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Evaluation of the concrete quality using destructive and non–destructive tests

Abstract

This work presents the results of an assessment carried out on the structure of a civil building to check the homogeneity of the concrete implementation. The determination of investigations of the structure was based on a preliminary study of documents and a preliminary visit of the book. Then a detailed visual inspection of the work was performed in which we achieved a record of disorders. These were qualified and quantified to the extent possible using auscultation devices and laboratory analysis. The profometer has been useful for the localization of reinforcements in concrete and the estimation of the thickness of coating. A Schmidt Rebound Hammer was used to evaluate the quality and compressive strength of the concrete. The carbonation depth was determined by the phenolphthalein method.

Keywords: auscultation, coating thickness, Profometer, schmidt rebound hammer, drilling cores, compressive strength test, carbonation depth

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Malek Jedidi[1,2]

[1]Higher Institute of Technological Studies of Sfax, Department of Civil Engineering, Tunisia

[2]University Tunis El Manar, National Engineering School of Tunis, Civil Engineering Laboratory, Tunisia

Correspondence: Malek Jedidi, Department of Civil Engineering, Higher Institute of Technological Studies of Sfax, B.P.88, 3099 Sfax, Tunis, Tunisia, Tel +216 9825 8681, Fax +216 7443 1425, email malekjedidi@yahoo.fr

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Introduction

Reinforced concrete can deteriorate under the influence of causes related to its original quality or to exploitation or environmental stresses. Apparent or hidden pathologies can occur. In order to know their nature, their extent and their evolution potential, a necessary diagnosis is made for taking decisions concerning the maintenance of the structure concerned. There are many methods or techniques of expertise that can help diagnose the main causes of deterioration, including non–destructive testing (NDT) that do not damage the buildings and allow contractors and building owners have an inventory of structures and pathologies. NDT such as the Schmidt Rebound Hammer have been widely applied to the study of mechanical properties and integrity of concrete structures.[1–6] The results of these investigations are most often presented in the form of graphic plates: sections, maps of anomalies and interpreted measurement profiles. In this context, a great deal of research has been done to prove that the physical properties of concrete can be related to the compressive strength.[7–9] In our study these auscultation techniques were adopted according to the type of disorders affecting the structure. Indeed, the profometer has been useful for the localization of reinforcements in concrete and the estimation of the thickness of coating. The evaluation of the quality and strength of the concrete was determined using a Schmidt Rebound Hammer; it is the most widely used instrument in the field of non–destructive testing of the compressive strength of concrete. This measurement technique is always approximate and is limited to depths of about 8 cm for surface measurements. The measurement of the carbonation depth was determined by the phenolphthalein method. The origin of the chemical disorders was determined by analyzes on two soil samples from the bottom of the excavations in order to assess their swelling abilities and their sulfate ion content.

Experimental study

Non–destructive tests

Measurement of the coating thickness of the concrete and location of the reinforcements by the profometer

The profometer is a light and compact metal reinforcement detector, uses non–destructive pulsed induction technology to allow the localization of metal reinforcement in concrete (Figure 1). It also makes it possible to estimate the coating thickness of the reinforcements. This test was performed on the specimens according to standards BS 1881, Part 204.[10]

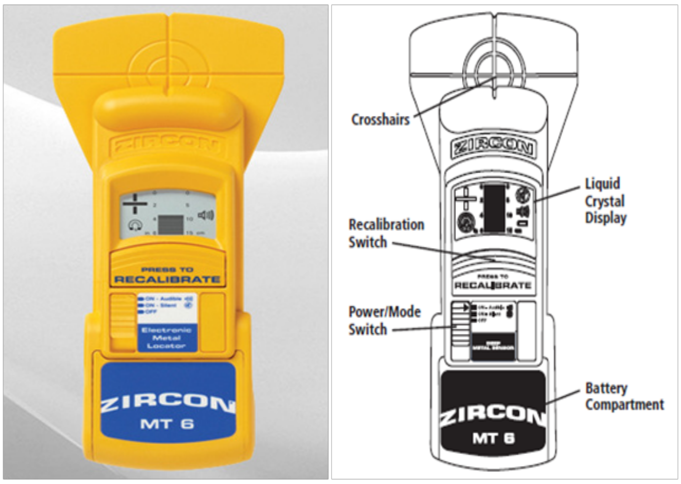

Figure 1 Profometer Zircon MT 6 Rebar Locator.

