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CONSTRUCTION OF AN EXPERIMENTAL CULVERT WITH FERROCEMENT PRECAST ELEMENTS

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ABSTRACT

This paper describes the construction of an experimental culvert with precast ferrocement walls and a cast-in-place reinforced concrete invert; its opening is 2,44m wide and 2,14m high. The deflections and cracks observed during the embankment execution are reported. The results indicate that reduced thicknesses can be used in this kind of structure with the consideration of the interaction between soil-structure and, as a direct consequence, a great reduction of the precast elements weight may be obtained.

INTRODUCTION

The purpose of this paper is to describe the construction of an experimental culvert using ferrocement precast elements. It is an application of a proposal for culvert construction that was presented at the Third International Symposium on Ferrocement, that has as main characteristics structural behaviour, that tends towards flexible pipes, and the use of precast elements which might be associated with cast-in-place reinforced concrete [1].

This construction proposal comprises: a) the use of smaller thicknesses than the ones normally used in walls, nearly equal to those used in ferrocement, as will be seen during this work, with the aim of profiting from the interaction soil-structure; b) the use of cross sectional shapes with favorable structural and hydraulic behaviours and c) constructive possibility for culverts with large openings, when transport is limited, using precast elements which build their cross sections.

DESIGN CONSIDERATIONS

After carrying out two precast pieces, as showed schematically in Fig.1-a, it was decided to modify the construction scheme in order to facilitate the manufacture of the precast elements by introducing hinges between the wall and the invert, as shown in Fig.1-b.

Thus, the invert is independent on the wall and can be built with precast or cast-in-place concrete. With regard to the structural behaviour, these hinges modify the bending efforts on the wall little and reduce significantly these efforts at the culvert invert, in this case.

