APPLICATION OF NON-DESTRUCTIVE TESTING IN EVALUATING REINFORCED CONCRETE STRUCTURAL ELEMENTS IN BUILDINGS

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ABSTRACT

Of recent a large number of existing reinforced concrete buildings have required reconstruction, renovation and improvement. This tendency poses a number of problems that have to be solved, the main one being to determine the actual strength condition of the structural components/elements of the building. It includes determination of the quality of materials used, specification of the types and description of apparent faults and damages and extent of wear of the building. To undertake this evaluation, non – destructive testing methods are used. In this paper, applications of non – destructive testing methods to determine the strength state of reinforced concrete columns with corbels and to establish their structural strength so as to determine the capacity of a mobile crane to be installed is outlined.

Keywords: *non – destructive testing, evaluation, reinforced concrete, deterioration, corbel, crane capacity, durability.*

1.0 INTRODUCTION

The performance and functions of reinforced concrete buildings, in practice, degrades, over time from peaks at the time of construction completion. Apart from damage which may be caused by fire, earthquakes or major typhoons during the buildings' life cycle, the lasting quality of safety, livability and other performance aspects gradually deteriorate as a result of physical, chemical or biological factors. Traditionally when buildings deteriorated to the extent that they are no longer able to serve their purpose or to perform to a certain expected standard, they were being demolished and replaced with new ones. However, this practice is gradually losing acceptance due to economic, environmental and social considerations. Furthermore, it is noted that premature deterioration of some buildings particularly in severe and harsh environmental conditions is being experienced hence the need for suitable maintenance, conservation, renovation or improvement are surely emerging [Al-Tayyib and Al-Mama, 1985].

Proper renovations/improvements sufficient to meet the needs of the remaining life cycle of the buildings are essential to economically maintain satisfactory environments, functions, and to extend their useful life span. In this case, correct evaluation of the cause and extent of damage to the structures is necessary to specify appropriate and relevant repair operations; as quickly and effectively as possible. In addition, measures to ensure that buildings are kept in healthy condition more than temporary expedients of renovations/improvements are needed. Therefore, testing technology is considered such a medium or measure for the quantitave measurement and evaluation of the deterioration phenomena and determination of modification or conversion solutions. In this regard, non-destructive test methods are used as compared to destructive test methods [Fookes, 1991]. Various non destructive methods of testing reinforced concrete have been developed over the years as shown in table 1 below.

Figure 1 Plan layout for the loading and off loading bay.

Non – destructive testing methods have been in use for about four decades (Shetty, 2006). During this period, the development of these methods has taken place to such an extent that they are now widely used as powerful tool for evaluating existing concrete structures with regard to their strength and durability apart from assessment and control of quality of hardened concrete. Though non-destructive testing methods are relatively simple to perform, the analysis and interpretation of test results require special care and knowledge.

In non-destructive testing methods, the specimen are not loaded to failure and as such the strength inferred or estimated cannot be expected to yield absolute values of strength. These methods, therefore, attempt to measure some other properties of concrete from which an estimate of its strength, durability and elastic parameters are obtained. Some of such properties are hardness, resistance to penetration of projectiles, rebound number, resonant frequency and ability to allow ultrasonic pulse velocity to propagate through it. The electrical properties of concrete, its ability to absorb, scatter and transmit X-rays and Gamma-rays, its response to nuclear activation and its acoustic emission allow to estimate its moisture content, density, thickness and its cement content.

Table 1 Non destructive methods of testing concrete (Shetty, 2000)

S/n	Method of testing	Measured Properties
1	Rebound Test	Elastic rebound of concrete, estimation of strength and concrete uniformity
2	Penetration Tests, Carbonation	Penetration resistance of concrete which are used for strength estimation
3	Dynamic or vibration Tests	Evaluation of durability and uniformity of concrete and to estimate its strength and elastic properties
4	Radioactive and Nuclear Tests	Measurement of density and thickness of concrete; Determination of moisture and cement content.
5	Magnetic and Electrical Tests	Determine concrete cover and measurement of moisture content and thickness of concrete.
6	Acoustic emission Tests	Study the initiatiation and growth of cracks in concrete.

