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Maintenance and Monitoring of Concrete Bridges

Maintenance et surveillance des ponts en béton

Wartung und Kontrollmessungen von Stahlbetonbrücken

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SUMMARY
Highway concrete bridges of the Tripoli second ring road suffered cracking due to structural and non-structural effects. A program of regular inspection, monitoring and maintenance of these bridges has been proposed to ensure durability and proper functioning. Stress has been laid on simple and accurate measuring instruments which led to the development of a Plumbline Deflectometer, described in this paper, for measuring deflections of bridge elements.

RÉSUMÉ
Les ponts en béton du deuxième périphérique autoroutier de Tripoli présentent des fissures dues à des causes structurales et non structurales. Un programme d'inspection, de maintenance et de surveillance a été proposé afin d'assurer la durabilité de ces ouvrages. La volonté d'obtenir des mesures précises de contraintes a conduit à l'élaboration d'un déflectomètre à fil à plomb conçu pour la mesure des déformations de chaque élément de pont.

ZUSAMMENFASSUNG
Die Stahlbetonbrücken auf der Schnellstraße der Zweiten Ringstraße von Tripolis haben durch das Auftreten von struktuellen und nichtstruktuellen Rissen Schaden erlitten. Ein Programm von regelmäßigen Untersuchungen, Kontrollen und Wartungsarbeiten wird zur Sicherstellung der Dauerhaftigkeit und der einwandfreien Funktionsfähigkeit vorgeschlagen. Die Beanspruchungen, resp. Dehnungen wurden mit einem einfachen, jedoch genauen Messinstrument, nämlich einem Schnurlot-Durchbiegungsmesser, bei den einzelnen Brückenelementen aufgenommen.

1. INTRODUCTION

Durable bridges ensure fullfilment of their intended function for whole of their design life. Durability reflects the overall strength, serviceability and resistance to environmental effects of the materials forming the structure. It is not only dependent on the original strength design and assumed characteristics of construction materials but is a function of the materials used in the construction, methods of construction, workmanship, environmental effects, applied load intensity and their duration, accidental loads and regular maintenance repairs. The construction of bridges in both developing and underdeveloped countries is also influenced by the consultants. It is often the case that foreign consultants are not fully aware of the environmental conditions of the clients country and generally base their designs on the standards, material specifications and the degree of workmanship prevalent in their own countries. The effect of sophisticated computer oriented analysis and design procedures will be invariably offset by the use of poor quality of local aggregates, occasional poor workmanship of the contractor, inadequate site supervision and lack of maintenance due to shortage of manpower and/or finances.

2. TSRR HIGHWAY BRIDGES

The main theme of this paper is a case study of Tripoli Second Ring Road (TSRR) highway bridges, completed in 1986,consisting of reinforced concrete decks supported on end abutments and intermediate portal frames with overhangs for multiple spans and, on end abutments only for single spans. Some of the decks are post-tensioned and the others are of reinforced concrete. These bridges became the victim of the problems of a developing country as mentioned above. Even during the construction, plastic shrinkage and plastic settlement cracks were identified in bridge decks and, thermal contraction and drying shrinkage cracks in the supporting end abutments. In addition to these cracks some structural cracks were observed, with a maximum width of 0.4 mm, in the cantilevers of supporting portal frame elements. Investigations were carried out according to the scheme presented (Fig.1). Some of these typical cracks in the supporting elements of the highway bridges are shown (Fig.2).

3. CAUSES OF CRACKS

Causes of concrete cracking of TSRR bridges are stated in [1]. The main causes of non-structural cracks can be attributed to type of aggregates, poor fines grading, dust content of aggregates, high water content of the mix, low humidity, high ambient temperatures, hot concrete, very large sections and poor workmanship, etc. The structural cracks occured due to improper reinforcement detailing , poor quality of concrete near the top surfaces of supporting cantilever elements, large concrete cover, premature loading, concentration of stresses, sudden change in sections and sequence of deck slab construction. The study of cracks in the TSRR bridge elements concluded that the observed non-structural cracks are mostly within the permissible limits, and are not structurally dangerous provided they are properly repaired and maintained. Some of them cause unsightly appearance and require cosmetic treatment. The other cracks can be treated with epoxy injection. The structural cracks in the cantilevers of the supporting portal frame structure required immediate attention from serviceability consideration. These elements have been strengthened by providing additional concrete fins to ensure durability. Both these types of cracks require regular inspection, monitoring and maintenance.

