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Defects and Repairs at an Interchange Bridge in Tripoli, Libya

Dommages et réparations à un pont routier à Tripoli, Libye

Schäden und Reparaturen an einer Strassenbrücke in Tripoli, Lybien

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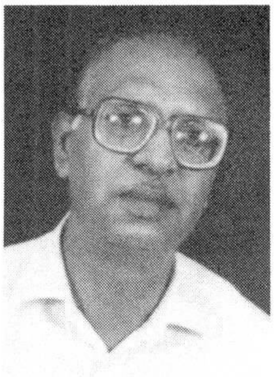

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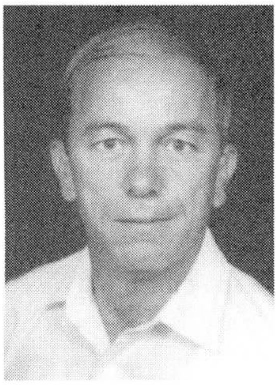

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SUMMARY

Areas of large voids and honeycombing were detected during construction in the soffit of a continuous reinforced concrete voided deck structure. These defects were mainly due to the congestion of rebars. More areas of voids and honeycombing were investigated using hammer soundings and impulse radar non-destructive methods. It has been observed that the versatility of impulse radar in detecting all the areas of voids is offset by anomalies, and the difficulties in the interpretation of the graphical data for deep and heavily reinforced sections. Since repairs of defects were not sufficient to satisfy the client about the structural integrity, an acceptance load test was carried out.

RÉSUMÉ

Des zones non compactes et des vides ont été détectés lors de la construction d'une dalle évidée en béton armé. Ces faiblesses étaient principalement dues à la congestion des armatures. De telles zones ont été détectées par des méthodes non-destructives, grâce à un sondage au marteau et au radar à impulsion. L'utilisation d'un radar à impulsion présente certaines difficultés d'interprétation. La réparation des défauts n'ayant pas convaincu le client de la valeur de la structure, il a été procédé à un essai de charge.

ZUSAMMENFASSUNG

Schwächungen in Form von Löchern wurden in der Unterfläche der durchlaufenden Stahlbetondecke gefunden, meistens durch die zu dicht eingelegte Bewehrung verursacht. Weitere ähnliche Zonen wurden mit Hammerschlägen und mit Impulsradar nicht zerbrechenden Methoden untersucht. Es wurde beobachtet, dass die Brauchbarkeit des Impulsradars, um alle geschwächten Gebiete zu finden, wegen Unklarheiten gestört war. Weil die Reparatur der Fehler die Kunden nicht zufriedenstellte, wurde eine Probebelastung für die Akzeptanz der Konstruktion als Ganzes durchgeführt.

1. INTRODUCTION

As a part of Tripoli Corniche Road, three highway interchange flyover concrete bridges Waddan, Karamanli and Hospital have been constructed in eighties in a length of about 5 km. Hospital interchange is the farthest from the city centre at the eastern end of the Tripoli Corniche ring road, and consists of an elevated structure having 18 spans which include adjoining side spans. The interchange was designed by Rendel Palmer and Tritton of Britain in 1986 and, constructed by Daewoo Corporation of S. Korea under the supervision of National Consulting Bureau, Tripoli from 1986 to 1988. The deck of this interchange is a continuous reinforced concrete voided structure. When the first soffit shutters of the bridge deck were removed areas of voids and honeycombing were discovered. Investigations by hammer soundings, Schmidt hammer and by drilling suspect areas were carried out to detect other areas of voiding. Hammer soundings successfully revealed the other additional areas of voids not detected by drilling, like the voids in the deck above bearing No.28. (Fig. 1.). Repairs of voids traced by drilling were carried out as explained later in this paper. Repair of areas detected by hammer sounding during the final inspection survey had not been done pending further investigations to establish detection of all voids and to assess the effect of large areas of voids on the structural integrity of the deck. It is an accepted fact that timely detection, cause diagnosis and treatment of construction weaknesses will ensure full life span of the structure.

2. CAUSES OF VOIDS

From the survey report of the voids in the deck soffit, it became obvious that the voids on each span were located generally at the quarter span and in some cases the midspan. When compared with 'as built' drawings it was found that the voids at quarter span coincide with the laps in the reinforcement, specially for span 5 which is more complex structurally being on the curved section of the deck and at the intersection with a slip road side spans. Some spans also have reinforcement laps at midspan. On other spans also voids have occurred at midspan where there are no laps in the reinforcement. So it was concluded that the major cause of the voids in the deck soffit was due to congestion of reinforcement and inadequate compaction during construction. In the areas of reinforcement congestion, the concrete did not flow around the reinforcement or under the void formers.

