Chapter 25

CONSTRUCTION

25.1 INTRODUCTION

Chapters 25 and 26 are intended to identify major problems commonly encountered in hill road construction and maintenance in developing countries. Broad outlines of the problems; suggestions concerning construction and maintenance practices in the context of environmentally conscious and cost-effective concerns; basic concepts on contract, specifications, and maintenance types; and pavement distresses and condition evaluations have been briefly discussed in this part. Overlay design methods for periodic maintenance of paved roads have been presented in Chapter 18 on Pavement Design in Part I of this Handbook.

Construction and maintenance planning, management, and contracting is a vast area which has many problems and solutions unique to the country and the project locations. It is not possible to address all these conditions in great depth in this manual. However, the material presented is expected to provide some insight into the key issues of construction and maintenance of hill roads.

The materials presented in this part are based on the American Association of State Highway and Transportation Officials (AASHTO) Pavement Design Guide 1985, lecture notes from the University of Washington, Pavement Design lectures, CETS 599-C autumn quarter, 1986 by Dr. Joe Mahoney, the Department of Civil Engineering, and the author's experiences with hill road construction and maintenance in Nepal.

25.2 PROBLEMS

The majority of road construction problems are associated with the shortcomings of feasibility studies and designs. However, considerable problems result from (i) improper planning, design, and enforcement of construction programmes; (ii) contracting methods; (iii) contract types; (iv) specifications; (v) construction estimates; (vi) construction operations; (vii) quality control; and (viii) historical records. Some of the problems are briefly discussed below.

25.2.1 *Project Cost Estimate*

The constructed costs of hill roads, in many instances, exceed hundred per cent of the original estimates. Major causes of variation are changes in objective or scope of work, extra work due to exposed site conditions, price escalations, fund constraints, and contractual problems. Hill road projects in developing countries span over a long time period and are accompanied by several problems associated with remote and difficult site conditions. Obviously, they involve several uncertainties that are difficult to account for in the project design. However, for major projects these uncertainties, if not recognized, give rise to unsound decisions that may lead to considerable risk to both the investment and the environment.

Engineering-geological, hazard-based designs and constructions help to minimize the risk of human-induced landslides and road failures. Minimizing economic risks involves rigorous investigation and analysis of cost variables and a sound approach to construction planning and management practices.

25.2.2 *Construction Cost Estimate*

The contractor's bid price is seen to vary from the owner's cost estimate by 50 per cent on the lower side to 10 per cent on the upper side. Exceptionally high rates are also possible sometimes when time constraints and uncertainties are very high.

25.2.3 *Construction Time*

Normally, in Nepal, 5 to 20 kilometres of hill road can be completed in one year. Rainy seasons and festivals in some countries reduce the net working time to 7 to 8 months in a year.

25.2.4 *Construction Planning, Administration, and Management*

The successful implementation of any project depends upon the quality of construction planning, administration, and management. Construction contracts are often associated with:

- unrealistic target setting,
- poor performance of contractors,
- too many conditions in the specifications (entire contract document, including general conditions of contract and technical specifications) and drawings, without properly accounting for them in the pay items under the schedule of quantities, and
- delays in owner's response to contractor's claims and change orders.

Public agencies, in developing countries, need to devote serious efforts to the planning, management, and administration of construction works. The contract industry is primarily labour intensive. Equipment procurement, owning, operating, and maintaining are complicated by limited choices, procurement regulations, uncertain work volume, lack of trained manpower, and the fact that professionalism in contractors is not well developed.

25.2.5 *Environmental Considerations*

Uncontrolled quarrying, indiscriminate side-casting, and indiscriminate rock blasting lead to destabilization of hill slopes and consequent landsliding. This influences the cost of maintenance and rehabilitations, land use patterns, and the safety of traffic users and local inhabitants. The indiscriminate cutting of trees for construction camps, fuelwood for construction labour, and timber for construction materials increase deforestation, erosion, and gullying. Design specifications and pay items do not traditionally provide for these considerations.

