

APPENDIX 4-5: HAULAGE METHOD SELECTION AND HAUL ROAD DESIGN

4-5.1 HAULAGE METHOD SELECTION

In aggregate quarries, haulage from the face to the processing plant is generally achieved through either conveyor systems or using dump trucks travelling on haul roads (or a combination of both). Conveyors are generally more commonly found in sand and gravel quarries although, increasingly, in-pit crushing and conveying systems are being installed in hard rock quarries. The following table provides key considerations for a number of important selection criteria to assist in selection of an appropriate haulage method to incorporate in design.

SELECTION CRITERIA	CONSIDERATIONS RELEVANT TO CONVEYOR SYSTEMS	CONSIDERATIONS RELEVANT TO DUMP TRUCKS
Site characteristics		
Site Geology	Suitable for homogeneous mineral not requiring selective excavation and haulage.	Provide flexibility where there is variable geology requiring selective excavation and haulage of different grades of mineral and non-mineral from multiple faces.
Haulage distance	Suitable for sites where long haulage distances would require additional trucks to maintain production rate.	Favoured for shorter haulage distances.
Operational life of site	High capital costs and therefore operational life must be sufficiently long to recover those costs.	Favoured if short operational life.
Design		
	Efficient design and planning of operation needed to minimize conveyor realignment during the operation and optimise conveyor length.	Allows more flexible phasing and working arrangements.
	Traditional straight conveyor alignments will minimize transfer points (expensive and requiring power supplies and regular maintenance). Curved and steep (to vertical) conveyor systems are available.	Truck haulage allows a more flexible design to accommodate space limitations in many small pits.
	May reduce requirement for and maintenance of haul roads including access by dump trucks to working areas (but access roads to all parts of the excavation are still required for inspection, management and maintenance).	Dump trucks require planned and maintained haul roads to excavation area.
Operational		
	Generally suitable for material up to 300mm. Ideal for sand and gravel. A mobile primary crusher is usually located at the conveyor head in hard rock quarries.	No specific size restrictions beyond size capacity of truck.
	Life expectancy >15 years.	Life expectancy c 7-10 years.
	Steep (to vertical) and curved conveyor systems now available (but access roads to all parts of the excavation are still required for inspection, management and maintenance).	
	Initial capital costs may be greater than trucks but annual operating costs lower. Minimal personnel requirements.	Capital costs vary and may be as high, or sometimes higher, than conveyor. Leasing or contract hire common. Annual operating costs including labour costs, training, maintenance, fuel <i>etc</i> are high.
	Predictable maintenance requiring little space and small number of fitters.	Maintenance requirements less predictable as wear and tear not easily controlled. Requires space for maintenance. Robust operating rules and well designed and constructed haul roads can significantly reduce wear and tear.
	Electricity – vulnerable to loss of supply. Potential for local generation (<i>e.g.</i> landfill gas).	High fuel usage – potential for biodiesel and technological developments.
	Operate in most weather conditions, although covered conveyors may be needed for material that becomes difficult to handle when wet.	Poor weather conditions may affect haul roads and interrupt production.
	Extended hours of working possible – poor light conditions/after dark when dump trucks cannot operate safely. Excavation area only needing floodlighting.	Generally unsafe to operate after dark or in poor light conditions.

SELECTION CRITERIA	CONSIDERATIONS RELEVANT TO CONVEYOR SYSTEMS	CONSIDERATIONS RELEVANT TO DUMP TRUCKS
Environmental		
	Continuous low level noise – may be reduced by housing. May argue for extended working hours since noise impact on nearby properties decreased.	Noise from trucks greater than that from conveyors and varies at any static receptor as the trucks move in relation to that receptor. Audible reversing alarms can cause intrusive noise where fitted.
	Minimal dust emissions - reduced by housing. Electrically powered – no exhaust emissions.	Dump truck movements on haul roads and loading activities are a major source of dust in quarries. Emissions from diesel fuel.
	Potentially less disturbance of ground and habitats by overland conveyors. Eliminates disturbance from regular dump truck movements.	Haul roads and large vehicles have significant ecological and visual impact, particularly on otherwise undisturbed or restored ground.
Health and safety		
	Eliminates most accidents involving mobile plant.	High proportion of quarry accidents involve dump trucks.
	Risk of injury during maintenance and blockage. Safety systems governed by regulations and legislation.	Risks from whole body vibration syndrome from driving on uneven ground.