The detection of metal frames and other metal building elements is not possible beyond 8 cm of concrete thickness. In the case of very dense reinforcement networks, reading is sometimes uncertain. The coating thickness is detected with an error of the order of 4 mm, and the diameter of the steel with an accuracy of 2 mm.

The procedure of the profometer Zircon MT 6 Rebar Locator is as follows:

1. Turn on the sound by placing the selector on either AUDIBLE or SILENCE. This is done in the air and away from any metal.
2. Clean the area to be scanned of any sand and pebble. If the surface is rough enough, slide a thin sheet of cardboard between the surface and the unit. The thickness of the cardboard must be deducted from the depth reading to determine the actual distance to the target using this method.
3. Place the profometer on the surface to be scanned and sweep

from one side to the other. As you approach, the number of depth bars increases. At the nearest point of the metal, the plus sign toggles at least accompanied by a sound signal (in AUDIBLE mode)

4. Once a target has been located, reposition the sure–looking pro–sphere and scan it perpendicular to your original scan direction to be sure you have determined the target's importance.
5. Read the value of the coating thickness of each bar: this is the maximum value displayed on the depth bar.
6. Mark the location of the frames. The Crosshairs on the top of the device show where awareness is maximum.

Schmidt Rebound Hammer test

The Schmidt rebound hammer is principally a surface hardness tester. It works on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges (Figure 2). There is little apparent theoretical relationship between the strength of concrete and the rebound number RN of the hammer. This test was performed on the specimens according to standards EN 12504–2[11] and EN 12309–3.[12] Schmidt rebound hammer test gave values of RN. The compressive strength of the concrete was derived using the chart provided with the device.[13] No action has been located within 40 mm of the flat faces of the specimen. The hammer has to be used against a smooth surface, preferably a formed one. Open textured concrete cannot therefore be tested. If the surface is rough, e.g. a trowelled surface, it should be rubbed smooth with a carborundum stone. RN was equal to the median of 9 measures spread.

Destructive test

Drilling cores from the hardened concrete

The hardened concrete cores were sampled according to standard NF EN 12504–1[14] using a core cutting machine (Figure 3). It is usually helpful to collect carrots not only in the most deteriorated areas but also in healthy areas. Comparative analysis of test results often helps to identify the causes of the damage. Core drilling should not affect the stability or structural strength of the structure. The positions of the reinforcements were detected before the coring using the profometer to avoid as much as possible to recover concrete specimens with reinforcements. The cores used to determine the compressive strength shall not contain any reinforcement parallel to their longitudinal axis. The diameter of core specimens for the determination of compressive strength in load bearing structural members shall be at least 3.94 mm. For non–load bearing structural members or when it is impossible to obtain cores with length–diameter ratio (L/D) greater than or equal to 1, core diameters less than 94 mm are not prohibited.

(A) (B) (C)

Figure 2 Schmidt rebound hammer test
A: Schmidt rebound hammer,
B: Carborundum stone,
C: Chart for determining the resistance as a function of RN.

Figure 3 Drilling operations from hardened concrete.
A: Core cutting machine;
B: Drilling operation;
C:Visual examination of cylindrical core specimen.

