

## SLOPE RISK ASSESSMENT OF NEAR VERTICAL CUTS IN HAWKESBURY SANDSTONE F3 FREEWAY, WAHROONGA TO HAWKESBURY RIVER, NSW

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### SUMMARY

A slope risk assessment analysis was undertaken on a total of 83 high angle road cuts in Hawkesbury Sandstone along a 20 km length of the F3 Freeway, north of Sydney.

Details of individual cut features and methods used to prioritise cuts for remedial works are given, together with a discussion on risk assessment as part of the design process for future freeway works.

### INTRODUCTION

The F3 Freeway forms the major transport link between Sydney and the Central Coast and Newcastle regions located some 100 km to 150 km northwards, with traffic movements of the order of 15,000 vehicles per day (1989).

Within the study area, the route of the freeway lies within a geological setting of rugged terrain dominated by the near flat lying Hawkesbury Sandstone of Middle Triassic Age. Local relief is in the order of 100 m - 200 m.

Construction of the Freeway was largely undertaken in the late 1960s to replace the older, two lane Pacific Highway, with a further southern extension constructed during 1986-87. Excavation methods appear to have been largely by drilling and blasting.

The resulting roadway from both periods of construction is characterised by alternating cut and fill sections with the cuttings typically steeply excavated in medium to high strength sandstone with some mudstone interbeds and occasional volcanic intrusives.

Some cuttings have intermediate benches, although most are continuous with slope angles up to 80° and heights ranging up to 70 m.

During 1994, Douglas Partners were engaged by the Roads and Traffic Authority of NSW (RTA) to undertake a Slope Risk Priority investigation on cuttings along the southernmost 20 km of the F3 Freeway, between Wahroonga and the Hawkesbury River.

This paper presents a brief chronicle of methods used to prioritise cuts for remedial works. Discussion on features of the cuts posing a potential hazard to Freeway users and risk assessment during future freeway design are also presented.

### TYPICAL FEATURES WITHIN THE CUTTINGS REQUIRING REMEDIAL WORK

The Hawkesbury Sandstone formation dominates the landscape within a 100 km radius of Sydney. It is a quartz sandstone with a maximum thickness of 250 m. The formation contains numerous thin mudstone interbeds but sandstone exceeds mudstone interbeds by about 20:1. (Herbert, 1980). Sandstone facies of the formation are both of the sheet or massive types. The sandstone has high in situ horizontal stresses which are relieved on excavation.

The Freeway cuttings have resulted in large exposures of all facies of the formation. The exposed strata is generally of medium to high strength and is moderately to slightly weathered. However, numerous bedding horizons of lower strength, highly weathered strata also occur along the Freeway route. During excavation, horizontal stress relief movement occurred along these bedding planes.

The formation in the area of the Freeway is also often characterised by steeply dipping, semi-orthogonal joint sets which can, upon intersection with the cutting faces, create slabs, blocks and wedges of rock, some of which are unfavourably orientated.

Some of the principal features of the weathered rock faces that are considered hazardous include:

- individual loose boulders or dilated joint blocks,
- zones of loosened joint blocks caused by weathering-out of horizontal bedding planes and/or joint zones,
- weathering and slaking of low strength clayey sandstone beds, forming undercuts to the slope or rock above,
- dilation of joints running at an acute angle to the rock face; the 'feather edges' of such blocks are potentially subject to progressive tensile or shear failure.
- the presence of surface rubble or boulders on the natural slope above the crest of the cutting which could be undermined by strong overland rain-water flow.
- vegetation, particularly trees which can force joints open, due to 'root jacking'.
- stress relief between blast holes and blast damage, including areas where rock material has not been removed outside of the pre-split line, has also resulted in loose blocks or slabs,
- slot forming, weathered out of dolerite dykes or sheared zones.

It is considered possible that vibration from the traffic may also have contributed to slight general loosening of the cutting faces by encouraging further stress relief movement along bedding planes.

#### SLOPE RISK RATING SYSTEM & INITIAL CLASSIFICATION OF CUTTINGS

Douglas Partners undertook an initial assessment of 83 cut faces along the 20 km section of the freeway in August, 1994, using the RTA Scientific Services "Slope Risk Rating System Guide" (version 1). This guide presents a recommended procedure for assigning a risk rating to slopes above roads based on quantitative levels for both the probability of occurrence and the severity of the consequences of slope failure.

The term, 'risk', is deemed to combine both potential for as well as consequences of slope failure.

The work was undertaken to supplement an earlier assessment of the cutting stability by the RTA Materials Services Branch in May, 1993.