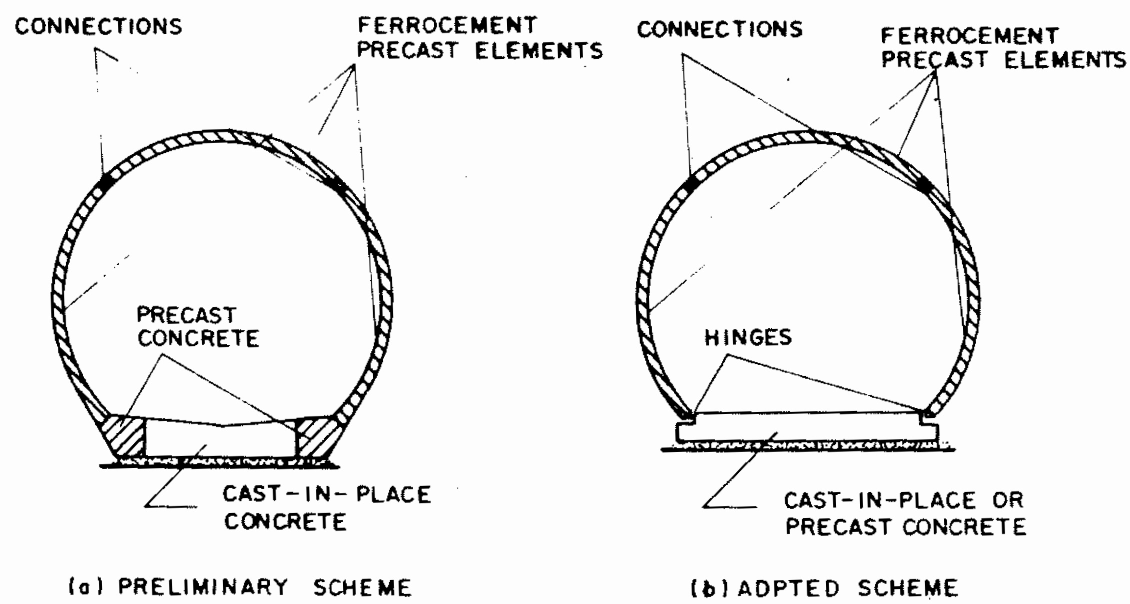


Fig. 1- Construction schemes

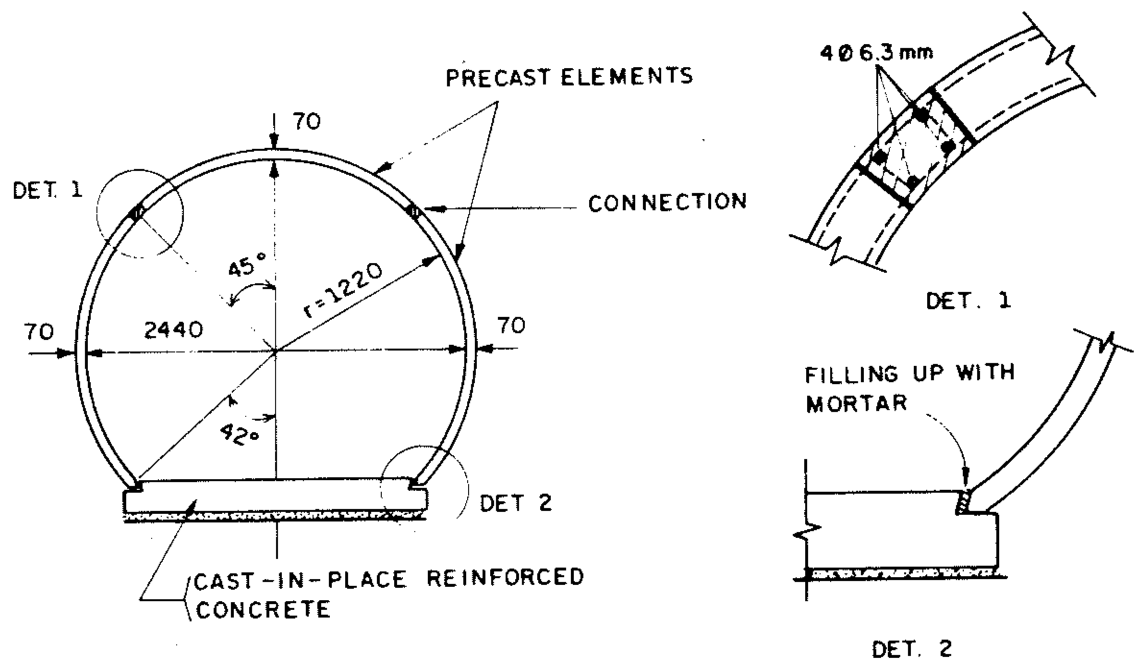
In order to compute the efforts, the culvert was conceived as a plane frame linked to the soil through several springs. The stiffness variation due to material cracking was considered. Computing was made by a specific software which was developed for this kind of structure and also takes into consideration the structure geometric non-linearity [2]. The actions considered were: its own weight, soil weight, lateral soil pressure and the vehicles effect taken as distributed load on the surface over the culvert. The structural design for the walls were according to the brazilian code Design and Construction of Ferrocement [3].

Figure 2 shows the geometry of the culvert, material specifications, information about the reinforcement and the material consumption.

With these dimensions the precast pieces could be manufactured in a single casting stage, without connections, since there would be no restrictions on transport gauge nor the weight would be excessive. However, as this is an experimental work, it was decided to adopt this decomposition as a basis for the evaluation of the proposed construction in certain situations, when necessary.

CONSTRUCTION DESCRIPTION

The experimental culvert was built in Altinópolis-SP, as part of one of the state highway SP-351 accesses to Altinópolis city. The culvert is approximately. 11.0 m long, corresponding to 9 precast pieces of 1.22 m each.. The soil over the culvert is 2.2 m high. The invert was made of cast-in-place concrete.



