# GUIDELINES FOR MINE HAUL ROAD DESIGN

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# Preface

The idea of developing a haul road manual or collection of guidelines was initiated by the late Professor Muirhead at the University of Alberta in 1999. Support and financial contributions for this work were obtained from NSERC, SMART (Surface Mining Association for Research and Technology) ATCO Power, and Finning. Both Syncrude Canada Ltd. and Suncor Ltd. provided access to road design data and methodologies. Syncrude Canada Ltd.'s internal reports were instrumental in verifying the strain-based design approach for haul roads that is advocated in this manual.

Two closely related documents form a basis for this manual. The oldest is the report by Kaufman and Ault (1977) entitled *Design of Surface Mining Haulage*. Monenco (1989) took the Kaufman and Ault report and updated it to reflect conditions relevant to Canadian mines. The Monenco report is unpublished and difficult to obtain. The questionnaire survey that is found in the Monenco report was repeated in 1999 for this document.

Content from the M.Sc. thesis by Kumar (2000) is also used in this document, especially in sections dealing with design of a haul road cross-section. Bruce Regensburg put together the section on haul road economics. In addition, haul road design issues were also gathered from various published sources that are referenced in these *Guidelines for Mine Haul Road Design*.

This manual is not meant to be comprehensive, rather it is intended to cover most of the issues important to haul road design for rear-dump trucks that have payloads greater than about 200 tonnes. This document is meant as an aid to Mining Engineers, Geotechnical Engineers and Management to construct quality haul roads. Haul road design is usually the product of a plan from the Mining or Civil Engineer with construction specifications from the Geotechnical Engineer. The Mining Engineer will work on the geometric parts of the haul road including vertical and horizontal curves, widths, super-elevation and location of the road while the Geotechnical Engineer will provide the material specifications and placement criteria.

Good haul road construction and maintenance practices are a key part of operating a cost-efficient fleet of trucks. Haul roads should be considered an important asset to a mining operation, in the same manner as trucks and shovels.

While much effort was expended to verify equations, graphs, and tabular data adopted from other sources, errors may have been missed. Therefore, users of this document are encouraged to contact the authors if errors are discovered. This will enable the first version of this manual to be improved and will allow it to evolve to better meet the needs of the mining industry.


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## EXECUTIVE SUMMARY

A common element of every surface mine that uses haul trucks is the construction of haul roads. These haul roads tend to be the lifeline of the production system and road problems will immediately impact on the productivity and/or costs of the mine.

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### Mine Survey Results

A questionnaire was sent to 37 Canadian mines requesting information on mine equipment used, method and procedures for road construction, and road maintenance procedures. Replies were received from 13 mines. These mines had a total of 50 km of in-pit roads with an average life expectancy of 1.4 years and 100 km of ex-pit roads with an average life expectancy of 8 years. Equipment used by these mines included cable and hydraulic shovels and haul trucks ranging in capacity from 35 tons to 360 tons.

The geometry of the haul roads varied as to the size of haulage trucks used. Maximum road grades tended to be 8% to 10% with the lower value being favoured. Super-elevations were limited to a maximum of 4% and road crowns varied between 1.5% and 4% with 2% being considered the best.

Haul road construction materials ranged from mine waste through to crush stone and, in some cases, geotextiles.

Haul road deterioration resulted in potholes, rutting, settlement, wash-boarding, and frost heaving. Damage was caused mostly by precipitation/runoff, heavy traffic volume, spring breakup, and poor compaction. Vehicle spillage was another major road problem.

Major maintenance activities were in the area of grading, plowing/scarifying/sanding and resurfacing. Dust suppression was mainly accomplished with water sprinkling (100%), calcium chloride (27%) and oil sprinkling (9%).

### Haul Road Alignment

Road widths are usually designed to be 3 to 4 times the width of the largest haulage unit (for 2 way traffic) with extra width employed on the curves. Horizontal curves are designed to ensure the driver of the haul truck can negotiate the curve safely at a given speed. Super elevations and their transitions are designed to minimize the centrifugal

forces on the haul truck while negotiating the curve. Super-elevations should be in the range of 4% to 6% depending on the curve radius and equipment speed.