4. PERIODIC INSPECTION AND MONITORING

A satisfactory structural response encompassing the durability aspect of TSRR bridges can be assured by carrying out periodic visual and physical inspection by qualified personnel in accordance with the provision of [2] followed by proper maintenance and repairs program.

Visual inspection will concentrate on examining all exposed concrete for the existence and severity of cracks and any deterioration of concrete itself due to chloride ingression and/or chemical reactions. The elements need to be inspected are the end abutments, intermediate supporting piers and their cross beams, bearings, deck slabs and the wing walls. When cracking is found, location of the cracks and their size should be carefully recorded for future reference and comparison.

Physical inspection will require taking some measurements of the response of bridges. It will involve recording the width and the depth of penetration of all cracks, measuring the deflection of the overhangs of the cross beams of the portal frames and deck slabs, settlement of foundations of the supporting elements, deformation of bearings specially for high skew deck slabs and, monitoring the amplitude of vibration of the deck slab under the moving traffic. It is well known that the stiffness of a structure can be best monitored by measuring dynamic characteristics like the natural frequency. A change in the frequency will directly reflect any change in stiffness of the structure.

Undeniably, there has been a serious concern by the public about the safety and durability of TSRR bridges after the addition of so called concrete fins to increase the strength of overhangs just before and after opening of the ring road. The present authors were involved in the planning of maintenance program of these bridges for the future.

5. INSTRUMENTATION

Certain techniques and instruments are already available for the inspection of bridges for monitoring their structural response [3]. But there is a need for simple and easy operating instruments, and procedures in developing countries. Some of them are recommended in Table 1.

The Plumbline Deflectometer (Fig.3) was developed by the authors to facilitate monitoring of vertical deflections of the overhangs of the cross beams of the portal frame supporting elements and that of the bridge decks. This instrument requires no scaffolding. It requires only two stainless steel studs to be fixed - one projected from the concrete element whose deflection is being measured and the other at the base. At the time of reading, the micrometer of the deflectometer is adjusted to make the string tight which occurs when the circular face of the conical plumb bob touches the bottom surface of the lower steel stud. It is a very light, handy and accurate instrument, having a range of 50 mm and a least count of 0.01 mm, which does not require much skill to operate it and can be used repeatedly. Amplitude and frequency of vibration can be measured by using an accelerometer transducer and a vibration meter.

6. ACCEPTANCE LOAD TEST

Acceptance load tests of some bridges were the requirement of the client before handing over of the bridges in the light of the occurrence of cracks in the supporting elements of various bridges. The acceptance tests were conducted on two bridges and their results were set against predictions of structural behaviour rather than against any arbitrary criteria under static vehicle loading applied for a short duration. The usual procedure of conducting load tests is according to CP 110 or ACI 318 - 83 which is applicable to reinforced concrete structures. The validity of long term load test, according to these standards is open to question since bridges are subjected to transient or time varying loads. For acceptance tests, loading for a short duration - necessary to develope static equilibrium before taking measurements - should suffice. There is an urgent need for writing specifications for accepting load test of bridges.

7. CONCLUSIONS

Inspection and monitoring the response of bridges should be conducted in a systematic and organised manner for as not to interfere with the flow of traffic for a long time by choosing instruments which are quite accurate, simple to operate and easy to install. Each bridge is to be inspected at regular intervals not to exceed 2 years by qualified personnel. Inspection should not be confined to searching for cracks which may exist but should include measurements for investigating the response of a structure during its use. Finally, regular and timely maintenance repairs of bridges will ensure durability for the whole of their design life.

FEATURE	PARAMETER	POSSIBLE INSTRUMENTS
Cracks	Width	Telescopic crack width recorder, demec gauge, glass tell tale or gypsum coating.
	Depth	Chisle & hammer, core samples, ultra-sonic pulse velocity (U.P.V.).
	Length	Ruler or a flexible cord.
Displacement	Vertical deflection	Plumbline Deflectometer, dial gauges, precision level or wire resistance strain gauge gadgets.
	Angular rotation	Clinometer, Plumbline Deflectometer for vertical surfaces.
Settlement	Foundations	Precision level (reference Mark)
Reinforcement	Stresses	Wire resistance strain gauges
	Bar size / Spacing	Profometer
Concrete	Quality	U.P.V. tests, Schmidt hammer
	Strength	Core test, U.P.V. tests.
Dynamic Response	Frequency & Amplitude	Vibration meter + Accelerometer

