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Scour Depth and Soil Profile Determinations in River Beds

Profondeur d'affouillement et détermination du profil du sol dans le lit des rivières

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Summary

Descriptions are given of various techniques that have been used in South Africa to obtain information from river beds for establishing soil profiles and to deduce the scour depth after floods. The techniques used included sampling by means of wash boring, vertical density logging using a gamma-ray probe, short-range seismic exploration and "Dutch probe" measurements.

Results are presented which were obtained in several rivers affected by severe floods in Natal in 1959. From these results it was possible to establish sub-surface soil profiles and to deduce the probable scour depth in the river beds. These results in turn proved of value in the re-design of bridge foundation structures and embankment protection works.

A description is also given of an automatic scour level indicator which has been developed for installation on various bridges to obtain regular and systematic information on scour depth during future flood conditions.

Introduction

The severe floods on the Natal south coast in MAY 1959, drew the attention of engineers to the problem of scour in river beds, and its significance for civil engineering structures. The National Institute for Road Research carried out extensive investigations in some of these rivers immediately after the floods, which were estimated to have been of a magnitude only to be expected to occur once every 100 years.

The geological history of these rivers has an important bearing on foundation conditions, while a number of other factors affect river flow characteristics in the estuaries in normal and flood conditions. The majority of these rivers have rocky beds a few miles inland but then expand into tidal lagoons. Du Torr [1] states that these estuaries represent "drowned" valleys which were filled up with estuarine silts and sands during depression of the land relative to the ocean. The depth to solid rock in the estuaries may, in some rivers, be in excess of 150 ft.

The outlets of the rivers investigated are normally near the south banks, usually with a rocky outcrop extending into the sea to the south. These rock outcrops, together with off-shore currents, are responsible for the formation of long sandbanks which extend from the north banks of the rivers. During flood conditions river flow migrates towards the north bank tending to break through the sandbank at this point.

Road and rail structures across these rivers normally consist of bridges near the south banks and approach embankments from the north banks. Under these conditions it was found that the embankments and the bridge caissons, which

Sommaire

On décrit plusieurs méthodes employées en Afrique du Sud pour obtenir des renseignements sur les lits de rivière afin d'établir les profils du sol et d'en déduire la profondeur d'affouillement après des débordements. Les techniques employées comprennent l'échantillonnage par forage à l'eau sous pression, l'enregistrement densité/profondeur utilisant une sonde à rayon gamma, l'exploration sismique à courte portée et des mesures avec la sonde hollandaise.

Les résultats donnés ont été obtenus dans plusieurs fleuves du Natal qui ont débordé en 1959.

De ces résultats il était possible d'établir les profils des sous-sols et d'en déduire la profondeur probable d'affouillement dans des lits de fleuves. Ces résultats se sont montrés de grande valeur pour les nouveaux projets de fondations de ponts et d'ouvrages de protection des berges.

On décrit aussi un indicateur automatique du niveau d'affouillement qui a été prévu pour être installé sur des ponts afin d'obtenir des renseignements réguliers et systématiques sur la profondeur d'affouillement pendant des débordements futurs.

were founded in the river sediments at considerable depths, were affected during the floods. The object of the investigation was to determine, by means of various tests, the depth of scour in the rivers, and to establish sub-surface soil profiles. This information was required for the reconstruction of affected foundations, as well as for the design of embankment protection works.

Techniques used in the Studies of River Beds

Soil sampling by means of wash boring.—The equipment used in this technique consisted of the following items :

- 150 feet of thin-walled, flush-coupled AX casing;
- a hardened and serrated cutting tip fitted to the bottom of the casing;
- a high-pressure water pump, capable of delivering about 12 gallons per minute, at a pressure of 80 p.s.i.;
- 150 feet of 3/4 inch high-pressure rubber hose;
- a tripod with block and tackle to extract the pipes;
- a raft to carry the pump and various accessories, such as chain tongs, etc.

The method consisted of rotating the pipe by means of chain tongs and washing up the material in the pipe by means of a water jet from the hose. This hose was pushed down the casing until its free end was just short of the cutting end of the pipe. Care was taken not to let the hose go beyond the end of the pipe as this would result in "blow-outs", with the water flowing upwards along the outside of the pipe, thus disturbing the surrounding material and preventing

samples being obtained. The material washed up through the casing was collected in sample bags from various depths and was used to establish soil profiles.

In the sandy beds of the rivers which were investigated, samples could be obtained by the above method to a depth of approximately 100 feet. When resistant or coarse material was encountered it was necessary to drive the casing down, using a protective cap and sledge hammer in addition to rotation and jetting.