Field observations of each cutting were recorded on Slope Inspection Reports (SIR), then used to establish an order of priority which reflected the need for further detailed geotechnical investigation; remedial or preventative action based on each observation being given a weighted score and recorded on a Slope Instability Score Sheet (SISS).

The instability score assigned to each slope allowed the slope to be placed in one of five classes which qualitatively represent the instability conditions. The five classes and corresponding ranges of instability score are given in Table 1.

Table 1. Classification of Slope Instability

Instability Class	Instability Score Range
Very high (VH)	> 100
High (H)	75 - 100
Moderate (M)	50 - 75
Low (L)	25 - 50
Very low (VL)	<25
Source: RTA (1994)	

A Consequence Assessment was also undertaken for each slope which qualitatively indicated the possible effects on road, traffic, human lives, services and property that could be caused by failure of that slope.

Road Class and traffic volume was a most important consideration in the Consequence Assessment. It is most likely that potential for disruption to traffic and services and loss of life would be highest on roads with the highest traffic flow.

A further consequence consideration involved assessment of potential disruption of services or loss of life resulting from the slope failure affecting occupied buildings above or below the slope.

A brief description of Road Class and a classification of Consequences Class are given in Tables 2 and 3 respectively.

Table 2 - Description of Road Classes

Road Class	Road Type	Daily Traffic Volume
1	Freeways, Tollways, National or State Highways	>10,000
2	National or State Highways State Roads	5000 - 10000
3	Regional Roads (Main or Trunk)	2000 - 4999
4	Rural Roads . Local Roads	<2000

Adapted from RTA (1994)

Table 3. - Classification of Consequence.

Consequence Class	Description of Consequence
Very High (VH)	High risk to life and/or total closure of a Class 1 road, resulting in an extended period of disruption to traffic and/or services and high cost of remedial works
High (H)	High risk to life and/or partial or total closure of one carriageway of a Class 1 road or total closure of a Class 2 road resulting in an extended period of disruption to traffic and/or services and high cost of remedial works
Moderate (M)	Moderate risk to life and/or partial or total closure of one carriageway of a Class 2 road, resulting in a temporary period of disruption to traffic and/or services and moderate cost of remedial works
Low (L)	Low risk to life and/or partial or total closure of a Class 3 road, resulting in a temporary period of disruption to traffic and/or services and low cost of remedial works
Very Low (VL)	Very low risk to life and/or partial or total closure of a Class 4 road, resulting in a temporary period of disruption to traffic and/or services and very low cost of remedial works

Initially, a High consequence rating was proposed for all cuttings as a result of the Freeway being a Class 1 road. However, some of the cuttings are only very low (<3 m high) and in their present condition were considered to present only a moderate risk to life, regardless of traffic volume. A downgraded Consequence Class, where applicable, was given to those cuttings.

When Instability and Consequence classes are combined, a Slope Risk Rating can be given based on Table 4.

Table 4. - Slope Risk Rating

INSTABILITY	CONSEQUENCE				
	Very High (VH)	High (H)	Moderate (M)	Low (L)	Very Low (VL)
VH	1	1	2	3	3
H	1	1	2	3	3
M	2	2	3	4	4
L	3	3	4	5	5
VL	3	3	4	5	5
Source: RTA, 1994					

Numbers 1 to 5 in Table 4 indicate risk categories in order of priority for further investigations or implementation of remedial, preventative or maintenance works as follows:

Risk Rating 1 - Immediate action

Risk Rating 2 - Urgent action

Risk Rating 3 - Regular maintenance, action as soon as possible

Risk Rating 4 - Regular maintenance, frequent inspections

Risk Rating 5 - Periodical inspections and maintenance

On the basis of Consequence Class and Instability Class, a Slope Risk Rating was calculated for each of the 83 cuttings.

The results indicated that 19 of the cut slopes inspected were considered to warrant a Slope Risk Rating of 1. The bulk of these slopes were located within cuttings along the older northern section of the Freeway although five cut slopes from the newer, southern section were also included due to specific features.

In general, the findings were consistent with those presented in the RTA Material Services Branch Report, with similar features noted.

Several cuttings were allocated a high Slope Risk Rating due to the removal of undergrowth in bushfires that swept through much of the area in January, 1994. These fires had exposed large colluvial boulders on natural slopes, above the cut faces, which dipped towards the freeway. These problem areas may not have been easily identified during normal vegetation conditions unless a detailed walk-over inspection had been undertaken.

#### COMMENTS ON THE SLOPE RISK RATING SYSTEM

Some general comments should be made regarding the workability of the draft RTA system as used for the investigation.

Whilst the Slope Inspection Reports allow for considerable detail of field observations to be recorded, the Slope Instability Score Sheets were often insensitive to specific details of defects.