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Compressive strength test

The compressive strength of core specimens was determined by destructive testing with a compression test machine according to the requirements of NF EN 12390–3.[15] Progressive loading with a rate of 0.5 MPa/s was applied to the crushing of the specimen. The value of the compressive strength was determined by dividing the value of the maximum load by the section of the specimen.[16] The core specimens were cut to reduce their slenderness to twice the diameter (Figure 4). If the slenderness (Ratio of Length to Diameter) of the core specimen is different from 2, the value of the compressive strength must be corrected by multiplying by the appropriate correction factors indicated in the Table 1.[17]

Table 1 Factor of correction of the compressive strength according to the slenderness of the core specimen

Ratio of length to diameter (L/D)	Strength correction factor
1,75	0,98
1,50	0,96
1,25	0,93
1,00	0,87

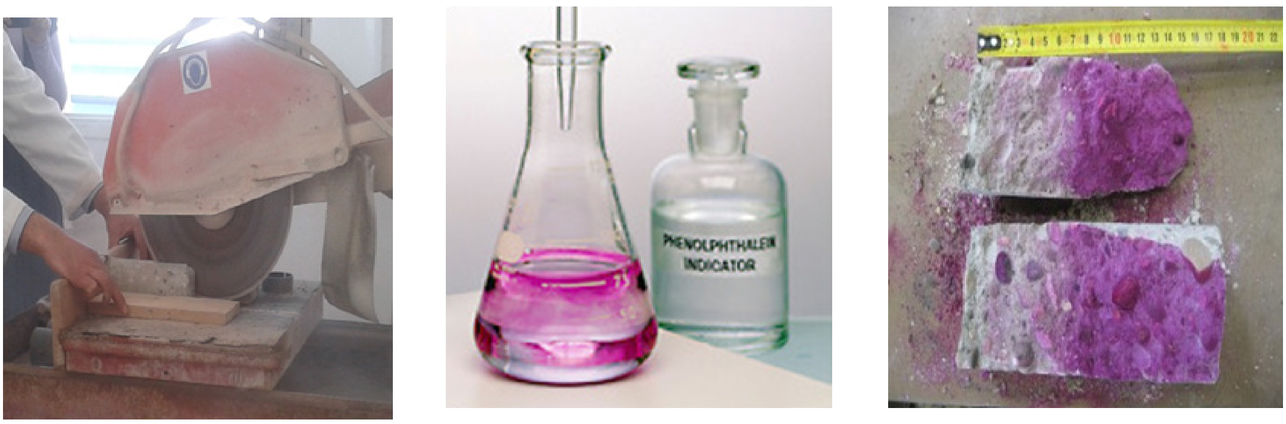
Measurement of hardened concrete carbonation depth

The measurement of the carbonation depth was determined by the phenolphthalein method according to BS EN 14630[18] on the cores removed. Phenolphthalein is a colored pH indicator whose turn is around 9. Phenolphthalein turns non–carbonated concrete red, and remains colourless in carbonated concrete.

The principle of the test consists in:

1. Slit the carrots along their longitudinal axis (if possible at mid–diameter of the carrot) (Figure 5A).
2. Spray the surfaces of the carrot with the phenolphthalein indicator solution (Figure 5B) to moisten them by ensuring that the spray does not run off the surface. When the concrete is very dry, a slight mist of water may be applied to the broken surface just before the phenolphthalein solution is applied.
3. Measure the carbonation depth d_k between the outer surface of the concrete and the edge of the colored region in red–purple and deduce the average carbonation depth d_{ka} (Figure 5C). The determination of depth of carbonation should be carried out immediately after collection

Figure 4 Compressive strength test of core specimens.



A B C

Figure 5 Measurement of hardened concrete carbonation depth.

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Results and discussion

Measurement of the coating thickness of the concrete by the profometer

The tests were carried out on reinforced concrete elements such as columns, beams and stringers. Figure 6 gives the values of the coating thickness corresponding to the analysis points. According to the results, we note that the average value of the coating thickness measured on the different surfaces is equal to 23 mm which is in accordance with the requirements of standard BS EN 1992–1–1.[19]