Density logging with radio-isotopes.—The equipment consisted of a radio-active density probe and transistorised field scaler [2]. The density probe contained a cobalt 60 source at the one end and a suitably screened Geiger-Muller tube at the other end, the whole probe and access cable being waterproofed for underwater work. The readings obtained from the scaler in counts per minute, inversely proportional to density, were normally plotted directly against depth. From an approximate calibration curve the readings could also be converted to total density in lb/cu.ft. The volume of material measured was roughly spherical and about 18 inches in diameter.

The probe, suspended by a steel tape, was lowered down the casing from which the wash boring samples were obtained, on completion of sampling. Density readings were then taken at 5 ft. intervals, and a vertical density profile plotted.

Short-range seismic exploration.—The equipment consisted of a special underwater hammer, a waterproofed seismic pickup and a transistorised time-interval meter [3]. The hammer consisted of a hollow cylinder with the lower end sealed off and the handle of a 15 lb. cylindrical hammer protruding from the other end. A cable from a switch on the hammer relayed a pulse to the time-interval meter at the moment of impact. Provision was made to increase the impact by the

introduction of percussion caps in the pipe below the hammer when necessary. A lead from the seismic pickup relayed the arrival of the first compressional wave from the hammer to the time-interval meter. The method consisted of exciting shock waves at increasing distances from the pickup by means of the hammer and measuring the wave travel time by means of the time-interval meter. In this way the velocities of compressional waves in the sub-surface layers as well as their depths below the surface could be established.

It was found that this technique was in general not sensitive enough to define small differences in layer composition and was therefore not very useful in defining the depth of scour. It was useful, however, in defining the depths of, and compressional wave velocities in the more resistant layers, both in the river bed and on the embankments.

Dutch probe soundings.—This technique, described by Kantey [4] was used as an additional source of information on sub-surface conditions. In practice the total resistance and point resistance are obtained at increments of depth and the value of the angle " ϕ " calculated.

Discussion of Results

The results of three different types of measurement (soil profile, density profile and Dutch probe), carried out at the Illovo River bridge site, are presented in Fig. 1 for a point on the centre-line midway between piers No. 2 and 3. At the Umpambinyoni River bridge site the above measurements were supplemented by short-range seismic tests.

Referring to Fig. 1 (a), the results of point and total resistance for the Dutch probe show a marked increase at a depth of 23 ft., while the point resistance decreases again at about 28 ft. The value " ϕ ", for which de Beer [5] assumed a critical limit of 30°, first exceeds this limit at a depth of 23 ft. If