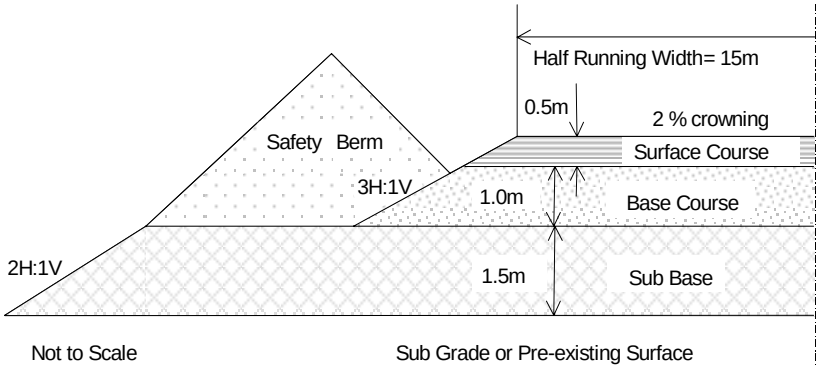
In the design of both horizontal and vertical curves, line-of-sight and stopping distance are key design criteria. Curves are designed so that the line-of-sight of the driver is equal to or longer than the stopping distance of the haul truck.

Grades (steepness) usually vary from –20% to + 20%. However, grades over 10% are used only for short distances in temporary situation. Haul road grades are usually dictated by mine plans and economics. The preferred maximum grade appears to be 8%.

Other salient points of road alignment are as follows:

- Sharp horizontal curves should not be designed at the top or bottom of hills.
- Intersections should be located at flat, straight alignments of the haul road.
- Road surface cross-slopes should be approximately 1:25 (4%) for good drainage
- Curve radii should always exceed the minimum turning radius of the equipment.

## Haul Road Design




Typical haul road cross-section.

A haul road cross-section can be divided into four distinct layers, namely sub-grade, sub-base, base course and surface or wearing course. The sub-grade is the existing ground surface on which road fill is placed. The sub-base, base course and surface course are layers of fill of increasing quality that are successively placed above the sub-grade to form the embankment fill.

*Sub-grade:* The sub-grade can consist of native in-situ soil or rock, previously placed landfill or mine spoil, muskeg, marsh or other existing surface over which a road is to be placed. Where the sub-grade comprises hard, sound rock or dense, compact gravel, little or no fill may be necessary as haul trucks can travel on the sub-grade surface. At the other end of the spectrum, soft clays and muskeg will require substantial quantities of fill to help spread the heavy wheel loads and prevent rutting, sinking or overall road deterioration. Such adverse conditions, if allowed to occur, pose a serious threat to vehicular controllability and create unsafe haul road segments. If the sub-grade lacks the

required bearing capacity, then it needs to be altered through suitable measures such as compaction or the use of geotextiles.

*Sub-base:* Sub-base is the layer of a haul road between sub-grade and base course of the road. It usually consists of compacted granular material, either cemented or untreated. Run of mine and course rocks are the general components of this layer. Apart from providing structural strength to the road, it serves many other purposes such as preventing intrusion of sub-grade soil into the base course and vice-versa, minimizing effect of frost, accumulation of water in the road structure, and providing working platform for the construction equipment.

*Base course:* The layer of haul road directly beneath the surface course of the road is called the base course. If there is no sub-base then the base course is directly laid over the sub-grade or roadbed. Usually high quality treated or untreated material with suitable particle size distribution is used for construction of this layer. Specifications for base course materials are generally considerably more stringent for strength, plasticity, and gradation than those for the sub-grade. The base course is the main source of the structural strength of the road.

*Surface course:* The uppermost layer of the haul road that comes directly in contact with tires is known as the surface course. A haul road surface is generally constructed with fine gravel with closely controlled grading to avoid dust problems while maintaining proper binding characteristic of the material. Apart from providing a smooth riding surface, it also distributes the load over a larger area thus reducing stresses experienced by the base course.