25.3 GUIDELINES

Except for the minor roads defined in Chapter 21, the following considerations are suggested for hill roads.

- Review the project feasibility study, designs, and cost estimates. Revise the project estimate on the basis of actual site conditions and the timing of the project.
- Plan the construction targets projectwise and yearwise with respect to project goals.
- Review the manpower and the construction administration and management capacity of the owner.
- Estimate construction materials and equipment needed for the whole project and annual progress.
- Prepare a procurement schedule for construction, local material and equipment, and material and equipment to be imported giving due regard to existing procurement regulations and capabilities.
- Assess the capabilities of local and potential international contractors.
- Decide upon the contracting method (Section 25.3). Decide upon the contract type (Section 25.4).
- Prepare construction contract packages.
- Prepare the contract packagewise with a detailed estimate giving due provision to environmental considerations.
- Prepare the contract document giving due regard to relevant owner and donor regulations and applicable specifications. Avoid general specifications as much as possible. See Section 25.5.
- Provide for environmental considerations in the bill of quantities, specifications, and drawings. See Section 25.6.
- Prequality contractors.
- Hold pre-bid conference.
- Invite bids.
- Analyse the bids thoroughly and prepare comparative statements. Hold a post-bid conference and implement the contract after the contract is signed.
- During contract implementation, maintain change order logs and schedule as well as the cost controls from the owner's point of view. The quarterly progress reports should indicate progress during the quarter, up-to-date progress, and percentage progress in relation to annual as well as total project targets. The experiences from the projects should be properly documented, analyzed, and disseminated, except for restrictive situations, so that the lessons from the project are of value to future projects of a similar nature.

25.4 CONSTRUCTION CONTRACTING METHODS

The selection of the contracting method depends upon the size of the project, the owner's capacity to supervise and manage the time for completion, and the degree of design details. The methods commonly followed in construction practices are outlined in the following passages.

25.4.1 *General Contract Method*

This method consists of a contract drawn up between the owner and a general contractor. The owner is usually represented by the firm that was responsible for the design of the contract document. The general contractor is the prime contractor and is usually specialised in works related to the project. It is generally assumed that the general contractor has unique skills that can reduce the cost of construction to the owner. These skills include the administration of construction operations, the efficient procurement of materials, the effective management of the workforce, and the thorough planning and coordination of the construction process. This efficiency is generally attributed to the fact that the general contractor maintains a staff of trained supervisors, has available trained mechanics and workers, and owns the equipment needed to perform the required work tasks. This type of contracting is mostly applied in public works which are large and require skills that are beyond the in-house capability of the owner.

25.4.2 *Separate Contracts or Piece Work Contract Method*

This is an arrangement whereby the owner takes charge of the management of the project ordinarily performed by the general contractor. The owner contracts the various portions of the work directly to several specialty contractors. This method is advisable only where the owner has a competent construction manager or construction engineer with proper authority. This method forces the owner to assume a greater risk than would be assumed with the general contract method. The extensive adoption of this method by public agencies in developing countries makes them susceptible to sociopolitical pressures, rendering project management very difficult.

25.4.3 *Design-Construct Method or Turnkey Method*

This method is like a general contract in which the responsibility for project design is also given to the general contractor. The project under this method will have a greater degree of constructability because of the scope given to the construction firm's experience to be used in the design. This method integrates design and construction functions within the firm. This method is also called a fast-tracking method because design and construction can be overlapped. In applying the method, care must be exercised to ensure that the firm has the in-house capability to design and construct. Brokering (sub-letting by the turnkey contractor) must be avoided.

25.4.4 *Force Account Method*

This is a mechanism whereby no contracts are written. The owners' workers or employees are solely responsible for the construction effort. Necessary materials, labour, equipment, and supervisors are provided by the owners. This method is not suited to large projects. Mostly routine maintenance works, small-scale works, and simple works are carried out by this method.