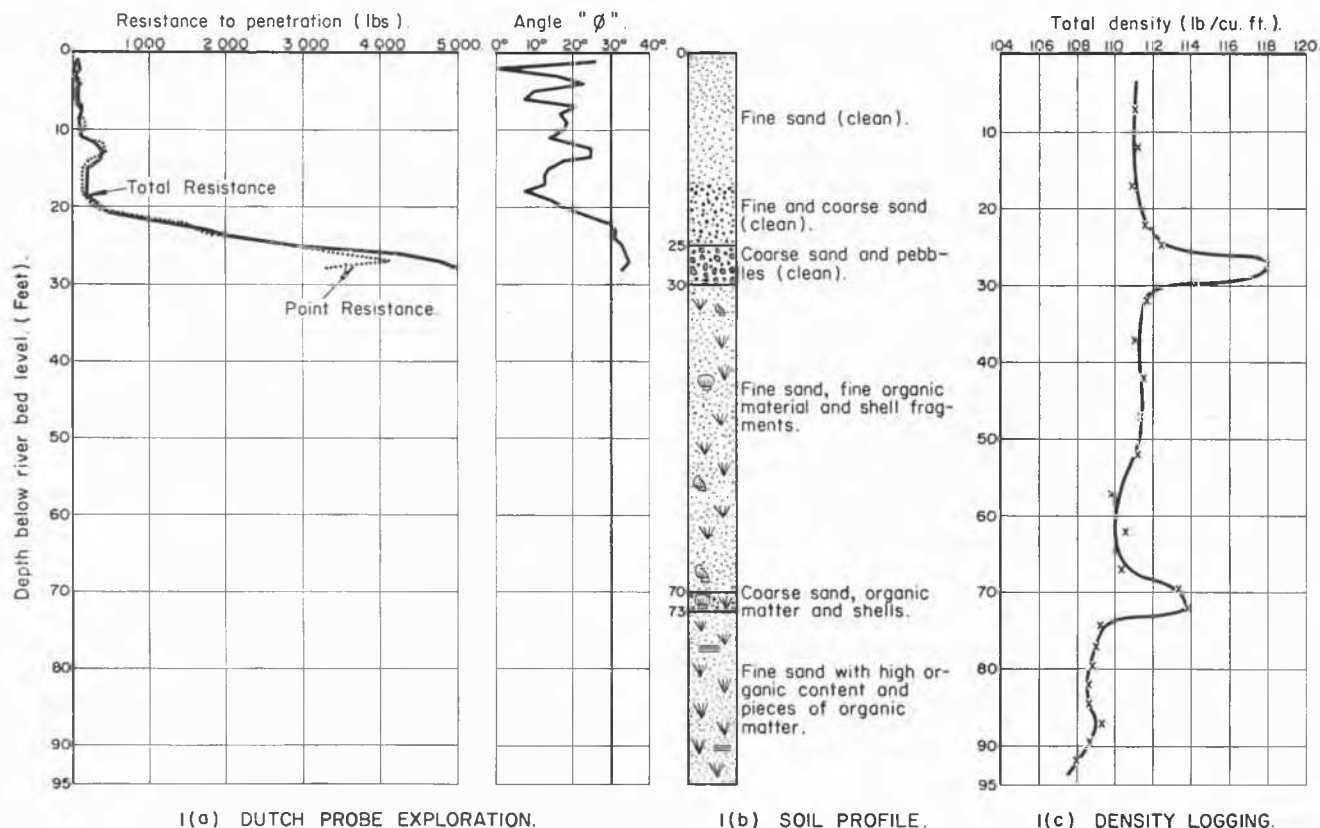


Fig. 1 Comparison of results of field exploration at the Illovo River bridge.
Comparaison de résultats d'exploration au pont sur le fleuve Illovo.

this depth is associated with a sudden increase in density the indications would have been that this was the depth of scour.

The soil profile shown in Fig. 1 (b) was drawn up from inspection of samples from wash boring and can only be regarded as an approximate description. The information obtained, however, shows a number of distinct features. Above 30 ft. there is a layer of coarse pebbles and sand grading into finer material towards the surface. Immediately below a depth of 30 ft., fine sand containing organic materials and shells indicates that this material could not have been deposited during the recent floods. The shells are a marine deposit and the presence of fine organic material indicates deposition under stagnant conditions. It is of interest to note that another layer of coarser material exists at about 70 ft. and probably indicates ancient scour activity, as this overlies material with a high organic content. Foundation conditions do not improve much, therefore, with depth of founding.

The density plot in Fig. 1 (c) shows an increase in density at a depth of about 25 ft. and an abrupt decrease at about 30 ft. Below 30 ft. the density tends to decrease slightly down to 70 ft. where an increase corresponds with the coarse layer shown in the profile.

Considering all the above results, the indications from the

by the former is probably due to the high resistance to penetration caused by an increase in particle size rather than an increase in density. Further measurements with wash boring and density logging just upstream of a caisson gave a scour depth of 37 ft., indicating an increase of about 7 ft. due to the obstruction of the caisson.

During the flood, failure of the bridge was caused by subsidence of caisson No. 3, which had been founded at a depth of 35 ft. In reconstruction, a new caisson was founded at a depth of 60 ft adjacent to the original position. The existing caisson No. 2 was also given protection by the installation of sheet piles founded at 50 ft.

In Fig. 2 a complete soil profile is shown upstream of a bridge and an embankment on the Umpambinyoni River where the embankment was completely washed away during the flood. In drawing up this profile use was made of results obtained from wash boring, density logging and seismic sounding techniques. The scour line on the south side probably represents conditions when the approach fill was still intact while the line on the north side represents conditions after failure of the embankment. In the reconstruction of the embankment, measures are being adopted for protection of the slope against erosion.

At another site, the Umzumbi River, flood water flowing parallel to the approach embankment undermined the sheet