In this article, particular emphasis is made to the application of rebound hammer test on hardened concrete and detection of reinforcement in order to assess the structural integrity of reinforced concrete columns with corbels so as to determine the capacity of a crane to be installed in an existent building.

2.0 SCHMIDT'S REBOUND HAMMER TEST

This is one of the commonly adopted test for measuring the surface hardness. The test instrument can be applied horizontally, vertically – upwards or downwards or at any intermediate angle. At each angle the rebound number will be different for the same concrete and require correction factors.

Although rebound hammer provides a quick inexpensive means of checking uniformity of concrete, it has serious limitations and these must be recognised. The obtained results are normally affected by the smoothness of surface under test; age of concrete element; size, shape and rigidy of the element; surface and internal moisture condition of the concrete; type of coarse aggregate; type of cement; carbonation of concrete surface; and type of mould.

Investigations have shown that there is a correlation between compressive strength of concrete and rebound number although there is still some disagreement regarding the accuracy of estimation of strength from the rebound readings. The variation of strength of a properly calibrated hammer may vary between ± 15% and ± 20% (Shetty, 2000). Therefore, the rebound hammer test indicates concrete strength indirectly and is also used to measure the surface hardness and check the uniformity of the concrete.

3.0 DESCRIPTION OF THE CASE STUDY BUILDING

In a commercial building constructed more than twenty years ago in Dar es Salaam, a loading and off - loading bay was provided as shown in figure 1 below. Reinforced concrete columns with corbels were constructed so as to support an overhead mobile crane which was to be installed.

Unfortunately, this project was not completed by then and subsequently after many years the owner of the building decided to purchase and install the intended crane. This necessitated to undertake investigation of the structural integrity of the columns with corbels since the designs for these structural elements /components were not available.

4.0 AIM AND COPE OF NVESTIGATION

The aim of the investigation was to specify the actual technical condition of the columns and corbels and materials used so that they can be used as input data for determining the capacity of the crane to be purchased and installed. The investigation was carried – out by visual inspection, non – destructive testing and testing of extracted samples in the laboratory. The Schmidt's rebound hammer tests were applied on the concrete to ascertain the quality and strength. Also, using detection meter type, location and size of reinforcement in columns and corbels was determined. The following activities were specifically performed:

(i) Visual inspection and studying the structural members involved;
(ii) Rebound hammer tests on selected columns at different levels and the slab for the loading and off – loading bay;
(iii) Drilling concrete cores from the slab;

(iv) Determining the size, number and spacing of reinforcement in the columns and corbels;
(v) Determination of concrete cover in columns and corbels;
(vi) Laboratory tests for drilled concrete cores to determine the strength of concrete.

5.0 RESULTS OF THE INVESTIGATIONS

5.1 Field Investigation

5.1.1 Visual Inspection

The structural members namely columns, corbels and slab were investigated. Visual inspection revealed that reinforced concrete structural members were in good condition. There were no signs of distress on the structural members. The actual dimensions of the columns and corbels were determined and the layout for columns at the loading and off loading bay are shown in figure 1. The foundations for columns were of monolithic reinforced concrete and were adequately reinforced.

5.1.2 Rebound Hammer Test

Rebound hammer test was carried out for selected five columns at different heights including the corbels and for the slab at the loading and off – loading bay. A summary of rebound hammer test results are shown in table 2. The results indicates the uniformity of concrete for columns with corbels. The estimated average concrete strength for columns is about 37.3 N/mm^2 .