Table 1 Instrumentation for inspection and measuring the response of concrete highway bridges

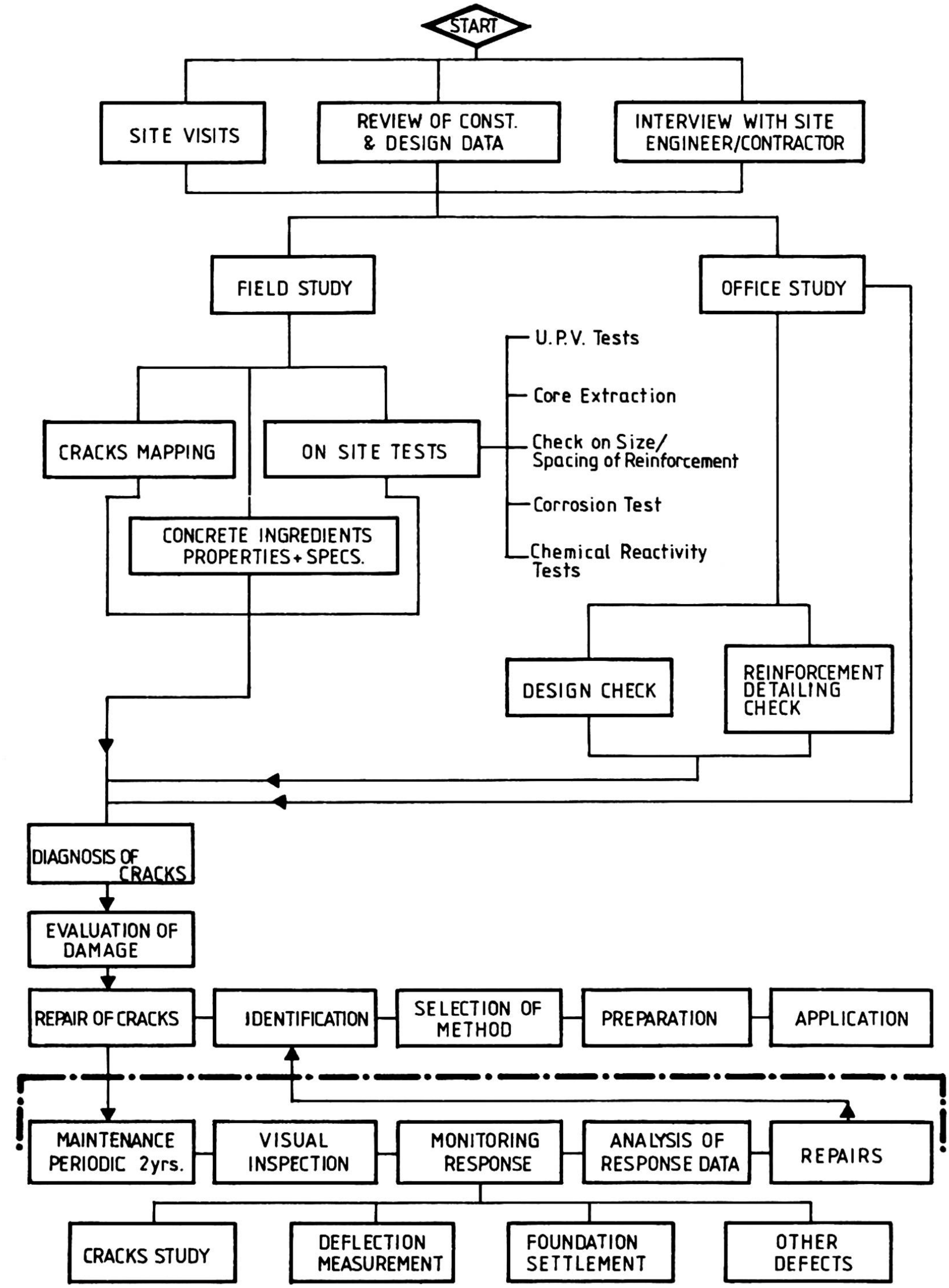

Fig. 1 Scheme of inspection, monitoring and maintenance

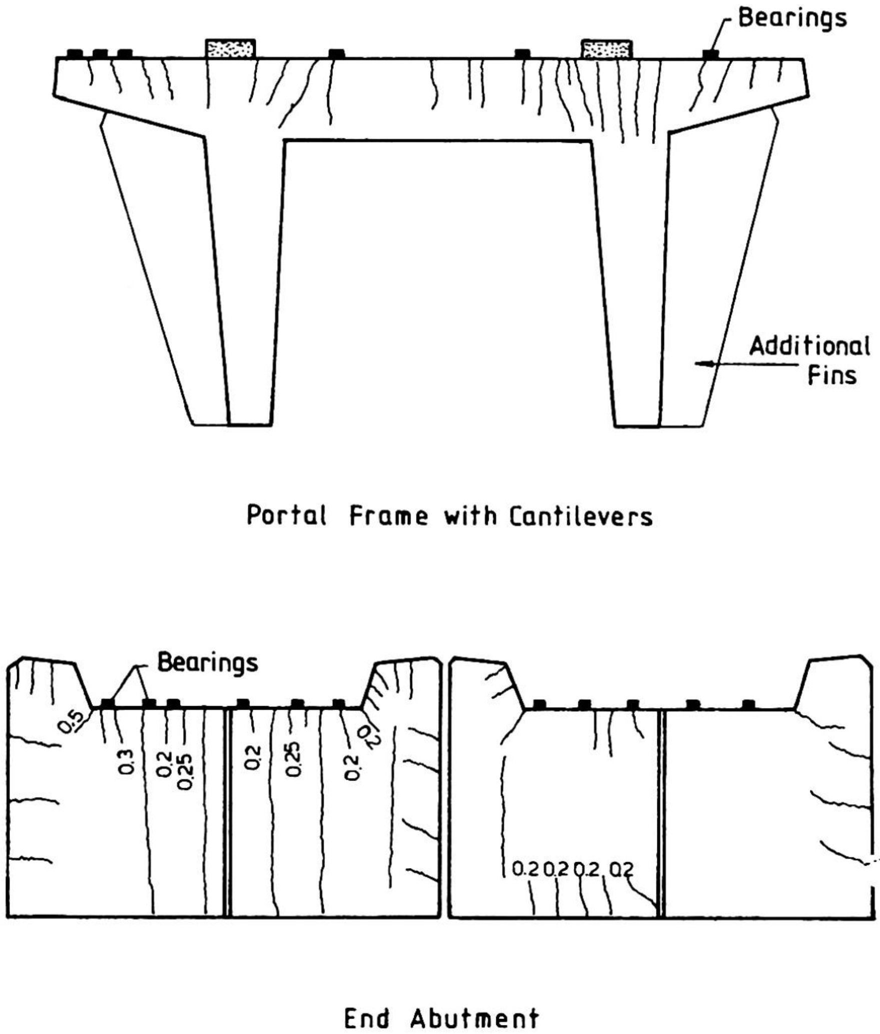

