RELIABILITY OF NONDESTRUCTIVE TESTS
A PRACTICAL EXPERIENCE

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ABSTRACT
Concrete is a versatile construction material used as primary material for project construction in the Middle East.
Unfortunately concrete deteriorates for many known and sometimes unknown reasons. Aggressive environment with hostile elements such as chlorides, sulfates, corrosive chemicals and carbon dioxide attacks the concrete, in presence of humidity and Oxygen, causing deterioration.
Concrete deterioration may be caused by concrete loosing alkalinity, or by steel corrosion, or by both. Projects with concrete structural elements, through their life cycle, need be investigated for many reasons. Heightening a building, changing its function, maintenance works and other reasons deem concrete testing necessary.
Concrete testing can be achieved through destructive and non-destructive methods. These methods are well documented and accepted by International Codes. However, this is not the end of the story!
Concrete testing in existing structures confronts the engineer with many challenges. Finishes concealing the concrete, such as plaster and paint, marble cladding, porcelain cladding, and other materials hinder the direct access to concrete elements. Use of the project while concrete testing is performed and the higher cost of core-testing hinder the engineer from performing a sufficient amount of destructive testing.
Through decades of field study of existing concrete structures, our offices have conducted many destructive and non-destructive concrete tests, through different independent laboratories, in Saudi Arabia. It was always our policy to perform non-destructive tests in conjunction with destructive reference tests. We were never satisfied by the non-destructive results obtained. These tests are subject to many sources of error that deem them unreliable, such as:
- Calibration of the instrument used,
- Environmental conditions affecting the instrument calibration,
- Experience and knowledge of the technician performing the tests,
- Preparation of the surface of the tested area,
- Location of the tested area,
- Presence of cracks and separated concrete cover,
These are but few reasons behind such impossible reliability of the non-destructive tests.
The engineer might have ended testing a pebble, a close-by steel stirrup, an embedded hole, a shallow conduit, etc...using instrument that was not properly calibrated, run by a semi-educated or uneducated personnel.

1- INTRODUCTION:
Concrete is a versatile construction material used as primary material for project construction in the Middle East.
Unfortunately concrete deteriorates for many known and sometimes unknown reasons. Aggressive environment with hostile elements such as chlorides, sulfates,
corrosive chemicals and carbon dioxide attacks the concrete, in presence of humidity and Oxygen, causing deterioration.

Concrete deterioration may be initiated by concrete losing alkalinity, or by steel corrosion, or by both.

Projects with concrete structural elements, through their life cycle, need be investigated for many reasons. Heightening a building, changing its function, maintenance works and other reasons deem concrete testing necessary.

2- DESTRUCTIVE VS NONDESTRUCTIVE TESTS:

No doubt, the destructive concrete testing, namely the coring is superior to other sorts of testing available. The cores obtained shall give a physical display of both the quality and performance of the tested concrete. Cores shall show the intactness of the concrete, the gradation of sand and gravel used, the properties of the aggregates used, the porosity characteristics, the presence of impurities, cracks, hidden honeycombing…and so on. Crushing the core shall give a direct indication of the strength of the concrete. The crushed core could be used then in chemical analysis, chloride and sulfates presence and cement content testing.

Concrete nondestructive testing in existing structures confronts the engineer with many challenges. Finishes concealing the concrete, such as plaster and paint, marble cladding, porcelain cladding, and other materials hinder the direct access to concrete elements. Nondestructive testing deals mostly with the strength of the tested concrete. However, the use of the project while concrete testing is performed and the higher cost of core-testing may hinder the engineer from performing a sufficient amount of destructive testing.

Through decades of field study of existing concrete structures, our offices have conducted many destructive and non-destructive concrete tests, through different independent laboratories, in Saudi Arabia. By large, reverting to nondestructive testing could not at any single time give us a reliable stand-alone result. Our offices concluded early enough that a reliable source of testing must associate with the nondestructive testing to support the results.

Nondestructive testing has inherent difficulties embedded in the process that must be clarified to deem these tests reliable. These difficulties are focused into three aspects:
1. The Site,
2. The technician, and
3. The instrument used.

These inherent difficulties are discussed in detail in the following paragraphs.

3- NONDESTRUCTIVE SITE TESTING DIFFICULTIES:

Some of the major difficulties that might face the engineer utilizing NDT as means to test and report a concrete structure are:

- Preparation of the surface of the tested area may be impossible. See figures (1)
Fig (1) - Deteriorated Column, hinders preparation of the area tested

- Location of the tested area may hinder the testing.
- Accessibility to the tested area, shall play the main role in the possibility of NDT testing.
- Presence of cracks and separated concrete cover, shall lead to wrong results. See figures (2).