25.4.5 *Professional Construction Management Method*

This is a method of construction contracting in which the owner employs a construction firm to perform professional services. The professional construction manager is generally hired before any design or construction work has been done. The professional construction manager's job is to constantly review the project to see how the cost and time of completion for the project can be reduced. The professional construction manager is paid on a fee basis whereas the designers are often paid in direct relation to the cost of the construction project. This type of contracting method is advisable on large complex projects when construction expertise is needed during the design phase.

25.5 CONTRACT TYPES

Contracts may be grouped into the following types.

- o Lump Sum Contract.
- o Cost Plus - A Fixed Fee Contract.
- o Fixed Price with Escalation Contract.
- o Guaranteed Maximum Cost or Cost Plus Incentive Fee Contract.
- o Performance Incentives (Shared - Savings' Provisions) Contract.
- o Unit Price Contract.

The selection of the type of contract depends upon the size of the work, nature of the work, reliability of estimates of quantities and cost of the work, time of completion of the work, and the extent of cost controls desired by the owner.

A Lump Sum Contract is awarded when the owner knows exactly the amount of work to be accomplished and time for completion is limited to one or two years.

A Cost-Plus-A-Fixed-Fee Contract is a negotiated contract and is usually awarded when the work is of an emergency nature and the owner does not have sufficient time for advertisement.

A Fixed Price with Escalation Contract is a fixed price contract with provision for price escalation. This is awarded for projects of long duration.

A Guaranteed Maximum Cost Contract is essentially a Cost-Plus Contract where the contractor agrees to guarantee that the cost will not exceed a stipulated sum. This type of contract is intended to provide an incentive to the contractor to hold the costs down, since the unlimited cost-plus agreement may result in a large increase in the cost of construction.

The Performance Incentive type of contract provides flexibility to cope with changed conditions. It also provides the owner with some protection against cost overruns. A target price is fixed by the agreement. The target price is made up of the actual cost to the contractor for doing the job plus a variable fee for head office, related business expenses, and profit. The fee is decreased if the final cost exceeds the target price and is increased if the final cost is lower than the target price. The increase and decrease in fee are expressed in a percentage of the underrun and overrun and are fixed by the agreement. The percentage increase in fee for underruns is usually much higher than the percentage decrease in fee for overruns.

25.5.1 *Unit Price Contract*

This type of contract is mostly used by highway agencies. The prices for different units of work are fixed by the agreement. Provisions for price escalations may be made in the agreement for projects of long duration. This type of contract allows flexibility for changed conditions, caused by variation in quantities, the full extent of which may only be possible to determine as the work progresses.

25.6 SPECIFICATIONS

The term 'specifications' is often used very broadly to include the contract document with the exception of the drawings. This would include:

- o invitation to bid,
- o instructions to bidders,
- o general conditions,
- o supplementary conditions,
- o bid proposal form,
- o bid bond form,
- o contract bond form,
- o list of prevailing wages and base prices of important materials,
- o non-collusion affidavit, and
- o technical specifications.

Technical specifications are needed to cover the qualitative items of the project and are used to modify or clarify what is shown on the drawings. In writing specifications, it should be remembered that each job is different and the type of specification is influenced by the type of contract, location of the project work, availability of construction materials and equipment, degree of supervision, and the construction techniques to be adopted. The designers, during detailed project designs, should consider most of these factors. Changes in the design, if necessary, should be made during preparation of the contract document. The contract document should make provisions for design improvements specific to the site conditions during construction for those projects where exact conditions can be ascertained only as the work progresses. Standard or type specifications can be helpful during the early stages of contract preparations but should never be used in a contract without careful review of their applicability.

The basic rule in writing specifications is to tell the contractor what the owner wants, not how to do the job, while protecting the owner's interests. Judgement and experience are required in writing specifications to protect the interest of the owner. Whatever type of specification is used, the contractor should not be confused. Use of the following phrases perplexes the contractor:

- o "as directed by the engineer",
- o "to the approval of the engineer",
- o "to the engineer's satisfaction",
- o "from an approved source", and
- o "at the owner's discretion".