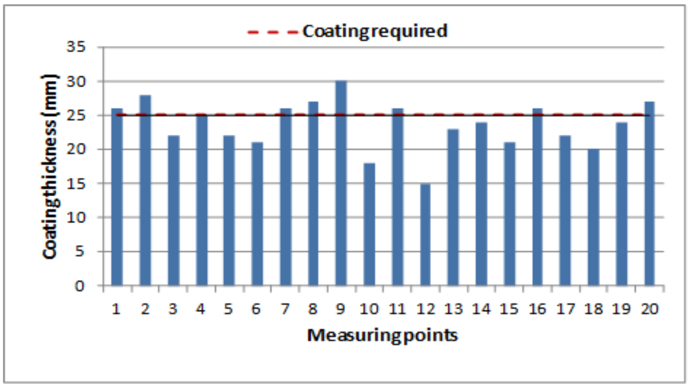

Figure 6 Measurement of the coating thickness of the concrete.

Schmidt Rebound Hammer Test

The Schmidt rebound hammer test was carried out on reinforced concrete elements such as pre–columns, columns, footings, beams and stringers. The Schmidt Rebound Hammer gives indications only on concrete on the surface and not at heart. Measurements made on old concrete can be so distorted if the concrete is carbonated. Indeed, a carbonated concrete on the surface increases the superficial compactness and therefore the compressive strength determined by the Schmidt Rebound Hammer test. Figure 7 gives the values of the compressive strength deduced from the Schmidt Rebound Hammer test carried out on reinforced concrete elements. It is noted that the compressive strength values (between 09 MPa and 25.5 MPa) are lower than the average value required for concrete dosed at 350 Kg/m³ at an age exceeding 28 days.

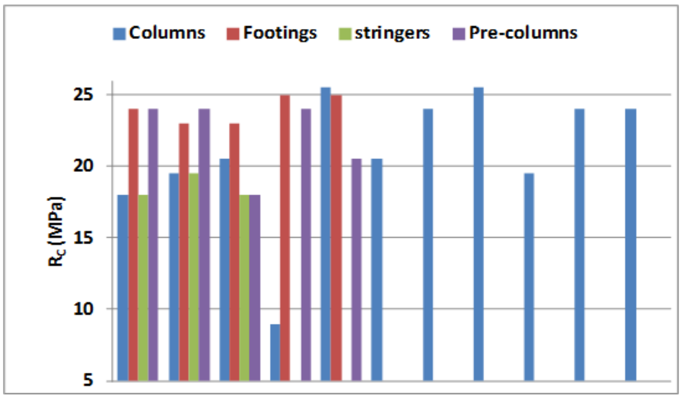

Figure 7 Compressive strength of reinforced concrete elements.

Compressive strength test

Figure 8 gives the values of the compressive strength of eleven concrete cores taken from the footings, pre–columns and columns. We note that compressive strength values vary between 8.10 MPa and 27.40 MPa. The density of the different cores has been also measured; it is between 2.15 t/m³ and 2.41 t/m³. The different cores have an average resistance of 17 MPa lower than the average value required for a concrete dosed at 350 Kg/m³ at an age exceeding 28 days.

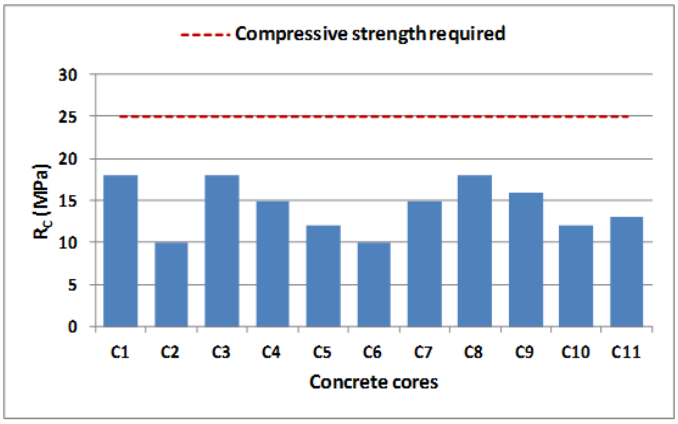

Figure 8 Compressive strength of reinforced concrete cores.

