

# SECONDARY COMPRESSION OF SILTY CLAY ADJACENT TO THE SWAN RIVER

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## 1. INTRODUCTION

The Narrows Interchange is constructed on land reclaimed from the Swan River Estuary in Perth, Western Australia. Preconsolidation techniques were used to eliminate primary consolidation and some secondary compression with subsequent settlement resulting from secondary compression.

For projects of this nature, postconstruction settlement can be estimated from the laboratory determined value of  $C_\alpha$ , the coefficient of secondary compression. Postconstruction settlements of the pavements within the interchange have been monitored since the opening in 1973. An analysis of this settlement data has provided field values of  $C_\alpha$  for comparison with the laboratory determined values.

## 2. HISTORY OF SITE

An area of 36 hectares was required for the Narrows Interchange (Fig 1) and associated works. This area was reclaimed from the Swan River in two stages: 28 hectares reclaimed in conjunction with the construction of the Narrows Bridge in the late 1950's and the remaining 8 hectares in 1965. The reclamation in each case was achieved by pumping silty clay from the river bed to comprise the bulk of the filling. This was subsequently topped with a layer of sand approximately 1m thick.

Subsoil investigations of the site after reclamation revealed alluvial deposits of very soft organic silty clay varying in thickness from 12m to 21 m. This is underlain by 6m of sandy clay, which is further underlain by limestone.

In order to improve the poor founding conditions, preconsolidation of the compressible stratum was necessary. This was attained by installing sand drains and applying a sand surcharge. 43 000 sand drains were installed by the displacement method and approximately 3 million m<sup>3</sup> of sand fill was imported for the embankments and surcharge. The rate of loading was controlled by the use of stability analysis based on vane shear strength tests.

The surcharge was in place for a minimum period of 2 years and settlements up to 7 m were recorded.

## 3. POSTCONSTRUCTION SETTLEMENT

The embankment design allowed a period of three years for construction of embankments and achievement of the desired degree of consolidation. At the end of this period excess pore water pressures had effectively returned to zero implying primary consolidation was complete.

In 1988 postconstruction settlement data for 110 stations within the interchange was plotted against the logarithm of time (typical plots are shown in Fig 2). These plots show a linear relationship and, except for 11 stations, indicate that primary consolidation was complete at the commencement of monitoring.

As with any project of this nature these postconstruction settlements have varied across the site and values in excess of 600 mm have been recorded with the average being 290 mm over a period of 19 years.

## 4. COEFFICIENT OF SECONDARY COMPRESSION

For most fine grained soils the magnitude of secondary compression is essentially directly proportional to the thickness of the compressible stratum at the completion of primary consolidation. Secondary compression appears to result from shear stresses since isotropic consolidation in triaxial compression tests causes very little secondary compression, whereas one-dimensional consolidation causes a significant amount. The coefficient of secondary compression is determined for complete lateral confinement such as is found in a laboratory consolidation test and assumed beneath the central portion of wide fills. It can be computed (Johnson 1970) as

$$C_\alpha = \frac{\Delta H_{\text{sec}}}{H_p \log \frac{t}{t_p}}$$

where

$\Delta H_{\text{sec}}$  = settlement as a result of secondary compression

$H_p$  = thickness of compressible stratum at time  $t_p$

$t_p$  = time corresponding to completion of primary consolidation

$t$  = time at which secondary compression settlement is computed

By computing the secondary settlement over a single logarithmic cycle of time this reduces to