3. THEORETICAL APPRAISAL

To assess the structural integrity of the deck due to the presence of voids at the quarter span and midspan, the designer has investigated for span 5 two conditions based on different assumption on the bond between the lapped reinforcement. Firstly, it was assumed that the whole area where the reinforcement bars are lapping are voided preventing transmission of bending stresses in the bottom longitudinal reinforcement. Results of the analysis indicated that under dead load only the deck section has sufficient capacity to withstand shear provided that the shear reinforcement have adequate anchorage to allow it to act as it is designed. Secondly, it was assumed that the bond between only 50 percent of the longitudinal bars are affected by voids because the laps in the reinforcement are staggered alternatively. According to 'as built' drawings, the amount of reinforcement in the bridge deck slab has been increased to control the crack width under service condition by decreasing the bar spacing from 125mm to 100mm. Calculations check as a continuous beam of unit width with this assumption of 50 percent effective reinforcement gave the maximum dead load moment capacity at ULS equal to 694 KNm/m against the maximum moment capacity of the section of 1550 KNm/m. Assessment of the full section capacity without voids yielded a maximum moment capacity of 2950 KNm/m employing F.E.M. analysis. The theoretical analysis revealed that for the full section the maximum DL moment is 21 percent of the maximum moment capacity of the section. When only 50 percent of the longitudinal reinforcement is considered effective then the DL moment increases to only 45 percent of the moment capacity.

Crack width calculations under the dead load with reduced reinforcement yielded crack width at the extreme fibre of 0.22mm compared to 0.09 mm for the full design section. So it can be concluded that the crack widths under dead load will be increased and under live load would exceed the design crack width for the section. However, site measurements taken of crack width at the mid span of deck soffit 5 and 6 using a microscope crack width recorder led to the detection of 0.1 mm wide cracks. These were in accordance with the calculations for crack width of the fully undamaged section under dead load with all the reinforcement effective.

Representatives of NCB, the designer and the contractor met to discuss the fears of the Client whether all the voids in the bridge deck have been found and repaired properly. To create confidence in the mind of the Client about the safety and the durability of the structure, another survey of the deck soffit using a reliable non destructive method was considered. It was agreed, on the suggestion of the designer, that the impulse radar technique will be the most suitable method for detecting these type of voids. Further, to satisfy the Client the decision for carrying out an acceptance load test on the bridge before opening to traffic will be taken after reviewing the results of the impulse radar method.

4. IMPULSE RADAR TECHNIQUE

Survey of the concrete surface by impulse radar is achieved by tracking a transducer radio anteunae over the surface to be investigated at a slow speed; pulses of energy are transmitted into the material which are reflected from any internal surface or structure change depending upon the difference in their permittivity or conductivity. The returning signals from each vertical scan build, as the transducer is moved, into a continuous transverse profile of the interior of the material as shown in Fig.2. A plane of energy is actually transmitted rather than a ray beam: this plane is normally set parallel to the direction of the survey such that all information streams refer to material directly below the survey line. More details about this method are given in references [1] and [2].

Signal attenuation is per unit wave length, and sets depth of penetration limit on this for any material, which will obviously be shallower for higher frequencies. Equally, target resolution decreases with increasing wavelength thus the selected frequency of the transducer is a balance between penetration and resolution.

The areas of the bridge deck selected for impulse radar survey were generally the areas of congested reinforcing steel, particularly around laps in the lower reinforcement. All areas investigated are shown in Fig. 1. All survey lines, both longitudinal and transverse, were set out on the soffit of the deck in areas marked out by the contractor. The majority of the data was collected from profile lines transverse to the deck and set at 250 mm centres. These line provided a general scan of the concrete condition to a depth of at least 250 mm. The transverse profiles were transacted by longitudinal profiles at 1 m centres arranged to examine the concrete condition immediately below the centre line of each void former. Survey lines were profiled using either the high resolution transducer with centre frequency set at 1000 MHZ, or the slightly lower resolution but deeper penetrating transducer set at 900 MHZ. In some cases both frequencies were used on the same line. This multi-frequencies approach was adopted in order to obtain as much information on the interior of the decks as possible.

5. TEST DATA

Figure 3 shows data collected with the 900 MHZ transducer along a longitudinal profile of deck 5. It can be seen that the hyperparabolic return from the reinforcement are interrupted: this is caused by the presence of a void reducing the energy coupled to steel thus sharply alternating the returning signal and creating a blank area in the data. The deeper void attenuating located between the reinforcement and the internal void former is not as readily identifiable within the data, but a disturbance or irregularity in the signals can be noted both as a cancellation or attenuation of signals from the reinforcement and also as a phase shift in the response from the metal skin of the internal void former.