4-5.2 DESIGN AND ROUTING OF ACCESS AND HAUL ROADS

The quarry design and site layout should consider all vehicle routing and site roads from the entrance and parking areas to the working benches and pit floor. An inadequately designed road may limit the future selection of plant on a site. The roads must be suitable for the anticipated vehicles and traffic volume at all stages of the life of the quarry. Site roads may be used by one or more of the following at the same time:

- Laden and empty dump trucks
- Other mobile plant e.g. excavators, dozers etc.
- Laden or empty road-going trucks including customers' vehicles.
- Maintenance vehicles and other smaller vehicles operated by the site, contractors or other visitors.
- Pedestrians – including site personnel, contractors and visitors.
- Mineral conveyors.

Haul roads and site roads must be designed for the three criteria of safety, cost effectiveness and environmental acceptability. Regulation 13 of the 1999 Quarries Regulations and Approved Code of Conduct requires that operators ensure, so far as is reasonably practicable that:

“(a) benches and haul roads are designed, constructed and maintained so as to allow vehicles and plant to be used and moved upon them safely; and

“(b) where necessary, effective precautions are taken, by the installation of barriers or otherwise, to prevent vehicles or plant accidentally leaving any bench or haul road.”

The guidance associated with this Regulation is as follows:

“106 The proper design of benches and haul roads is essential. They must be suitable for the type and size of machinery and loads used on them. Vehicles must be able to move safely and without risk of accidentally leaving the bench or from any instability of the face or bench. The operator also needs to consider the effect of vibration on the bench or haul road from any use of explosives.

“107 The minimum width of the bench and the type of machinery which can be safely used on it should be considered during the design, appraisal and, where appropriate, the geotechnical assessment of the excavation or tip. They should be reviewed as the working methods and excavation or tip develop. Benches need to be wide enough for the type and volume of traffic using them and take account of the traffic systems in force, for example one-way systems.

"108 Benches and haul roads must be designed to avoid dangerous sharp bends and gradients. They must also be maintained so that they do not develop bumps, ruts or potholes which may make control of vehicles difficult or cause health problems due to whole-body vibration.

"109 Regulation 17 of the Workplace (Health, Safety and Welfare) Regulations 1992 (the Workplace Regulations), which applies to quarries, deals with the organisation etc of traffic routes. Operators must take the regulation and relevant sections of the Approved Code of Practice into account when making arrangements to comply with regulation 13 of the Quarries Regulations. The design and construction of traffic routes inside buildings is also covered by regulation 12 of the Workplace regulations."

Edge protection on roads is the subject of the Approved Code of Practice and related guidance associated with regulation 13 (paragraphs 110-117). The subject of edge protection is considered in more detail below.

The requirements of regulation 13 are aimed at minimizing the risk to personnel. However the design and maintenance of good quarry roads may have significant operational, and therefore financial, benefits for the operator from reduced wear and tear on plant and maintaining a smooth and efficient haulage cycle.

The principal considerations for the quarry designer are the method of construction, safe operation and environmental impacts of the haulage system.

4-5.2.1 Construction

The quarry design should reasonably aim to minimise the volume of mineral sterilised by the haul roads. In shallow or very large sites, initial temporary ramps excavated in the mineral may be replaced by ramps constructed from compacted quarry waste or other fill material during the progress of the operation so that no mineral is sterilised. In deeper, hard rock quarries, this may not be feasible (lack of sufficient fill material or insufficient space) and the pit floor may, in some cases, be accessed by a single spiral haul road.

Construction practices can be critical to the security of haul roads. For example, poor blasting practices may leave bench edges with loose or broken material unsuitable for supporting a road or edge protection, such that a road which 'on paper' might appear appropriate, is compromised by poor construction. Assessment of such risks, and recommended prevention (control) measures should be included in the design report prepared for the quarry safety file.

The stability of the slopes above and below the haul road must be included in the geotechnical analysis of the proposed quarry faces.

4-5.2.2 Safe and efficient operation

Gradient and vertical alignment

The gradient of the haul road must be appropriate for the number, size, type and load of vehicles using the road. The HSE advises that, for rigid bodied vehicles, roads should be designed no steeper than 1 vertical in 10 horizontal (ref). Steeper road gradients may be acceptable over short distances under some circumstances where suitable vehicles are in operation.

Among the hazards of steep, poorly designed (or constructed) haul roads with potentially fatal consequences are:

- The stopping distance of a vehicle travelling down a steep haul road may exceed the forward visibility such that an accident with an oncoming vehicle cannot be avoided.
- Vehicles may be travelling downhill at speeds which exceed the breaking capability of the vehicle.
- The handbrake may not be effective when parked on a steep slope.