$$C_\alpha = \frac{\Delta H}{H_p}$$

where

$\Delta H$  = settlement corresponding to one log cycle of time

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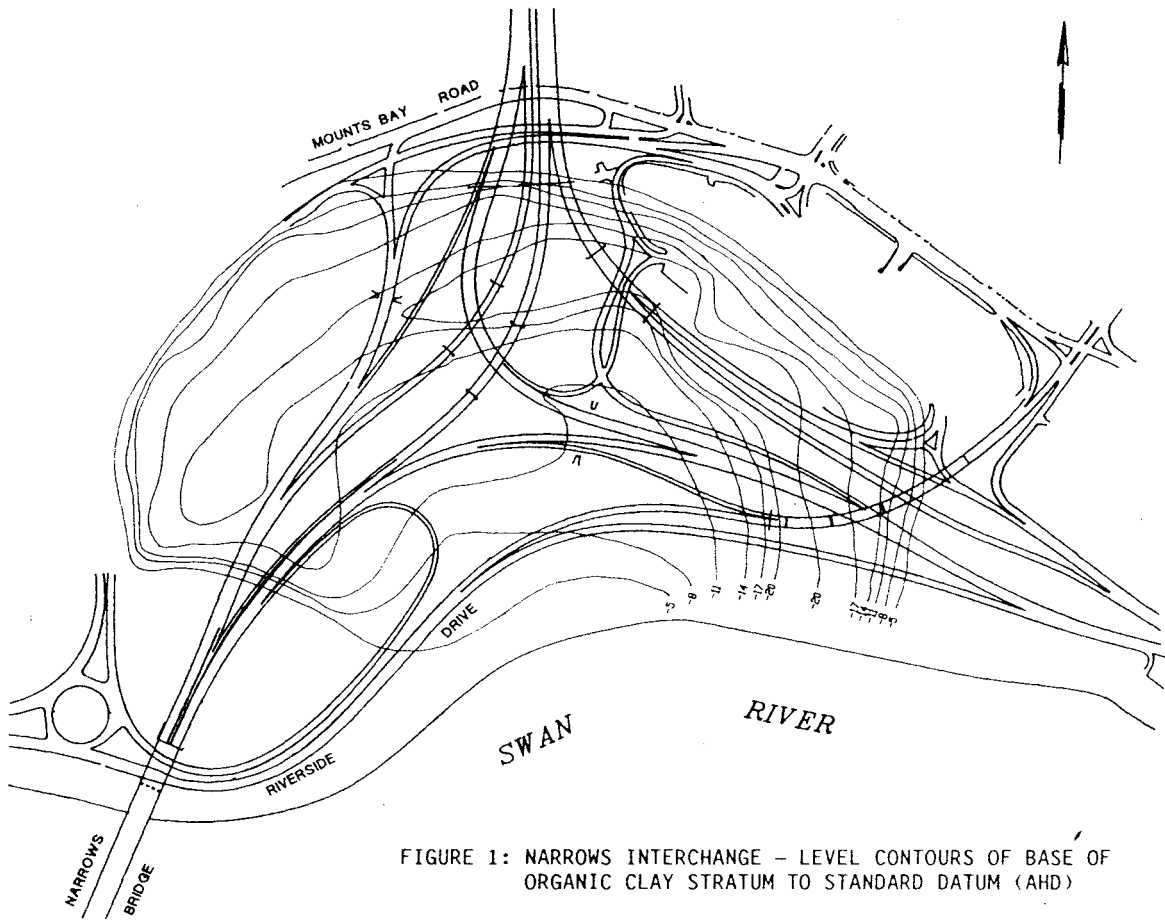


FIGURE 1: NARROWS INTERCHANGE - LEVEL CONTOURS OF BASE OF ORGANIC CLAY STRATUM TO STANDARD DATUM (AHD)