The procedure of investigation by impulse radar at site included collection of data, interpretation and investigation of anomalies by drilling into specified target areas. The information obtained from the drilling investigations and further hammering testing has been used to eliminate or confirm anomalous signals interpreted from the data. According to the experience of the present authors, the versatility of the impulse radar technique has been offset by the difficulties in the interpretation of the collected graphic data. The final data analysis and subsequent location of defects have been the result of correlation between data interpretation and the drilling investigations. It has been found that hammer echo survey, although time consuming yielded either similar or better detection of voids and honeycombing areas compared to impulse radar technique due to complexity of graphic interpretation. After the completion of impulse radar survey, 5 new voids were detected on span 5 and one on span 16 by the representative engineer using hammer echo survey. Although it was concluded from the results of the impulse radar survey that all the significant areas of voiding and honeycombing of the bridge deck have been detected and repaired but it is still possible, as shown by latest hammer echo survey, that some of the voids and honeycombed areas have remained undetected. In order to satisfy the Client about the structural integrity of the bridge before the final handing over an acceptance load test has been carried out by the contractor.

6. REPAIRS

Following the detection of voids in the soffit of bridge deck an extensive program of repairs has been undertaken. Two types of voids were identified for which different strategies were employed. The first type of defect included extensive areas of voids between the reinforcement and the underside of the void former. The procedure of repairs consisted of breaking the defective concrete and saw cutting the edges of the repair area. Prior to concreting the repair the exposed reinforcement was cleaned by sandblasting. For the large volume repairs an access from the top surface of the deck was provided by coring to the top surface of the void former, cutting through the top and bottom sections of the void former and installing a plastic pipe. A soffit shutter was fixed and the void concreted through the plastic pipe using 10 mm maximum size aggregates. On completion of the concreting the plastic pipe was removed, the top of the void former repaired and the concrete above the void former reinstated.

The second type of defect involved thin section repair where voids were detected below or extending only to the bottom layer of reinforcement. Again, the damaged area was fully broken out and the edges of the repair area saw cut. The repair of the defect was carried out using Febset 'non flow' epoxy mortar.

Durability of the repairs was questioned by the Client due to the location of the interchange close to the sea. Keeping in mind the possibility of occurrence of shrinkage cracks around the perimeter of the repairs and to prevent the ingress of chlorides through the cracks, all the concrete surfaces have been coated with Dekguard elastic, produced by Forsoc of U.K.

7. ACCEPTANCE TEST

The load tests were carried out on spans 5,16 and 8 (without defects) to satisfy the Client that the defects that occurred during construction have been satisfactorily repaired and the deck is capable of carrying its design load. The load tests results satisfied the code acceptance criteria of maximum deflection for any span and for recovery which always exceeded 80%.

8. CONCLUSION

Appearance of defects like areas of large voids and honeycombing in the bridge deck during the construction stage is a matter of concern. Such defects should be thoroughly investigated and their effect on the structural safety evaluated. An acceptance load test following the repairs is recommended to restore the confidence of the Client.

REFERENCES

1. BUNGEY J.H., MILLARD S.G., Radar Inspection of Structures, Proc. I.C.E. Structures and Buildings Jnl., May 1993.

2. PITT J.B., Use of Impulse Radar as a method for the Non Destructive Testing of Concrete Slabs, Building Research and Information, Vol. 20, No.3, 1992.