Hardened concrete carbonation depth

Carbonation is a source of degradation of reinforced concrete structures, which affects their durability. This phenomenon leads to the de passivation of the reinforcements and their oxidation. This is why it is necessary to evaluate the stage of aging of a concrete with a view to its repair knowing until, at a given moment, the carbonation has penetrated, that is to say the limit of protection still existing relative to the locations of the frames. Figure 9 gives the values of the carbonation depth measured on the cores taken from the footings, pre–columns and columns. We note that the average carbonation depth is equal to 14.27 mm which is less than the value of the coating (23 mm). These results confirm that the reinforcements are sheltered from the carbonation phenomenon.

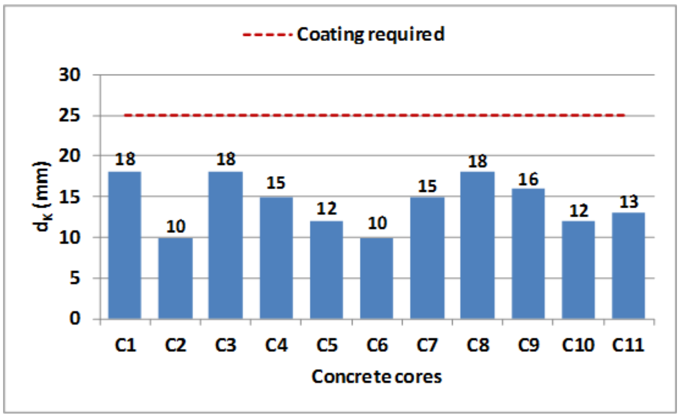

Figure 9 Hardened concrete carbonation depth of reinforced concrete cores.

Inflation test and sulfate ion content SO_4^{2-}

The collection of two soil samples from the bottom of the excavations was carried out in order to assess their swelling abilities and their sulphate ion content. The chosen depth was about three meters. Table 2 illustrates the results for the two samples tested, it is noted that the average content of sulfate ions is equal to 1025 mg/l and the average water content is equal to 8.74%. These results confirm that the soil is non–swelling.

Table 2 Results of infiltration and sulfate ion content SO_4^{2-} tests

Samples	Depth (m)	Water content (%)	Sulfate ion content SO_4^{2-} (mg/l)
1	-2.5	8.53	1030
2	-3	8.96	1020

Conclusion

Through this work, it has been shown that the realization of a diagnosis is essential for the proper maintenance of buildings. Various auscultation techniques were discussed with their limitations and their use according to the disorders observed. The simplicity and speed of the test contrast with several drawbacks which can lead to misleading or useless results. The results of compressive strength deduced from Schmidt Rebound Hammer Test are significantly influenced by several factors.

The following conclusions can be drawn:

I. The profometer allowed the localization of metal reinforcement in the concrete and the estimation of the coating thickness. The combination of the results of the coating and carbonation measurements shows that there is no risk of development of a corrosion phenomenon since the thickness of the coating of the steels greatly exceeds the depth of carbonation.

II. Concrete compressive strength deduced from Schmidt Rebound Hammer Test on pre–columns, columns, footings and stringers show an average resistance of 18 MPa lower than the average value required for a concrete dosed at 350 Kg/m^3 at an age exceeding 28 days. This measurement technique is always approximate and is limited to depths of about 8 cm for surface measurements.

III. The compressive strength deduced from the axial compression tests on the concrete cores show an average resistance of 17 MPa lower than the average value required for a concrete dosed at 350 Kg/m^3 at an age exceeding 28 days.

IV. The values of the carbonation depth measured on the cores taken from footings, pre–columns and columns confirm that the reinforcements are sheltered from the carbonation phenomenon.

V. The results of sulfate ion content $SO4^{2-}$ and infiltration tests on soil samples from excavations confirm that the soil is non–swelling.

VI. Following these results, we note that the probable causes of the disorders are the differential settlements of the foundations caused by the infiltration of wastewater as well as the poor quality of the concrete recorded.

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Conflict of interest

The author declares there is no conflict of interest.

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