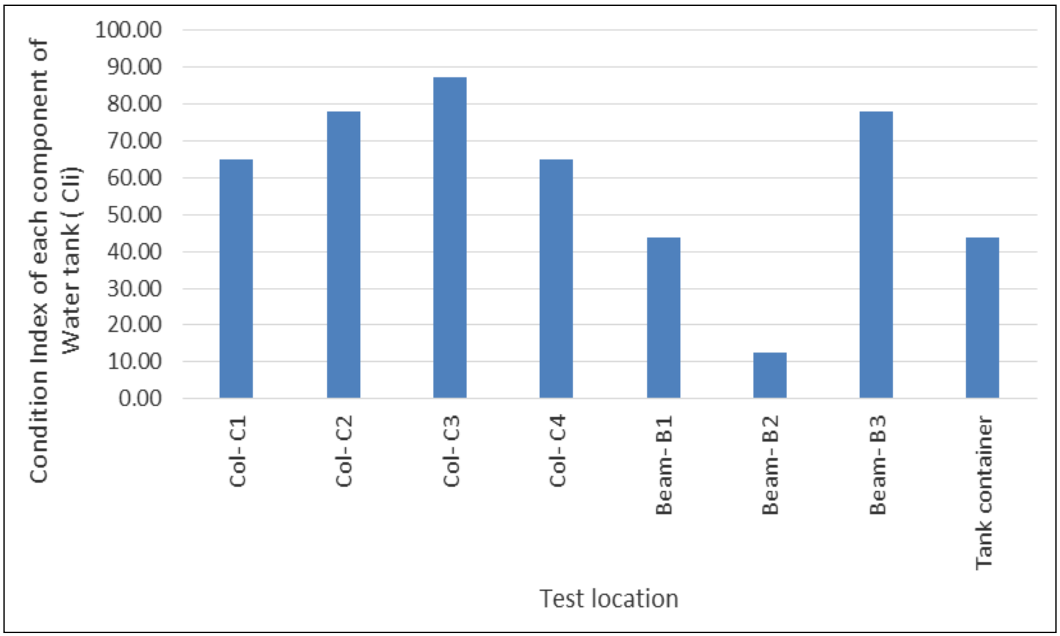

Fig 15: Condition Index of each component of Water tank (CII) at Walgaon village

From the above study it was observed that the Condition Index of each component of Water tank (CII) Walgaon village.

Conclusion

Different NDT methods, based on different principles, with their individual advantages and limitations, have been studied. It has been acknowledged that NC plays an important role in assessing the state of existing structures, and there is a sharp need to develop standards for non-destructive testing and the interpretation of NDT results. The main advantage of NDT methods was their ability to check in place. A great expertise is required to interpret field observations and test results. Non-Destructive testing provides useful information by identifying hidden or unknown defects, as well as repair or replacement of RC structures may be planned according to the results of NDT. The combination of various methods of non-destructive testing is the best way to assess structures.

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