These are exacerbated if the vehicle is laden. If the road is rutted, slippery, soft or uneven, the risks of losing control or tipping are greater if the road is steep. Poor road design may lead to the imposition of restrictive speed limits on steep sections of roads, which may then affect the productivity of the site. Speed limits must be included in the quarry health and safety document (Mines and Quarries Regulations 1999 Regulation 14) and must be suitable for the vehicle braking capabilities, loads, road gradient and site conditions.

Steep gradients lead to reduced speed limits and slower uphill journeys, particularly if laden. As a consequence, haulage cycle times are reduced and productivity may be affected unless additional plant is used (at considerable increase in cost). Maintenance and repair costs of vehicles are increased because of greater wear and tear – particularly of breaks.

(Superelevation)

Route and layout

The principal function of the quarry roads is to get the mineral and non-mineral from the quarry floor to the processing plant, stockpiles and tips, and from there to the site entrance. The quarry operator wants to achieve the haulage cycle from the pit floor in the shortest possible time in order to maximise the production rate. Roads may also serve maintenance areas, offices and welfare facilities, employees and visitors parking areas, restored areas under maintenance. The selected road layout needs to accommodate the economic requirements alongside safety and environmental considerations. Some of the considerations when deciding on the route of the main haul roads are:

- Slope stability and rockfall risk. Avoid areas at risk, mitigate – slope design, rockfall protection measures (catch ditch, netting or rock bolts).
- Head on vehicle collisions – maintain sight lines within the stopping distance of the vehicles using that road.
- Vehicles leaving bench – minimise sharp bends
- The environmental impact of alternative routes
- The road usage and in particular potentially dangerous crossing points
- Single or 2-way routes – a one way traffic circulation system is always safer than a 2-way system but may sterilise more mineral and require more space in the pit.
- Minimise reversing – design of tips, loading and tipping areas, parking areas, plant, adequate road width
- Horizontal alignment
- Horizontal curves should be designed so that:
 - Adequate sightlines are maintained to within the vehicle stopping distances.
 - Vehicles can negotiate the bends safely at the speed limit. Curve radii should be greater than the minimum turning radius of the vehicles.
 - Hazardous bends are avoided. Where tight bends are unavoidable, for example switchback road in a quarry with limited space, the design should adequately mitigate the risks of a vehicle leaving the carriageway on the bend. Some of the design solutions are shown in Fig. *

Road Width

HSE guidelines (ref) (ref Quarry fact file) state that the width of the carriageway should be at least 2 times the width of the largest vehicle to use the road. For a 2-way road, the running width should be 3.5 times the maximum vehicle width. This is to ensure that the vehicles can safely and confidently use the road without undue speed changes. The one-way carriageway width is not wide enough to allow two vehicles to pass in the event of breakdown. An additional width of 1.5m would allow the haul road to continue being used in the event of this happening.