MATERIAL SPECIFICATION

FGC - f_{ck} = 25 MPa   Concrete (invert) f_{ck} = 18 MPa

Reinforcement: wires ($\phi < 6.3$mm) - 600 MPa
rods ($\phi \geq 6.3$mm) - 500 MPa
welded mesh 50mm x 50mm, $\phi = 3$mm - 600 MPa

REINCORCEMENT (for linear meter)

	in-side		out-side	
	mesh	wire/rod	mesh	wire/rod
crown FGC	1 layer	10 ϕ 4.7mm	1 layer	-
side FGC	1 layer	-	1 layer	5 ϕ 4.7mm
invert RC	-	10 ϕ 8mm	-	5 ϕ 6.3

ferrocement reinforcement cover - 12.5 mm
concrete reinforcement cover - 30 mm

MATERIAL CONSUMPTION (for linear meter)

FGC - 0.43 m^3 Concrete - 0.36 m^3

Welded mesh - 11.7 m^2 Wires and rods - 40 kg

WEIGHT OF PRECAST PIECE

Piece with 1.22 m - 12.5 kN

Fig. 2- Main characteristics of experimental culvert

The precast pieces were made in the Structure Laboratory the Engineering School of São Carlos, almost 170 km distant fro the work place.

In the precast elements, it was employed a fine granulated concrete (FGC) by using as aggregates sand and fine crushed stones (ϕ < 6.3mm). The proportion of these aggregates was made in dry mixture tests to obtain the smallest clearance index. The composition of the fine granulated concrete (FGC) was: 1.0 kg cement, 1.75 kg dry sand, 0.75 kg fine crushed stones and 0.4 kg water. The average compressive strength of FGC, measured cylindrical test samples, was 42 MPa after 28 days

The precast elements were fabricated using a wood mould covered with metallic sheets. By small adaptations this mould would be used for the two kinds of precast elements. Two vibrator of 1/4 HP were adapted to the mould to compact the FG Springs were fixed at the invert mould to improve vibrat efficiency.

The reinforcement, composed of two layers of welded mes and complementary wires of 4.7 mm, was assembled using gau its position in the mould was assured by plastic spacers.

The elements were moulded in a horizontal position retired after 18 hours, the next day, by turning the mould the vertical position (photos 1-2). In addition, the elements were placed in a water tank for 7 days.

The assembly of the elements in order to built the culvert pieces was carried-out with the help of a gauge corresponding the drawing of cross section of the culvert in scale 1:1 on a level concrete floor (photo 3). A frame was used to place the elements over the gauge. Adjustments were made with threaded bars which passed through element holes.

The connection reinforcement were placed after mounting the elements. In addition, the connection surfaces were cleaned with a water jet under pressure, wetting for almost two hours and subsequently the connections were moulded. A vibrator that was employed to compact the FGC came in the connection reinforcement (photo 4).

At least two days after moulding the connections, the precast pieces were lifted to their normal operating position with the help of a frame with two manual pulley systems.

The transportation of the finished precast pieces until the work place was made in one step by two trucks. A digging machine, employed as crane, was used to put the precast pieces on the invert (photos 5-6).

Immediately after setting all the precast pieces, the gap between them and the invert was filled with mortar of 1 part cement, 2 parts sand and a cement/water ratio of nearly 0.5 and with a high plastic consistency in order to be applied using a trowel.

Before beginning the embankment work, special cloth bands were placed among the precast pieces in order to prevent the access of soil. To complete the embankment, a manual soil compactor, a small road roller and a mechanic shovel were used. Up to the top of the culvert the manual compactor and the small road roller were used; above this level the mechanic shovel without soil in its bucket at the first 0.3m and with soil in its bucket, above this measure was used (photos 7-8).

The soil used for the embankment came from the natural deposits close to the access which formed part of the culvert. The soil had the following characteristics: liquid limit - 46; plasticity limit - 32; plasticity index - 14 and CBR Index - 9%. The degree of compaction of the embankment, measured in seven layers was not less than 95% of the normal proctor. This soil is very unfavorable considering its participation in the strength mechanism due to the interaction soil-structure.

REMARKS ABOUT THE STRUCTURAL BEHAVIOUR

During the execution of the embankment, some measurements were taken in three culvert pieces concerning deflections between crown and invert and between the opposite laterals, using a convergence measuring instrument. Figure 3 shows values concerning these deflection due to the embankment height.