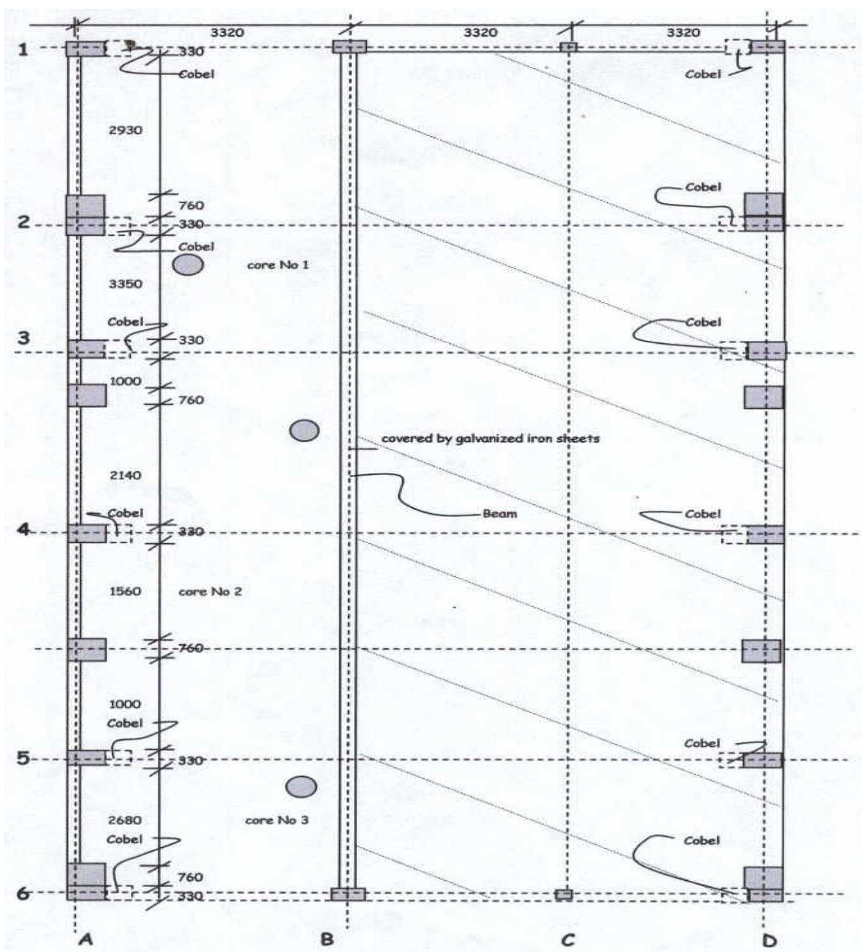

Figure 1 Plan layout for the loading and off loading bay.

Table 2 Rebound numbers and estimated strength for columns and corbels

Column	Corrected rebound numbers	Estimated concrete strength N/mm^2
A1	39	38.7
A2	38	37.0
A3	37	35.3
A4	38	37.0
A5	39	38.7
Average	38	37.3

5.1.3 Detection of Reinforcement

The size, number and spacing of reinforcement in columns and corbels were determined using a reinforcement detector and are shown in figure 2. Indicated also are the concrete covers in columns and corbels. Reinforcement used were high tensile steel.