Fig.2 Typical cracks in the supporting elements of TSRR highway bridges

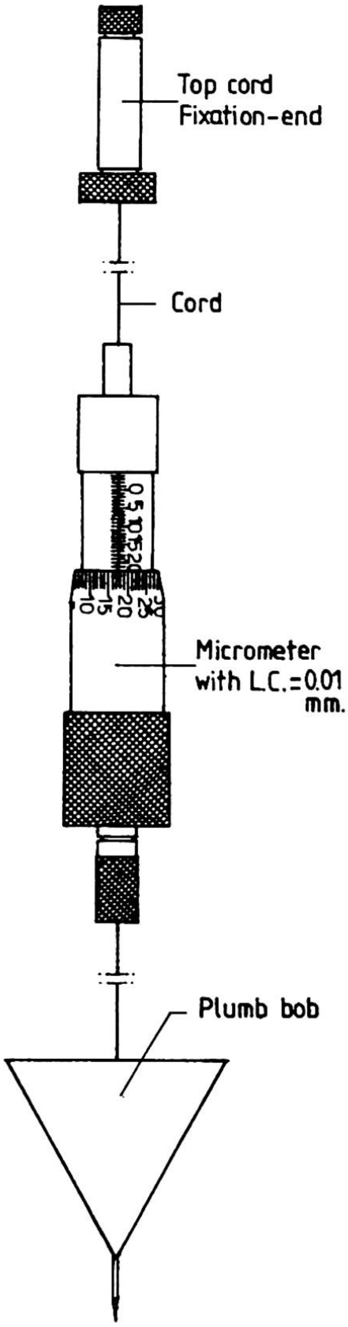

Fig.3 Plumbline Deflectometer

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