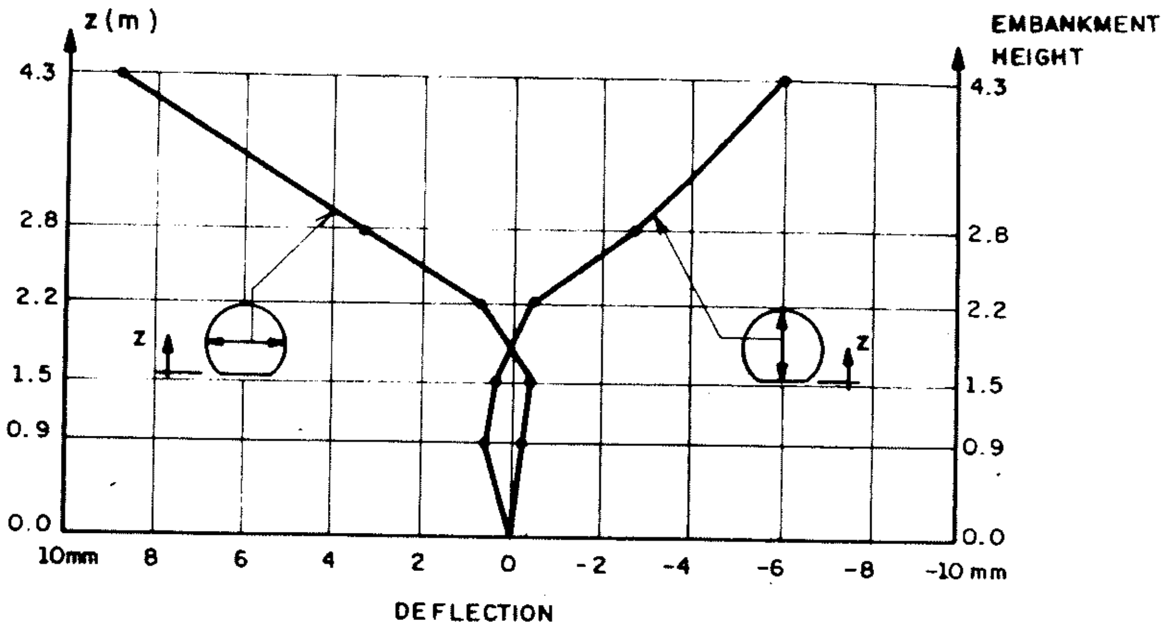


Fig.3- Deflections versus embankment height

The first visible crack, with width of 0.05 mm, appeared at the crown of one piece, with about 0.3 m of soil on the top of the the culvert. This crack was not expected. Its earlier occurrence was caused by the equipment which compacted the soil over the culvert.

Further new cracks appeared as soon as the culvert was nearly its final level. Thus, systematic cracking occurred, at the crown of almost all the pieces, as was theoretically expected. The width of these cracks was around 0.05 to 0.1 mm.

A critical examination 6 months after the embankment had been made showed that no new cracks came out, neither had the old ones increased their width.

Considering the deflections that were measured and applying the computer model employed in the design, a structural behaviour evaluation indicates that the required bending level is very close to that which was previously estimated and, consequently, that the structural safety can be considered to be within the pre-established limits.

CONCLUSIONS

It is technically possible to reduce the thickness of culvert walls, considering the interaction soil/structure. This makes it possible to reduce significantly the weight of the precast elements. Thus, it is of great interest in this kind of construction to use ferrocement or reinforced concrete with reduced thickness. In addition, it is possible to make use of precast concrete for large openings with relatively light elements with the decomposition of the structure in situations where the transportation of the elements is limited by highway gauges.

ACKNOWLEDGEMENTS

The construction of the experimental culvert was supported by Engineering School of São Carlos and FINEP (a brazilian research financial support agency), through the "Technical properties and development of components and construction systems on ferrocement" agreement, whose final report presents a detailed description of the construction [4]. The author wants also to thank the CNPq - National Council for Scientific and Technologic Development for their support and the DER- Highway Department of São Paulo State, for making possible this study and the development of this work.

