

Assessment and Design Methodology for the Identification and Remediation of Rock Snagging Hazards on Road Cuttings – A Case Study from the Hervey Range Road Safety Upgrade Program Project

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1. ABSTRACT

Hervey Range Developmental Road (83A) is a two-lane, two-way single carriageway rural road connecting Townsville to Hervey Range and outer suburban residential areas such as Alice River and Rangewood. As part of a safety upgrade program along Hervey Range Road, identification of rock snagging locations and design of value for money smoothing solutions were required to be undertaken due to the need for widening of the sealed road alignment and the proximity of the existing rock cuttings relative to the road. An assessment methodology for identifying what constitutes a rock snagging hazard in a quantitative sense is either not well defined or inconsistent when considering published literature (such as various state road authority specifications and other Australian road design guidelines). In light of this, a definition of a rock snagging hazard was developed for the project and can be qualitatively defined as a rough, sharp or jagged rock protrusion or depression which has the potential to constitute a hazard to vehicular navigation. This paper describes the qualitative and quantitative assessment criteria and design methodology that has been adopted to address the risks associated with rock snagging hazards on irregular and often jagged road cuttings that are close to the edge of the road using the Hervey Range Road Safety Upgrade Program project as a case study. The assessment of rock snagging hazards without the necessary budget for detailed field assessment and mapping, as well as fit for purpose detailed survey, can complicate the ability to provide cost effective remedial solutions to this type of problem. Two-dimensional analysis of survey can often prove problematic with regards to identification of the hazards. This paper discusses how interrogation of the available information through rendered three-dimensional survey assessment in conjunction with digital video recorder (DVR) footage and still imagery, as well as use of conventional two-dimensional analysis of cross-sections and long-sections, can be used to provide value for money smoothing solutions. An innovative design methodology incorporating the vertical extent of treatment on slopes to reduce the risk of safety in construction as well as reducing the construction costs was also implemented as part of the project.

Keywords: Rock Snagging, Rock Smoothing, Design Methodology, Range Road

2. INTRODUCTION

Rock snagging is a poorly defined safety hazard prevalent along range roads, where unremediated cuttings are common. These hazards present a considerable risk to motorists, whether due to the “can opening” effect of smaller protrusions, or possible collisions with larger protrusions or depressions. Various transport authorities identify the risk posed by rock snagging without providing an actual description or method of identification for what constitutes a rock snag. Consequently, a description and method of identification had to be produced to provide a basis for an assessment. Rock snagging was defined to be a rough, sharp or jagged rock protrusion or depression which has the potential to constitute a hazard to vehicular navigation. With an understanding of what rock snags were, a quantitative assessment to identify them was required.

3. PUBLICATIONS REGARDING THE IDENTIFICATION OF ROCK SNAGGING

The only publications from a transport authority that discussed quantitative values for rock snagging was Austroads – Guide to Road Design Part 6. Section 4.4.6, which stated that there were no guidelines available for the acceptable roughness of rock faces. However, reference to a Federal Highways Administration approval letter (referenced within Austroads) regarding the vertical relief on the face of rigid barriers states that the roughness tolerated is minimal, with a maximum height of 64mm for any irregularities in the surface of the barrier above where contact with the wheel would occur. This criterion was considered too stringent for rock cuttings and would be unfeasible to apply.

As the case study was a Department of Transport and Main Roads (DTMR) project, DTMR technical specifications (MRTS) and the geotechnical design standard (GDS) were considered. The only information applicable from these documents was from Section 16 of MRTS04, where there are to be no overhangs outside the edge of the table drain from rocks batters and the design shape of the finished batter is not to extend away from the design line further than the lesser of 300mm or one third the height of the batter. This supplied a more reasonable deviation from the design slope in comparison to Austroads but did not consider the increased risk of larger protrusions closer to the road level.