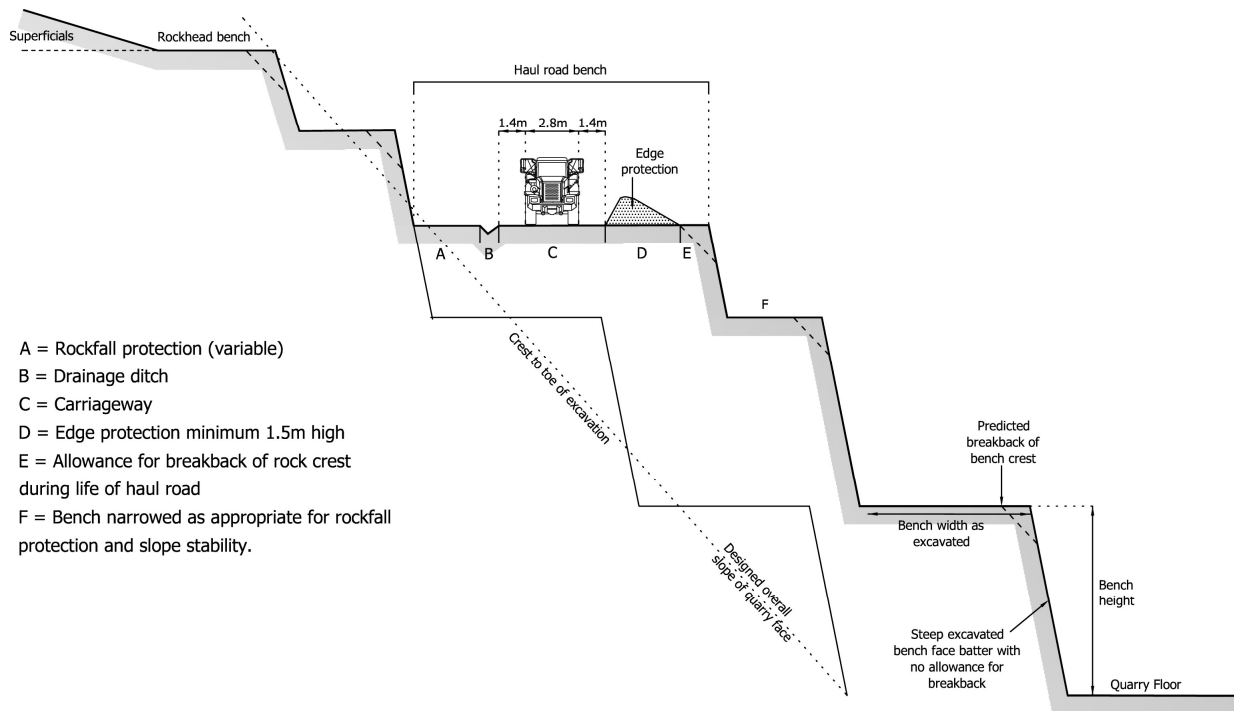


Figure 1: Design principles for haul roads incorporated in benched quarry slopes

In addition to the carriageway, the quarry road may also need to accommodate:

- Minor debris falling from the face immediately above the road and collecting at the base of the face. Rockfall protection measures may be required including a rockfall catch ditch, although risk from rockfall should be minimised by considering alternative routes.
- Drainage
- Edge protection (see below)
- Allowance for breakback of the bench crest during the life of the road. The amount of breakback will depend on the geotechnical character of the face.
- Additional width on bends to accommodate the circular clearance diameter of the vehicles.
- Additional allowance on busy roads for pedestrian routes. Pedestrians should, where possible, use different routes or be separated from the carriageway by a barrier.

Figure 1 illustrates how the width of the bench carrying a quarry haul road suitable for dump trucks might be determined as part of an overall slope design by the quarry designer.

A comprehensive design manual published by the US Bureau of Mines in 1977 (ref) includes recommendations for the design of all aspects of surface mine and quarry haul roads, much of which is still very relevant today.

Edge Protection

The Quarries Regulations 1999 (Regulation 13 (b)) states that 'where necessary, effective precautions are taken by installation of barriers or otherwise, to prevent vehicles or plant accidentally leaving any bench or haul road.' This applies to any area of the site, including tips, areas around water bodies etc. The design of haul roads and working areas must provide sufficient space for adequate edge protection. Guidance on the design, construction and maintenance of suitable edge protection is given in the HSE Approved Code of Practice (ref). The aim of edge protection is to 'stop the largest, fully loaded vehicle crossing it when travelling at the maximum foreseeable speed'. In practice in most situations, a vehicle will impact the edge protection and be

deflected back onto the road by the structure. The critical factors which must be considered during quarry design are;

- Edge protection should be constructed as continuous bank of unconsolidated quarry scalplings or similar material. Compacted material will not absorb the impact of a vehicle, which may ride over the structure. Narrow gaps may be left for drainage. Alternatively crash barriers are occasionally used where space is limited. Lines of rocks are not suitable.
- The minimum recommended height is 1.5m or half the height of the largest wheel using the area, whichever is the greater. The inside slope (impact face) should be constructed and maintained as steep as possible. A typical bank occupies 4-5m of bench width.
- Higher protection (and therefore a greater width of bench to accommodate it) may be needed in areas where a greater risk of vehicles running through the edge protection are identified – for example at bends where the vehicle may approach at a greater angle.
- The bank (or crash barrier) must be constructed on firm ground. Loose, unconsolidated fill or a broken bench crest may give way and compromise the performance of the edge protection. It is advisable that an additional allowance is made on the outside of the edge protection bank for break back. The allowance will depend on the geotechnical analysis.

Surfacing

Design and maintenance of a good haul road surface

- Reduce vehicle wear and tear
- Minimise whole body vibration syndrome
- Minimise dust emissions from the surface
- Allow the designed maximum speed limits to be maintained

The type of surface will depend on the volume and type of vehicles using the road and on the specific site conditions, the anticipated life of the road and environmental considerations including proximity to residential properties. A particular surface may be recommended as part of the design if particular conditions or users are anticipated, for example access to pit floor by customer's vehicle will require a well maintained road with a smooth surface. The monitoring, maintenance and treatment of road surfaces to minimise dust and physical injury should be included in the Environmental Statement and in the site safety file.

Drainage

Surface water run-off may damage the road surface and cause erosion of the benches if drainage measures are not well designed, maintained or of sufficient capacity. The management and treatment of surface water run-off must be considered as part of the quarry design and environmental assessment processes.