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Photo 1- Precast element moulding

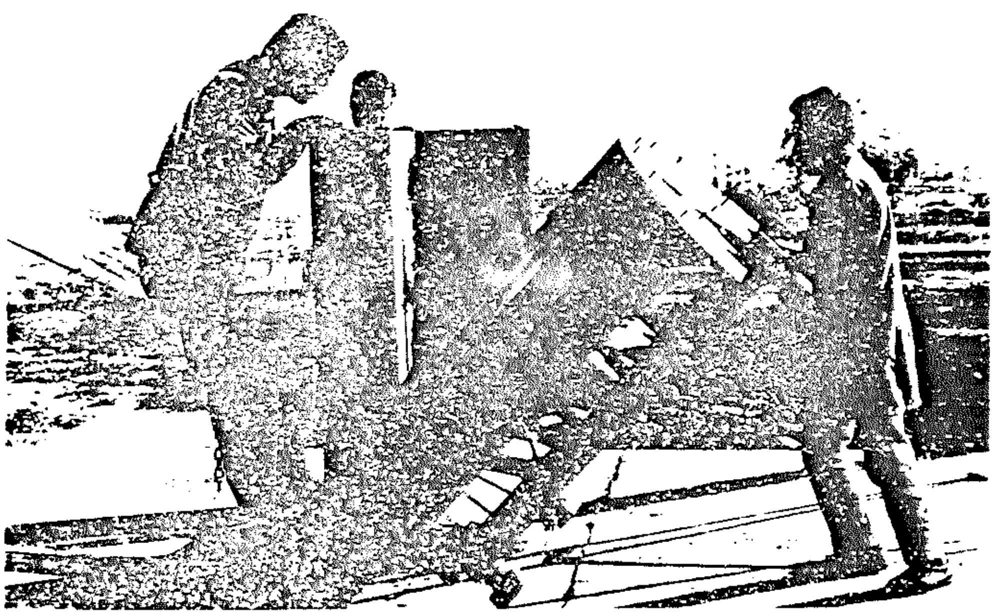

Photo 2- Removal of a precast element after turn the mould

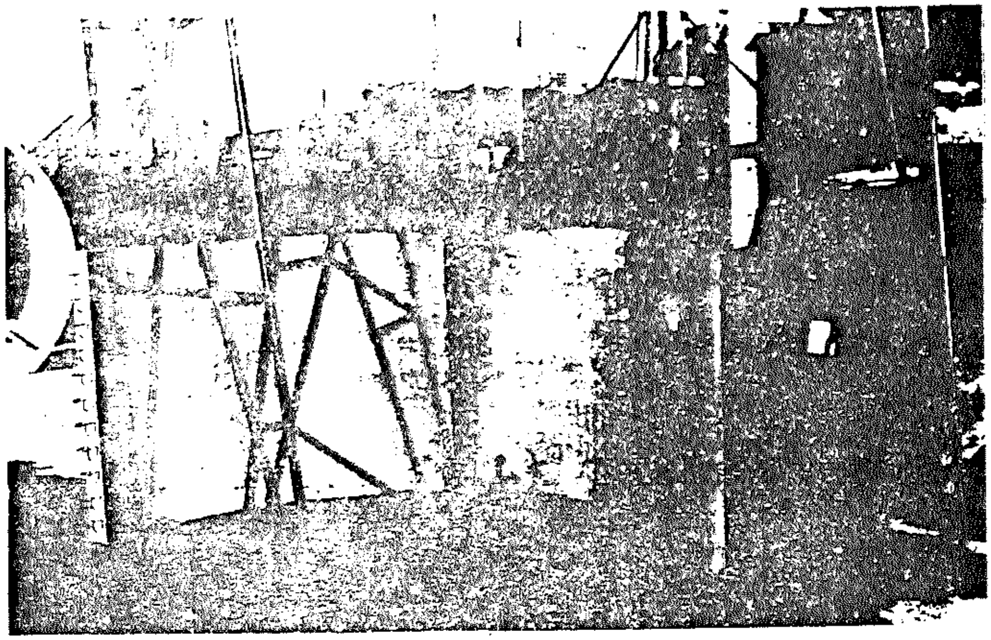