To further refine the assessment criteria, the New South Wales Roads and Maritime Services (RMS) Quality Assurance Specification R44 was also considered. R44 Section 3 specifies that cuttings must not have undulations in the general plane of the batter and that batter tolerances should be calculated regarding the height and steepness of the batter at any given point. This provided the consideration of increased risk for protrusions on lower sections of the slope and are detailed in Table R44.3, detailing the excavation tolerances for batters in cuttings.

4. ADOPTED METHODOLOGY

While RMS provided the most thorough criteria, conformance with DTMR technical specifications would allow a wider application of the methodology. This change meant that the maximum allowable tolerance away from the roadway for slopes steeper than 1H:1V would be limited to 300mm instead of 600mm. These values have been provided as part of Table 1.

Table 1: Adopted Tolerance Criteria for Rock Snagging

Location	Tolerance (mm) ^a	
	Slope 1H:1V or flatter	Steeper than 1H:1V
At the toe of the batter	+0 / -150	+0 / -200
0m to 2m above the toe of the batter	Interpolate	Interpolate
2m to 4m above the toe of the batter	+300 / -300	+300 / -300

^a The "+" is the tolerance towards the roadway, while the "-" is the tolerance away from the roadway.

As DTMR and Austroads specifications do not specify whether the tolerance is to be taken as a vertical, horizontal or perpendicular to the slope plane, the RMS method was adopted where all tolerances shall be measured perpendicular to the slope plane.

Areas within the first 2m (vertical height) of the batter are considered the highest potential risk due to being the most important to prevent snagging. This is with consideration of the height of passenger vehicles, RMS R44 limiting the tolerances within this region and Austroads stating that the first 1m of the cutting is important when trying to prevent snagging. However, where significant heavy vehicle traffic is present, consideration should also be given for the potential of snagging above 2m. A vertical height of 4m is suggested as the upper extremity of potential treatments based off the height of heavy vehicles (i.e., type 1 and 2 road trains).

To ensure that treatments are not overly excessive, limiting the height of treatments based on the horizontal offset from the toe of the batter is suggested. As a result, steeper slopes will require a greater height of treatment in comparison to flatter slopes. As part of the adopted methodology, horizontal offsets greater than 1m away from the toe of the batter should be achieved before considering the rock snagging hazard outside the reasonable area to treat. A simplification of this that can be used is that slopes of 45° or less require a treatment height of 1m, slopes greater than 45° and up to 60° require a treatment height of 2m and slopes greater than 60° require a treatment up to 4m.

Rock snagging is also unable to be assessed in only a conventional cross-section analysis, with several issues arising due to the application of 2D analysis to a 3D problem. A significant issue is that undulating slopes, which are a potential collision hazard, are a type of rock snagging that may be unidentified without 3D assessment. Smoothing solutions also need to consider the risk posed to vehicles that may collide with the treated area and tapering the solution back towards the rock cutting is required. 2D analysis also presents an issue when considering the constructability, estimation of quantities and budgeting of costs for tendering purposes. As such, a 3D assessment is needed to accompany 2D analysis.

5. APPLICATION OF METHODOLOGY TO DEVISE CASE STUDY TREATMENT OPTIONS

When applying the methodology, consideration is needed for the challenges presented by an irregular 3D slope face. Removing the hazard via scaling would be the simplest solution, however, the likelihood of uncovering even more problematic geology meant that this should be reserved for small scale locations. There was also the issue that scaling would not allow for the treatment of depressions, where an infill treatment is required. This was considered as Option 1 for treating rock snagging.