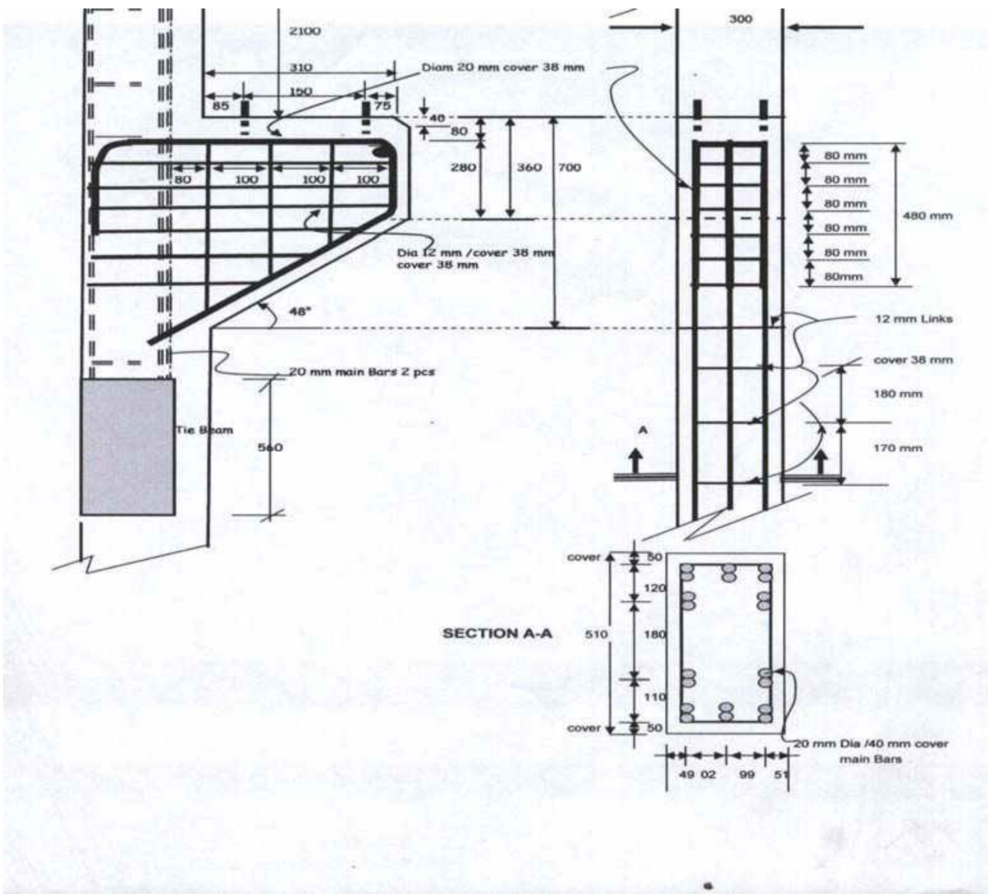

Figure 2 A section of a corbel.

5.2 Laboratory Tests

Visual inspection of drilled concrete cores revealed that granite aggregates of size ranging from 13 to 20 mm were used. The condition of all concrete cores was very good. The laboratory strength test results for concrete cores are summarized in table 2. The average concrete strength for the tested slab is 27 N/mm^2.

Table 2 Compressive strength for concrete

S/n	Sample No.	Strength (N/mm^2)
1	1	29.3
2	2	26.2
3	3	25.3
Average		**27**

6.0 Determination of the crane capacity

After establishing the dimensions of corbels and columns, the size and type of the provided reinforcement in the corbels and columns, and also the strengths for the reinforcement and concrete for these structural elements, the crane capacity was determined using the following expression(Park and Paulay, 1975).

$$A_s = V.l/z.f_y \qquad (1)$$

where A_s is the area of tension reinforcement, V is the total load (dead and live load) carried by the corbel, l is the distance from the point of application of the load at the corbel to the face of the column in this case is 235 mm, f_y is the characteristic strength of reinforcement (high tensile reinforcement), and $z \approx 0.85d$, where d is 620 mm (i.e. 700 – 80 mm) shown in figure 2.

Since A_s and f_y are known (detected in section 5.1.3), l and z are determined from figure 2, then from expression (1) the total load V is determined taking into account the safety and impact load factors. Therefore, the established maximum crane system load (weight) which include the load(weight) of the girder applied to a corbel, crane bridge weight to the corbel, trolley weight, hoist weight and the load(weight) to be lifted/carried by the crane was found to be 10 tons.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The technical investigation and non destructive tests performed, together with the laboratory tests carried out has enabled to:

(i) Determine the strength, quality and homogeneity of concrete, concrete cover which played part in establishing the capacity of a mobile crane.

(ii) Establish the type and size of reinforcement utilized in the columns and corbels and hence the area of reinforcement and strength which have been used as input data to determine the capacity of the mobile crane.

This has demonstrated the potential of non – destructive testing technique to assess objectively the general technical condition of the columns and corbels, which turned out to be good;

7.2 Recommendations

In view of the above observations and conclusions, the following recommendations are made:

(i) Non – destructive testing can be used for determination of as – built(or current) structural details especially where construction records (drawings and documentation) are inadequate or missing, or in locations with suspected discrepancies between as – built structural details and record documentation due to errors or out of torelance construction.

(ii) Non – destructive testing is suitable for assessing and monitoring progressive deterioration or ageing in concrete structures.

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