For example, on each SISS a specific score was allocated to the slope, dependent on total height. However, no allowance was given for the height upon the slope where various defects occur.

Similarly, whilst much information was recorded on the SIR regarding size and location of loose debris, boulders or blocks, there was little variation in allowable scores on the SISS.

Furthermore, it is considered that scores may be allocated on the SISSs for components that may not be applicable for the slope type. This was evident during the investigation when scores were allocated for degree of seepage, which was largely weather dependent and not considered to be a major stability factor for these slopes.

## DETAILED SLOPE STABILISATION ASSESSMENTS

A second phase of the slope risk priority investigation involved recommendation of specific stabilisation measures on five selected cuttings that had been identified as having a Slope Risk Rating of 1 during the earlier phase.

Initially each cutting was photographed from the top of the opposite cutting, using a 35 mm SLR camera. This was carried out on an overcast day, to reduce shadow effects. Following development and printing of the films, a photomosaic was prepared for the full cutting comprising multiple plates with transparent plastic overlay.

The photomosaic was then taken into the field by a two man team of engineering geologists.

The cutting was taped longitudinally to identify horizontal chainages. It was also taped vertically at a number of points to allow heights of individual features to be estimated.

Following the taping, the cutting was carefully inspected from carriageway level, from the top of the cutting and from the opposite side of the cutting, noting various features which were considered hazardous and noting the necessary treatment. These features were directly highlighted on the photomosaic overlay and checked from various angles.

In the office, the recommended stabilising measures were transcribed onto the photomosaics and a table prepared describing the measures and giving a priority rating to each feature. These annotated photomosaics and the table were then independently reviewed by the Principal Engineering Geologist.

The recommended stabilisation treatment for the potentially unstable features noted included:

- scaling and cleaning of sections of the rock face and upper batter slopes.
- removal of vegetation from the rock face and from a 5 m wide zone at the top of the cutting,
- removal of individual dilated rock or joint blocks on the face.
- subhorizontal rock bolting across open feather-edge blocks.
- pinning by vertical dowels of undercut sandstone blocks at the top of the cutting.
- pattern bolting, meshing and shotcreting areas of rock being loosened by weathering-out of joints and bedding planes.
- scaling and then shotcreting of fretting low strength clayey sandstone and shaly beds,
- construction of a rock fence near the crest of the cutting to arrest any larger debris which may fall from the natural slope above.
- pattern bolting, meshing and shotcreting of dolerite dykes or sheared zones.

Based on experience, the priority of treatment was subdivided into six classes, namely 1, 1-2, 2, 2-3, 3 and 4.

Features with a priority of 1 or 1-2 were recommended to be treated in the near future. Features with a priority of 2 or 2-3 required treatment within two to three years, whilst features with a priority of 3 or 4 required treatment within five to ten years.

A brief report was prepared for each of the nominated five cuttings. Each report incorporated full colour photocopies of the photomosaics with the accompanying table listing all features to be treated on that cutting.

## GEOTECHNICAL SUPERVISION OF REMEDIATION WORKS

Geotechnical input has been provided by Douglas Partners during both the tendering process and construction phase of remediation works undertaken on the cuttings.

In some instances, nominated priorities for various features to be stabilised have been changed during the course of the work following closer inspection from a cherrypicker and from on site discussions between representatives from Douglas Partners, the RTA and the contractor. The RTA supervisor on site has usually been able to authorise variations to the work undertaken with minimum delay.

For example, where closer inspection indicated that rock slabs or blocks nominated for scaling were too large or awkwardly placed to be safely removed, bolting or dowelling the block or slab in place was given as an alternative.

## DISCUSSION AND CONCLUSIONS

A slope risk assessment of high angle cuttings along the F3 Freeway, undertaken by Douglas Partners was carried out as part of the RTA management and maintenance programme for the safe operation of the freeway.

This ongoing maintenance is expected to continue for the foreseeable future and will require the long term allocation of funding, given the magnitude of the area to be assessed and the potential recurrence of certain defects even after remedial work has been undertaken (for example, regrowth of the trees).

Given this high cost of controlling or managing the risk to road users associated with rock slope failures on steep cuttings, some consideration needs to be given to the proportion of capital funding allocated to protective measures on cuttings for future roadworks or for reducing slope angles during the construction phase.

Additional funding for benching cuttings or additional shotcreting or bolting may be more preferable than a "wait and see what happens" philosophy given the increasingly litigious nature of society.

Where potential risk of future slope instability is foreseen as a result of design of future roadworks, the degree of risk should be ascertained considering instability class and consequence of failure of the feature. Features identified as having an unacceptable level of risk should have remediation work implemented during the construction phase.

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