To effectively treat rock snagging where scaling was not feasible, a solution that can be applied over complex geometries including protrusions and depressions was required. Initially, a shotcrete solution with mesh was suggested, but it is difficult to adapt mesh reinforcement to adequately support the shotcrete around complex geometry with depressions often being found in conjunction with protrusions. This meant that alternative reinforcement solutions were required, and as such fibre-reinforced shotcrete or fibrecrete were selected as the preferred solutions. The weight of the fibrecrete would seldom be sufficiently supported by the slope and required dowels to act as supports for the treatment. To ensure that the dowels had adequate corrosion protection, as well as assist in transferring the weight of itself to the dowels, a minimum cover of 100mm was needed over protrusions. Consequently, the protrusion would be extended towards the road, which increases its severity. Tapering the protruded areas back into the slope at such an angle that it would not present a hazard to vehicles, would rectify this. To do this, reference to DTMR technical specifications and Austroads was needed to consider the effect of a vehicle impacting the treated slope, which requires the treatment to have similar considerations to concrete barriers. This is highlighted in Section 4.4.6 of Austroads – Part 6, where cuttings and rock faces should be designed to provide a smooth face that will act as a rigid barrier, allowing errant vehicles to slide along and stop gradually. To adhere to this, Section 5.3.5 of Austroads – Part 6, specifies a flare rate to be applied to the treatment, while limiting the encroachment angle to no greater than 25°. Section 5.3.14 of Austroads – Part 6 is used to assess the encroachment angle of a vehicle on straights relative to the design speed. The DTMR Road Planning and Design Manual (RPDM) Supplement to Austroads – Part 6, Table 6-4 (which supersedes Table 5.5 of Austroads – Part 6), specifies the minimum flare rate relative to the design speed and shy-line. The offset of the shy-line from the pavement edge is also specified in DTMR RPDM Supplement to Austroads – Part 6, in Table 6-3. Once these additional safety considerations had been applied, this was considered as Option 2 for treating rock snagging.

There were also locations where there were only depressions and did not require a treatment to further extend the slope face towards the road. In these cases, this meant that no taper was required as the edges of the treated area acted only as infill for the depression. However, it still required dowels to support the treatment. Given the simplification of treatment in comparison to Option 2, this was designated as Option 3 for treating rock snagging.

While Option 1, 2 and 3 covered the requirements of all situations along Hervey Range Road, there were instances where a significant volume of shotcrete would be required and consequently, a non-cost-efficient solution would be specified. To minimise these volumes, an extension to the considerations of Option 2 were adopted. Instead of a fibrecrete solution, the façade geometry of the treatment was adopted from precast concrete barriers as stipulated in DTMR Standard Drawing SD 1458, which limited the treatment to 1.05m high. This treatment would effectively operate in the same way as a concrete barrier but would infill the entire area behind the façade. Due to the limited height and consistent geometry of the façade, formwork can be made for the option, allowing for a poured concrete solution. Due to the same issues with reinforcement as Option 2, fibre-reinforced concrete was used to provide adequate reinforcement for the treatment, which also required support from dowels. This treatment was also required to consider the tapering requirements of Option 2 as it extended the slope face towards the road. Using this treatment significantly lowered the costs in several locations and was designated as Option 4 for treating rock snagging.

After considering potential drainage issues, including at least a 5° slope angle at the top of the structure for Option 2, 3 (where applicable) and 4 would allow for runoff to flow over the treatment while limiting the effects of erosion behind it. Typical sections depicting Options 2, 3 and 4 are provided in Figure 1, 2 and 3 respectively.