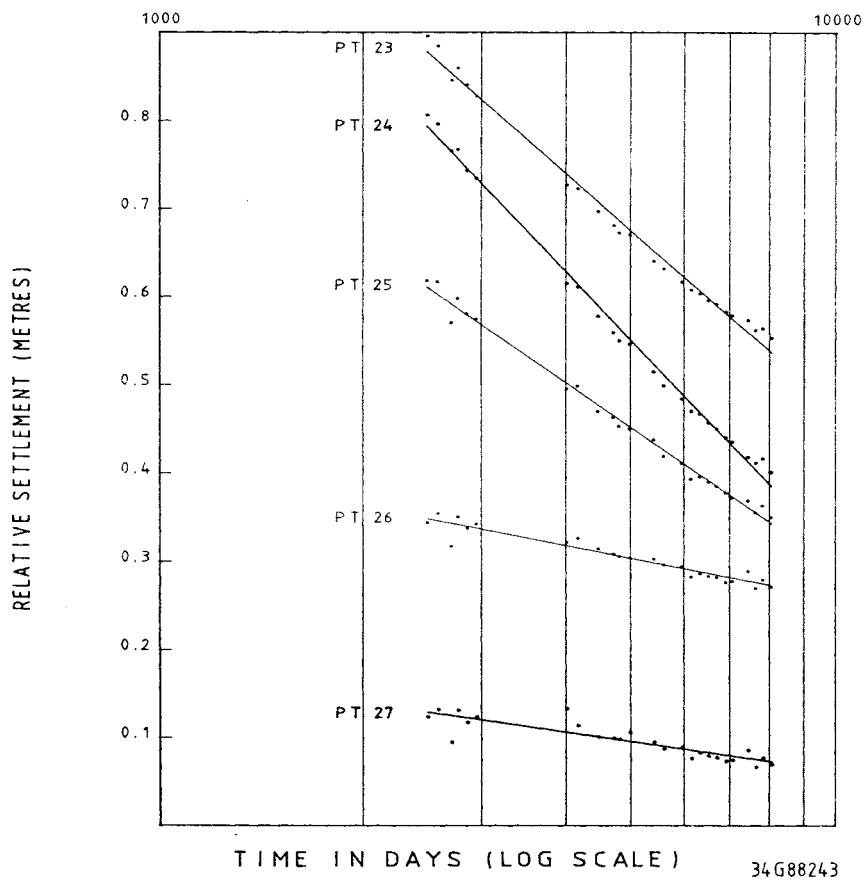


FIGURE 2: TYPICAL NARROWS INTERCHANGE SETTLEMENT STATION PLOTS - POSTCONSTRUCTION SECONDARY SETTLEMENT OF THE ORGANIC CLAY STRATUM. POINT 23, 24, 25, 26, 27

Back analysis of the post construction settlement enabled the determination of a field value for  $C_\alpha$ . This was determined for all 110 settlement stations and had an average value of 0.024 with a standard deviation of 0.020

## 5. DISCUSSION

Laboratory tests performed on the silty clay by Soil Mechanics Ltd in London and Main Roads Department in Perth during 1965 indicate a  $C_\alpha$  range of 0.014 to 0.025 (Soil Mechanics Ltd, 1968). These results were obtained from six disturbed and six undisturbed samples taken at various depths from two boreholes at the interchange. The laboratory tests were carried out at  $\Delta P/P$  ratios (load increment to previous load) of 1 approximating that expected in the field after the completion of works. The relationship between moisture content and  $C_\alpha$  was determined and the  $C_\alpha$  range cited above was for the average natural moisture content of the silty clay (130%).

The laboratory determined values were thought to be high and it was hoped that a major portion of the secondary compression settlement would occur during primary consolidation. However secondary

compression of the silty clay stratum has resulted in postconstruction settlements within the range predicted by laboratory determined values of  $C_\alpha$  at the design stage of the project.

## 6. REFERENCES

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# The Briseis (Cascade) Dam Failure

## FRONT COVER

This shows the remains of the Briseis (Cascade) Dam which failed sixty years ago on the 4th April 1929 and resulted in the loss of 14 lives plus extensive flood damage.

The dam had been constructed by the Briseis Tin and General Mining Co. Ltd. Its purpose was to provide sluicing water at the open cut tin mine in the Ringarooma riverbed at Derby 5km downstream.

The dam was an early example of the concrete face rockfill (CFR) dam type. Its principal dimensions were:-

maximum height	24m
crest length	137m
crest width	1.5m <sub>3</sub>
volume	28 400m <sub>3</sub>
upstream slope	1:1 at lower levels to 0.5 (H): 1(V) near the crest.
downstream slope	1:1

The rockfill consisted of granite boulders, with an approximate mass of 3-8 tonnes each, placed to a void ratio of  $\sim 0.46$ . The foundations were of massive granite.

The upstream face consisted of a 0.3m thick reinforced concrete slab. The crest was capped with a 0.15m thick slab with 0.5m high parapets near each of the abutments. The spillway occupied the central 70m portion of the crest and discharged directly on the downstream face of the dam. Its estimated maximum capacity was 200m<sup>3</sup>/sec.

At the time of failure the flow over the spillway was estimated at 600m<sup>3</sup>/s. The failure commenced when stones and boulders were dislodged by waves of water impacting on the downstream face.

The main causes of the failure were an under estimate of the design flood, the consequent lack of spillway capacity and the inability of the dumped rockfill boulders in the downstream face to withstand the flood discharge.

The dam was re-built some years later, again as a CFR dam; however the downstream face was flattened to 1.75 (H) : 1(V) and the spillway capacity was increased.

At the inquest into the death of the 14 victims of the dam burst the verdict of the jury was: "....."....they came to the conclusion that the bursting of the dam was the result of an abnormal and unprecedented volume of water which may have been caused by a cloud burst, or by an extraordinary rainfall in the catchment area of the dam, and they advised that no blame was attachable to anyone....."

One can only wonder what the judicial outcome would be under similar circumstances today.

The failure of the Briseis dam is the only failure of a large dam in Australia for which a loss of life has been recorded. Hopefully it will also remain the last.

Ed.