Fig (2) - Deteriorated Girder can not be tested with NDT concept

- Location of the steel reinforcement shall interfere with the test results. See figures (1).

4- THE LAB TECHNICIANS:

Though there are methods and means prescribed in ACI to test and approve a lab technician, none of that is applied or requested in the Muddle East. Lab technician’s prequalification might be only his kin-relation with the lab proprietor. As a matter of fact, a lab technician must enjoy those prescribed ACI prerequisites, with emphasis on the following requirements:

- Knowledge of the technician performing the tests,
- Experience of the technician performing the tests,
- Presence of the Engineer during testing,
- Wrong aiming of the instrument may deem the reading useless,
- Correct recording of the results, in the event of reading many results to obtain a median.
5- THE INSTRUMENTS:
The instrument used must also be scrutinized for reliability. It is not enough to rely on the lab reputation; an engineer must make sure that the following points are well addressed prior to any NDT testing procedure takes place:
- Calibration of the instrument used; some labs would not even think of that, due to the associated cost, uninterrupted business, or far distance to the calibration authority. See Fig.(4).

![Fig (4) - Testing Device is calibrated](image1)

- Environmental conditions affecting the instrument calibration; humidity and excessive heat may affect the readings obtained.
- Presence of associated index charts. Realistic charts may not be available to compare results obtained.
- Full attention paid to recognize right NDT testing. Unrecognizable sudden failure of the testing device may, if goes without notice, deem testing false and delay or hinder the testing process. See Fig. (5)

![Fig (5) - Surface Preparation is not always feasible](image2)

6- THE WAY OUT:
The said shortcomings stated above are but few reasons behind such impossible full reliability of the non-destructive test results.

The engineer might have ended testing a pebble, a close-by steel stirrup, an embedded hole, a shallow conduit, etc…using instrument that was not properly calibrated, run by a semi-educated or uneducated personnel.

Such dilemma may be evaded. It was always our policy to perform non-destructive
tests in conjunction with destructive reference tests. Testing was performed in our presence. Testing locations at site, instrument used and the technician performing the tests were all under our direct supervision in our presence.

Though we were never satisfied by the non-destructive test results obtained, due to the shortcomings explained, these test results were used in companion with the destructive test results obtained through an associated test performed simultaneously with the nondestructive tests in one or more locations. See Fig.(6), Fig.(7) and Fig.(8).

Fig (6) - Coring is taken near NDT Location for result comparison

<table>
<thead>
<tr>
<th>Test Parameters</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Soluble Chloride (Cl)</td>
<td>0.020</td>
</tr>
<tr>
<td>Acid Soluble Sulphate (SO₄)</td>
<td>1.710</td>
</tr>
</tbody>
</table>

Fig (7) - Chloride and Sulfates Contents are obtained through Coring.

<table>
<thead>
<tr>
<th>Test Parameters</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Soluble Chloride (Cl)</td>
<td>0.014</td>
</tr>
<tr>
<td>Water Soluble Sulphate (SO₄)</td>
<td>0.124</td>
</tr>
</tbody>
</table>

Fig (8) - Core Testing Displays Concrete Characteristics:

Sand /Gravel sizes and contents, Porosity, Friability…etc

7- CONCLUSIONS:
The following conclusions are guidelines for the engineer to interpret and implement the nondestructive test results:

1- Use an independent certified reputable lab for testing.
2- Your qualified engineer must attend the testing procedure.
3- Investigate the instrument used.
4- Enquire and read the latest calibration performance date.
5- Enquire and brief-test the technician assigned.
6- Assign the test locations required.
7- Show test locations on the drawing.
8- Tabulate the readings by test location and number of readings.
9- Do not perform computations on the site.
10- Make a coring at the first location assigned for nondestructive test.
11- Make a coring at the last location.
12- If the project is large, i.e. more than thirty locations are tested, make an intermediate coring.
13- If the testing is not finished within a working day, start the next day with a new coring.
14- Take a copy of the test results obtained to control the Lab report later. See fig.(9) and Fig.(10).

![Fig (9) - Reliable Results](image)

**Compare C-4 to S-4 by Schmidt Hammer**

$F_c' = 17.29$ MPa with 24

**How Much Reliability in NDT?**

![Fig (10) - Compare S-4 to C-4 in Coring Results](image)

**$F_c' = 24$ MPa with 17.29**

**How Much Reliability in NDT?**

8- REFERENCES:

1- All Text and Photos by the author.
3- "In Situ Strength Evaluation of Concrete Histories and Laboratory Investigations", Kopf, Rowland J., Cooper, Claude G., Williams, Freeman W. *Concrete International*, March 1981

4- “Quality Control and Acceptance Inspection as viewed by the Testing Laboratory”, Henry, Robert L., *Concrete International*, September 1982