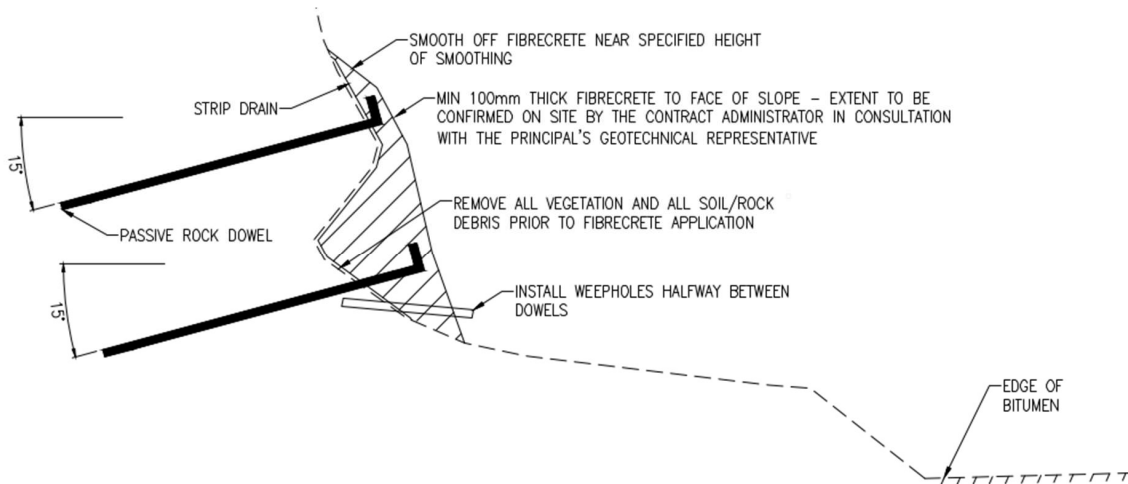


Figure 1: Typical section of Option 2.

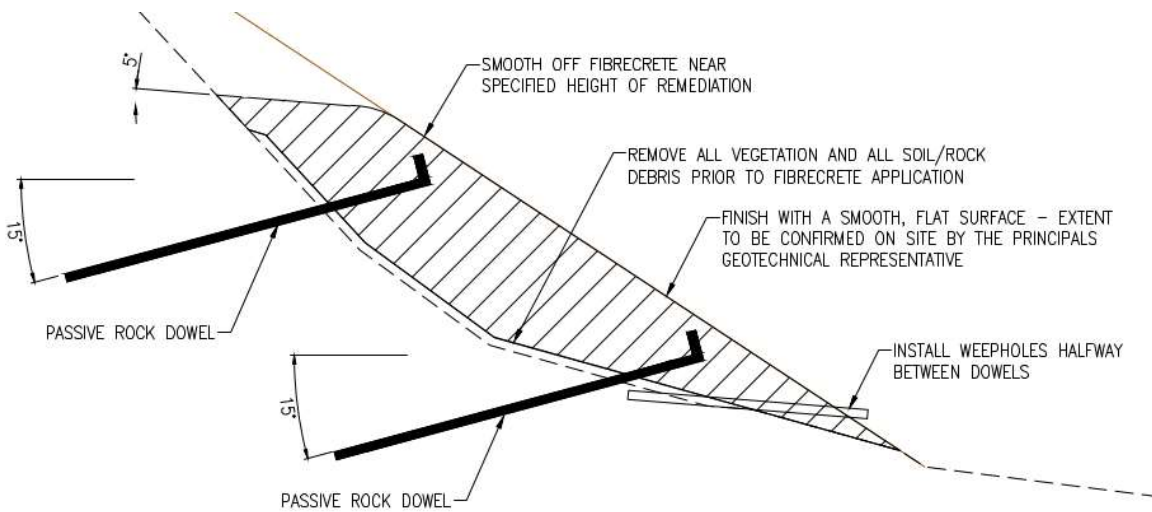


Figure 2: Typical section of Option 3.