Photo 3- Assembly of elements to built a precast piece

Photo 4- Moulding of a connection between precast elements

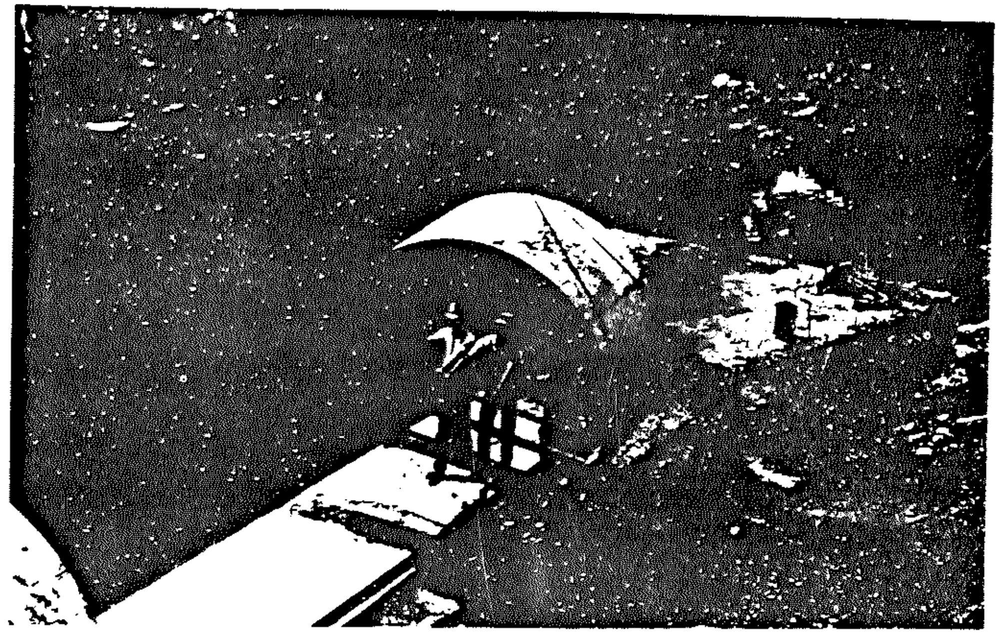

Photo 5- Placement of a precast piece on culvert invert

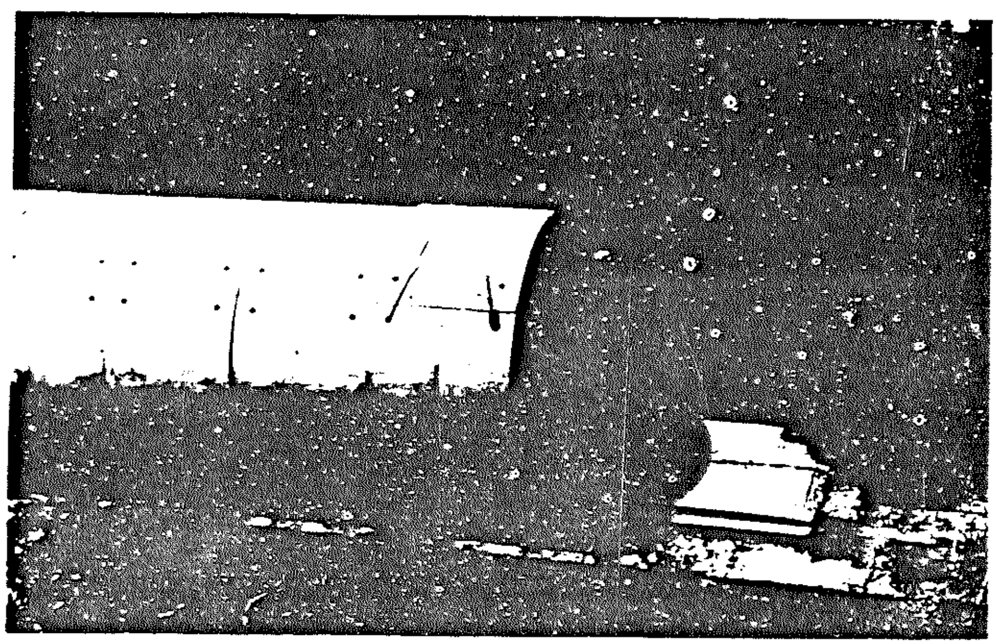