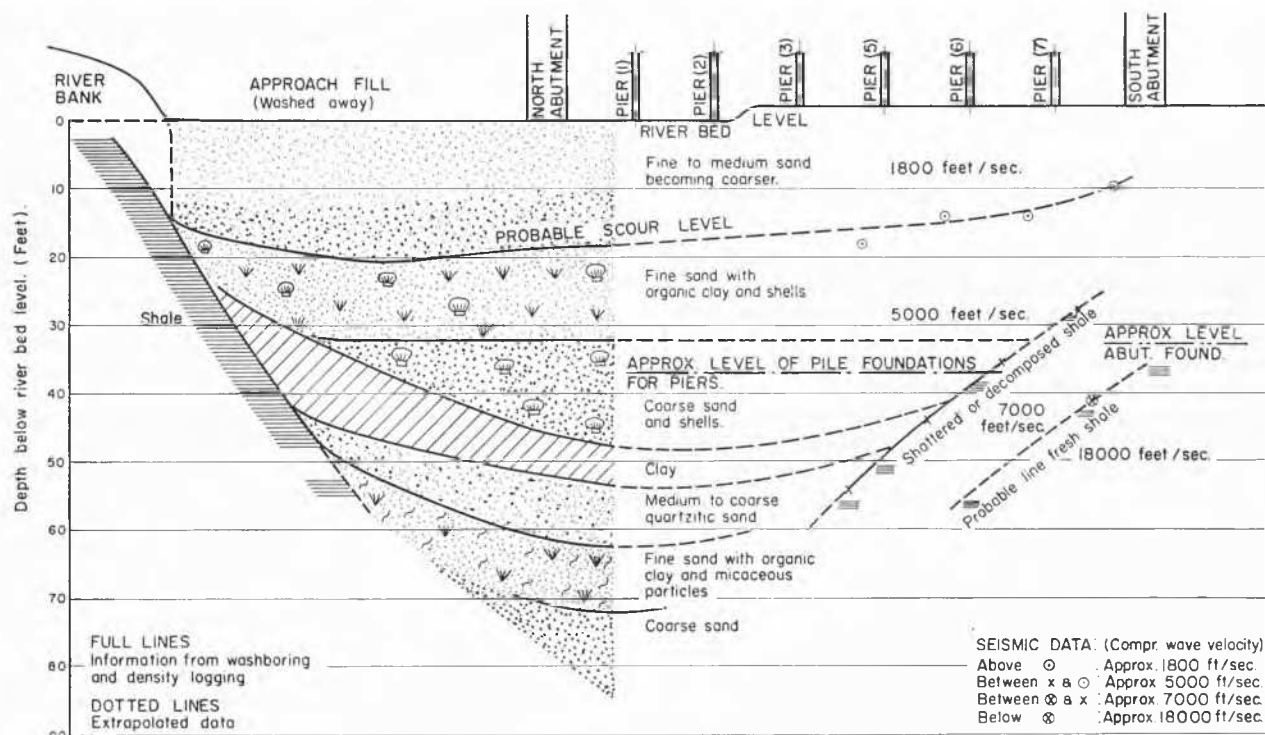


Fig. 2 Cross section showing foundation conditions at Umpambinyoni River bridge site.

Coupe en travers montrant les conditions de fondation au pont sur le fleuve Umpambinyoni.

Dutch probe alone are that the scour level may be at a depth of 23 ft., i.e. where there is a sudden increase in point resistance and where Φ is greater than 30° . From the results of the other two techniques, however, it must be concluded that the scour level is at about 30 ft, corresponding to the base of the coarse material and the lower level of the dense layer shown in the density plot. It is assumed that the coarse material would have been deposited first after the flood had passed its peak. The difference obtained between the probable depth determined by the first method and the other two methods is about 7 ft. The shallow depth indicated

piles founded at a depth of about 13 ft. for protection of the toe, causing distress of the slop and damage to the northern abutment.

Automatic Scour Level Indicator

As a result of the information obtained in the scour investigation, it was decided to develop an instrument with which a continuous record of the depth of scour in a river bed can be obtained during flood conditions. It is hoped that, with the installation of several of these recorders, it will be possible to build up systematic data on river scour, which can be

The installation, shown diagrammatically in Fig. 3, consists of

ists of three parts; a concrete pile containing stainless steel electrodes, a pressure switch, mounted on the bridge pier, and a box containing the exciting and recording gear, mounted in a recess under the bridge sidewalk.

motor is then switched off automatically. The transistor oscillator, delivering 1 watt at 200 c/s, supplies a 60 volt potential which is switched, via a 1,000 ohm resistance, between one of the electrodes and ground. The voltage across the unknown resistance is fed to an Esterline-Angus recorder, 1 mA full scale deflection, via a protective resistance and rectifier. The deflection on the recorder is inversely proportional to the electrode-ground resistance, and it has been found from laboratory work that the electrical conductivity is different in water, undisturbed sand and sand in a state of continuous disturbance.

Consecutive electrodes are selected for measurement by means of a rotary switch driven from the clockwork mechanism of the recorder and these results give an indication of scour level. The instrument is capable of recording continuously for 5 days before the clockwork mechanism must be rewound, the recording paper changed, and all the 1.5 volt, 10 ampere-hour dry cells, supplying 12 volts to the oscillator, and 18 volts to the motor, replaced.

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