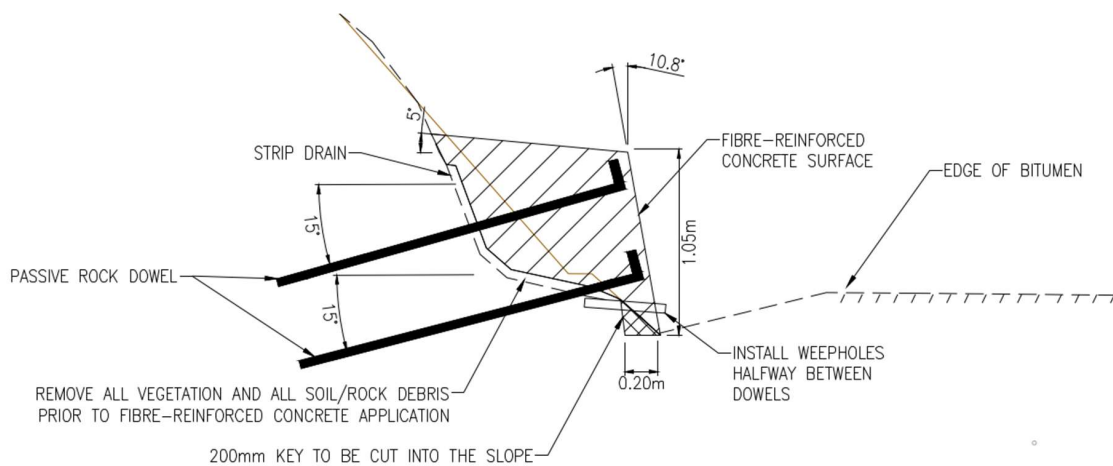


Figure 3: Typical section of Option 4.

6. CASE STUDY: HERVEY RANGE DEVELOPMENTAL ROAD

Hervey Range Developmental Road (83A) is a two-lane, two-way single carriageway rural road connecting Townsville to Hervey Range and outer suburban residential areas such as Alice River and Rangewood. As part of a safety upgrade program along Hervey Range Road, identification of rock snagging locations and design of value for money smoothing solutions were required to be undertaken due to the need for widening of the sealed road alignment and the proximity of the existing rock cuttings relative to the road. By applying the assessment methodology provided in Section 4, twenty-two (22) locations were identified that needed rock snagging treatments using the options provided in Section 5.

The basic parameters such as height and length can be estimated with 2D analysis and site imagery (i.e., DVR and Google Earth), but by utilising 3D assessments the tolerance at multiple locations could be assessed rapidly with more accurate information. The increase in accuracy also allows for better estimation of the slope and treatment heights, slope coverage, surface area and volume of materials, which is useful for generating a more cost-effective design. An example of which can be shown in Figure 4, where the dark areas on the slope correspond to depressions, with the light area in the depressions being greater than 600mm away from the design surface.

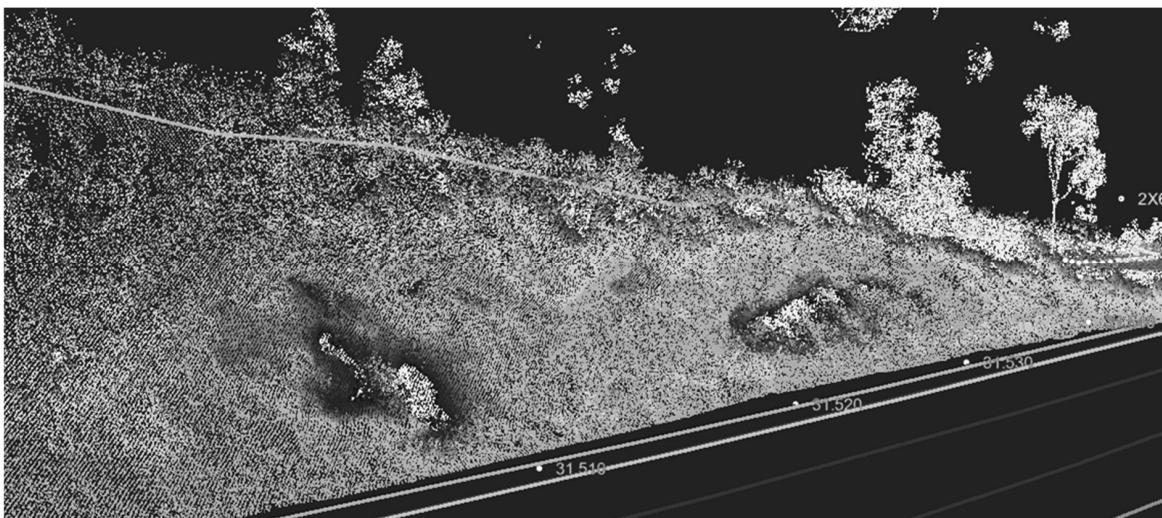


Figure 4: Example of 3D assessments from Ch. 31505 to 31535

Options were assigned based on the construction limitations and cost-effectiveness, which was performed by calculating the cost of the volume of material and considering the addition of other elements like dowels. Each option would result in varying thicknesses and the calculations of components like dowel length were dependent on the option chosen due to changes in parameters (i.e., average thickness and surface area). Table 2 outlines the chosen option for each location, as well as some basic information in regard to the slope.