Photo 6- Adjustment of a precast piece on culvert invert

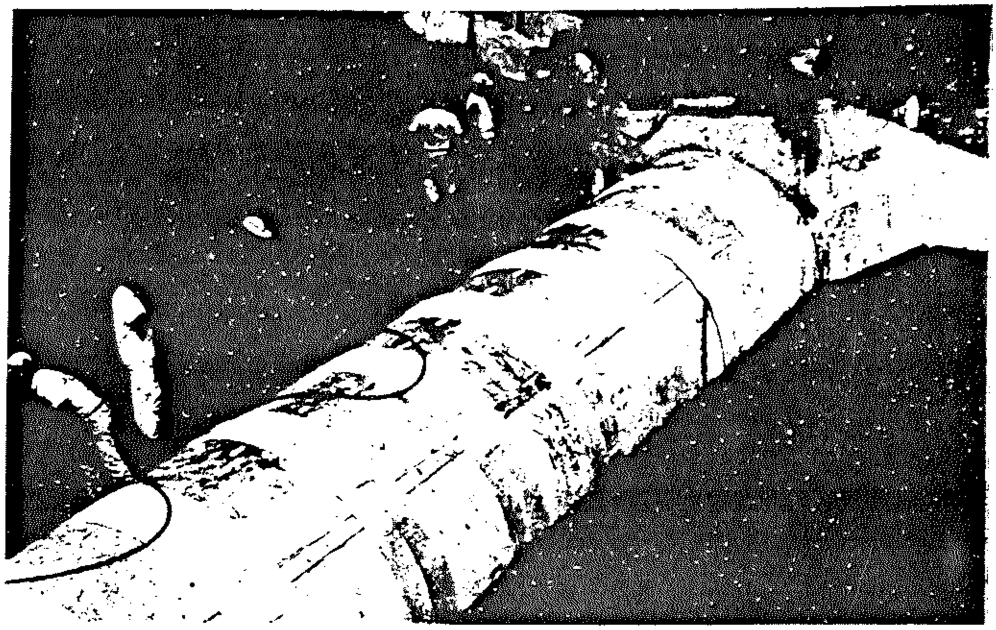

Photo 7- Embankment under the culvert crown

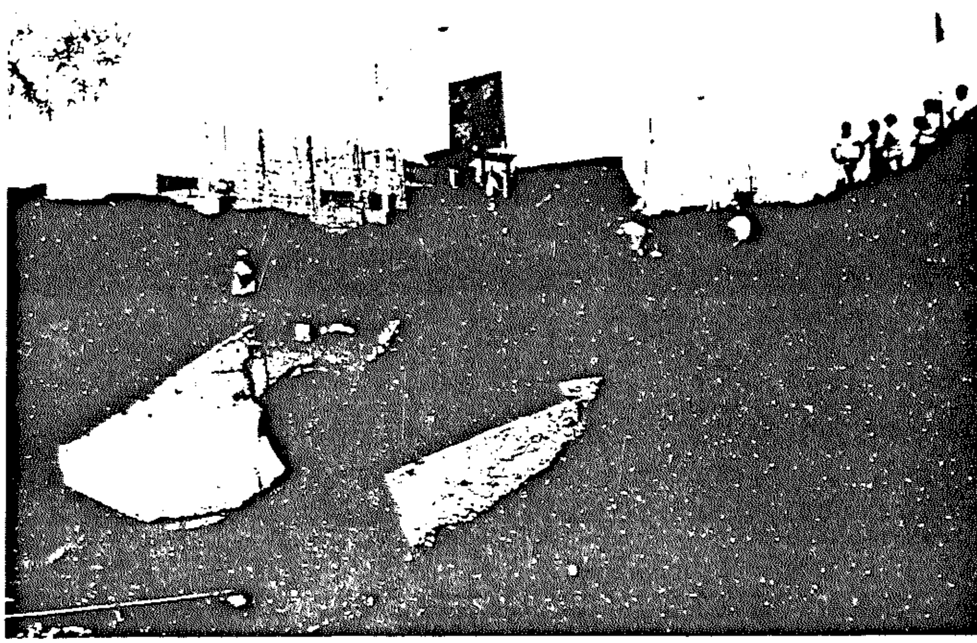

Photo 8- Embankment above the culvert crown