The design of the road can be optimized by using the California Bearing Ratio (CBR) or a newer method based on a critical strain criterion and the construction material's resilient modulus. In both cases an understanding of haul truck tire interactions is necessary. Recent work in Australian coal mines and Syncrude Canada Ltd's oil sands mines indicate the designs based on a critical strain criterion (maximum vertical deformation) are better than CBR designs for haul roads.

## Road Surface

When designing the surface layer of the road, the two major concerns will be the adhesion to the road and the rolling resistance.

Adhesion is important from a safety aspect of keeping the haul truck from sliding off the road and rolling resistance is important from the aspect of truck speed and productivity. Another consideration is the "dusting" properties of the surface material. If the material is easily broken down by traffic or naturally has an abundance of loose fines then dust suppression will become a major road maintenance factor.

When considering surface material for construction of haul roads, the following types of material can be used:

- Compacted gravel

- Crushed stone
- Asphaltic concrete
- Roller compacted concrete (RCC)
- Stabilized earth

Adhesion of the equipment to the road is a major safety consideration and materials that maintain good traction in wet or freezing conditions are desirable.

Rolling resistance in surface mines can vary from 1.5 % to 20+% depending on the quality of the roads. Roads that afford rolling resistances of less than 3% result in haulage equipment working at its ultimate capacity whereas rolling of resistances of above 20% can bring some types of haulage equipment to a complete stop. Using the right materials and construction methods for road surfaces can decrease the rolling resistance significantly and result in increased productivity and lower costs.

Another safety and environmental hazard caused by road surface is the "dusting" problem. Roads should be designed with enough fines to act as binders for the larger particles. However, an excess of fines will result in these particles being released to the atmosphere when repeated stress is applied by the equipment tires. All haul roads that do not have a "sealed" surface, will create dust. The dust problem is mainly dealt with by application of water. However, some mines use calcium chloride or oil mixtures to reduce the dust. Research is ongoing in this area to find a better solution to the problem.

## Haul Road Economics

Haul road construction is a necessary cost in all surface mines that use mobile equipment. The cost of haul road construction varies in different types of mines and even from mine to mine in the same industry. Hard rock mines tend to have an abundance of sub-base and base materials, while soft rock mines must select good in-mine material, import or manufacture these materials. In almost all mines, materials for the surface layer must be imported and/or manufactured.

Haul roads can be classed from a quality point of view into the following categories

Temporary Roads
- Short life
- Minimum thickness
- Low specification material
- Inexpensive to build
- Used mainly for shovel or dump access

Semi-Permanent Roads
- Medium life
- Engineered to desired thickness
- High specification material
- Relatively expensive to build
- Used for main haul roads in pits and out-of-pit hauls in non-final pit walls

Permanent Haul Roads

- Long life
- Engineered to ultimate thickness
- High specification material (may even be paved)
- Expensive to build
- Used for final out-of-pit haul roads and roads on surface

The economics of haul road construction is much more complicated than just calculating the cost of road construction. For a true understanding of haul road economics, **full life-cycle costs** must be considered.

Included in the life cycle costs of a haul road are the following items:

- Road construction costs
- Road removal costs
- Impact on productivity of the fleet
- Differential road maintenance costs
- Extra fleet operating and maintenance costs
- Extra stripping costs
- Time value of money

When considering the quality of the road to construct, the most important items are:

- Life of road
- Use of road (amount of production over the road)
- Location of road (is it permanent or does it have to be removed?)

In most mines, road construction practices are based on previous practices rather than economics. In many cases, previous practices have produced cost effective roads since they are based on experience and judgmental (empirical) background. For instance, mines tend to place temporary roads (low cost construction) to shovel faces, semi-permanent roads (medium cost construction) for main in-pit haul roads and permanent (higher cost construction) for out-of-pit haul roads. From a "time of use" perspective, this may make sense since economic analysis of haul road construction would indicate the same choices. However, the road type selection may not be optimized without a true economic evaluation.

## Summary

This manual is designed for the engineers and management who are involved in design, construction and maintenance of roads. Information available within the manual is based on existing reports, empirical data and geotechnical theory.

For further information or to purchase a copy of the Guidelines contact:

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