Table 2: Designation of Options for Identified Rock Snagging Treatment Areas

Start Chainage (km)	End Chainage (km)	Height (m)	Length (m)	Angle (°)	Average Thickness (m)	Suggested Treatment
27.441	27.449	0.80	8.0	46	0.25	Option 1
27.449	27.454	0.96	5.0	40	0.20	Option 1
27.572	27.618	1.05	46.0	64	0.40	Option 4
27.869	27.953	1.00	84.0	44	0.45	Option 4 ^a
28.101	28.120	2.00	19.0	56	0.15	Option 3
28.477	28.519	1.05	41.6	46	0.25	Option 4
28.663	28.695	1.05	31.8	48	0.55	Option 4
28.718	28.726	1.00	8.0	26	0.70	Option 3

Start Chainage (km)	End Chainage (km)	Height (m)	Length (m)	Angle (°)	Average Thickness (m)	Suggested Treatment
28.897	28.915	0.58	18.9	47	0.15	Option 2
28.925	28.963	2.00	38.5	48	0.35	Option 4 ^a
29.165	29.258	2.00	93.0	57	0.40	Option 4 ^a
29.495	29.548	2.00	53.0	55	0.40	Option 4 ^a
29.645	29.656	1.00	11.0	35	0.35	Option 2
29.977	29.999	1.05	22.5	57	0.25	Option 4
30.130	30.145	1.05	15.0	60	0.40	Option 4
30.145	30.152	2.00	5.0	60	0.30	Option 2
30.232	30.262	1.05	30.0	47	0.55	Option 4
30.262	30.335	1.05	73.0	60	0.40	Option 4
30.360	30.418	1.05	57.5	55	0.45	Option 4
30.464	30.525	1.05	61.0	52	0.35	Option 4
31.505	31.535	1.05	30.0	46	0.40	Option 4
31.731	31.752	1.05	20.6	50	0.35	Option 4

^a Scaling or splitting is required prior to implementation of the suggested treatment.

By scrutinising the results in Table 2, some trends can be noticed in the application of options:

- Option 1 was able to be applied due to the limited height of the slope and the rock snags being solely supported by a soil matrix.
- Option 2 is effective on slopes with lesser thickness, limited height, or relatively flat slope angles. Being a spraycrete, its application is versatile but more costly when considering the volume of material applied in comparison to the poured concrete of Option 4.
- Option 3 is limited by the presence of protrusions, but it is extremely effective at targeting shallower depressions regardless of the height at which they occur. Depending on the position of the depression, Option 3 is also able to out-perform Option 4 where thicker applications of concrete are required.
- Option 4 is the most adaptable option with the height of the slope not affecting the volume of material needed. The only instances where Option 4 is outperformed is where thinner applications of material are applied to steeper slopes, or on shallower slopes where a significant amount of material is required to infill behind the façade.

7. CONCLUSION

While rock snagging was initially poorly defined yet still considered a safety hazard, the combination of publications from different transport authorities allowed for quantitative and qualitative definitions to be provided. This allowed for the methodology to be combined with design considerations to provide treatment options for real-life application. This in turn allowed for the calculation of the most cost-effective option, which was best performed by including 3D assessments with conventional 2D analysis. This was due to 3D assessments helping better identify parameters for effective cost-estimation and also simplifying the identification of potential rock snagging hazards. As such, the definitions and methodology in this paper are considered not only feasible but effective at assessing the different design aspects required to treat rock snagging hazards.

8. ACKNOWLEDGEMENTS

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