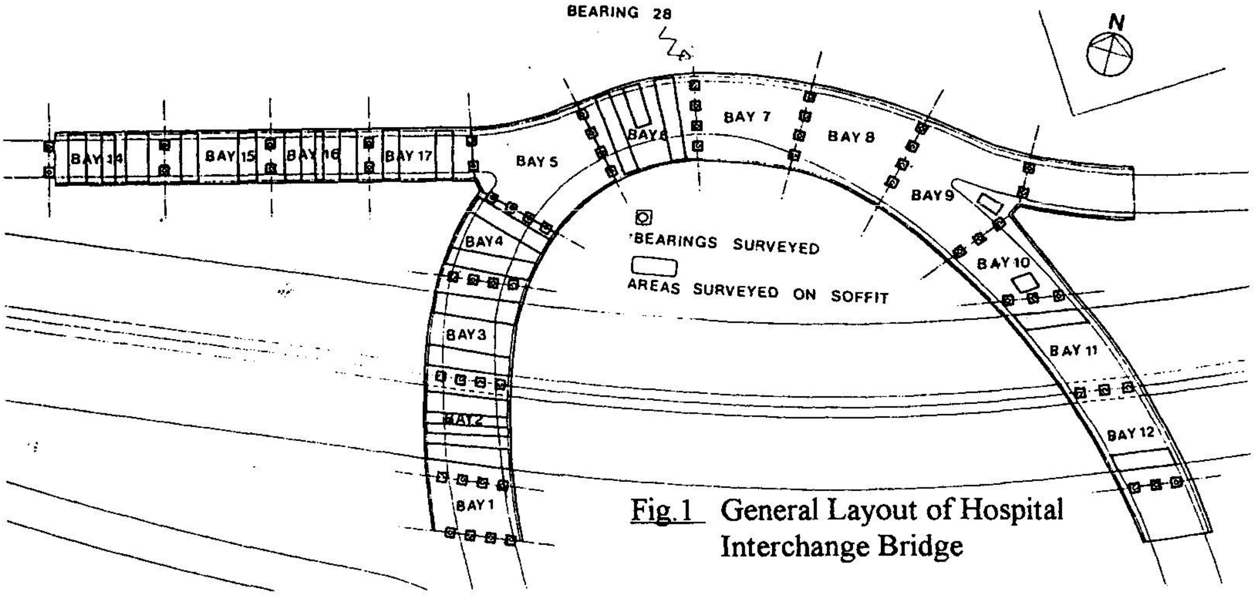
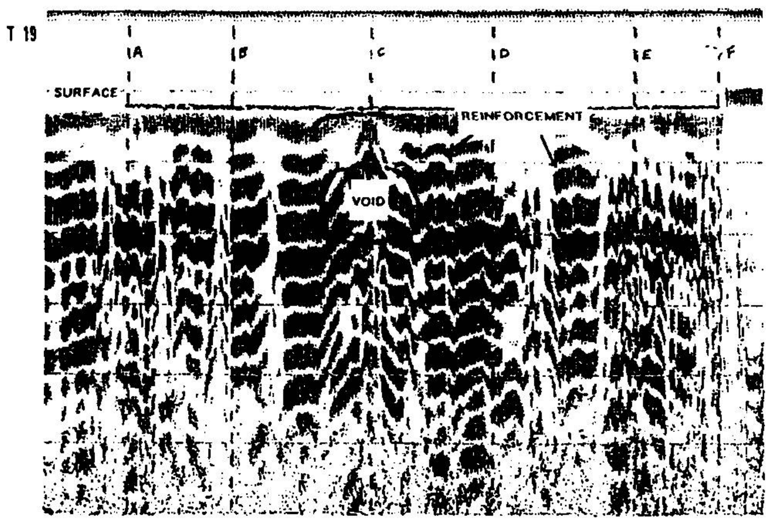


Fig.1 General Layout of Hospital Interchange Bridge

Fig. 2
Radar Output for Transverse Scanning Profile (Span 5)



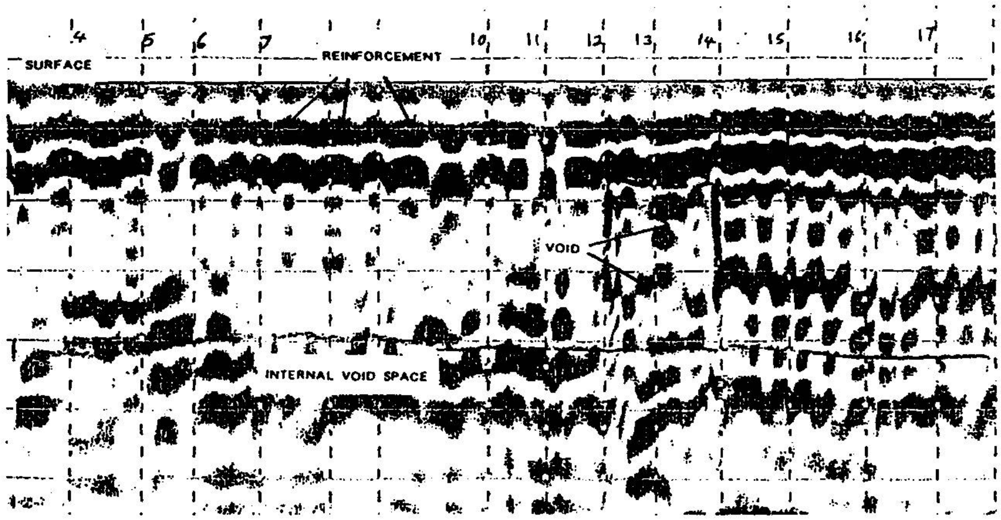


Fig. 3 Radar Output for Longitudinal Scanning Profile (Span 5).