Use of words such as any, either, and/or, and etc are difficult to interpret, for example:

- o "eliminate any defect",
- o "paint either side",
- o "remove debris and/or lumber", and
- o "perform excavation, etc".

In the following sections are brief descriptions of the common types of technical specifications.

25.6.1 *Design Specification*

In this type of specification, a specific kind or type of material is to be used, a particular dimension is required, and the installation instructions are given. If the specification concerns a method, it will state exactly what the contractor is to do in detail to satisfy the requirement. The owner, by using this type of specification, warrants by implication that the specifications will produce the desired results if it is followed by the contractor. Thus, the contractor is not liable if the desired end result is not obtained.

25.6.2 *Performance Specification*

This type of specification focusses on the end product, rather than the means of getting the product. The specification does not stipulate the method to be used. It might, however, offer suggestions that might be employed to obtain results. The performance, in terms of end results, might be stipulated in terms of quality, actual in-place operation conditions, finish, colour, appearance, tolerance, and clearance. The responsibility and selection of materials and methods for design rests with the contractor.

25.6.3 *Performance and Design Specification*

This type of specification should be avoided in all instances, since the contractor cannot be responsible for performance if he follows the specified procedures.

25.6.4 *Reference Specification*

Both performance specification and design specification can use reference specification. In this type of specification, reference is made to the technical specifications, established tests, make items, or formal procedures developed by owner, institutes, or societies to ensure that a product conforms to the expected performance.

25.6.5 *Standard Specification*

This is the entire set of technical specifications developed by the owner for the types of work to be handled frequently by the owner. These are often adopted by the agency concerned with modifications

to satisfy unique conditions, if any. The advantages of using this type include time-saving in writing specifications and easing the efforts of contractors in familiarising themselves with the specification.

Specifications can also be grouped as closed types, open types, proprietory types, and multiple proprietory types. Public works should avoid closed types or proprietory types of specifications, since these types do not foster free competition among several manufacturers of the product required in the contract. The owner may therefore lose the opportunity for cost savings because of the limited scope for contractors to get the lowest price for delivering the project.

25.7 ENVIRONMENTALLY CONTROLLED CONSTRUCTION PRACTICES

25.7.1 *Construction Equipment*

In dealing with the construction as well as the maintenance of hill roads of long lengths, it may not, in many instances, be possible to avoid completely the use of equipment such as bulldozers, excavators, loaders, and graders even if the project is designed primarily for the labour-intensive method. Indiscriminate use of bulldozers may lead to uncontrolled side-casting and destabilization of hill slopes. Therefore, equipment planning for hill road excavations should use a combination of bulldozer, excavator, loader, and dump trucks coordinated in such a way that side-casting and landslide triggering is minimum.

25.7.2 *Side-Casting*

The problems associated with side-casting are loss of topsoil, devegetation of downhill slopes, risk to property and life in the valleys, disturbance to and landslide triggering on the downhill slope, loss of construction material (stones) that could be made available from the excavation, and blockage of drainage channels. However, full control of side-casting without use of equipment is a practical difficulty, since end haul by labourers is not realistic for distances exceeding 20 metres unless cut and fill for each cross-section is fully balanced by design.

25.7.3 *Quarrying*

Hill road construction requires considerable stone aggregates, block stones, boulders for walls, drainage structures, and pavements. Low cost considerations tend to result in indiscriminate quarrying since transportation costs are quite high. However, the ultimate cost involved could be much higher than the apparent saving, if the risk resulting from destabilization of hill slopes caused by uncontrolled quarrying is not duly accounted for.

25.7.4 *Blasting*

Traditional practices of rock blasting on hill roads in developing countries do not, in most cases, take into account the opening up of new planes of weakness and resulting rockslides caused by uncontrolled use of explosives. Rock slope failures triggered by blasting in heavy rock cuts are often very large and irreparable.

Rock slope excavations require that the slope be cut to the steepest possible angle so that the requirements of both cut slope stability and minimum volume of cut are fulfilled. Blasting methods adopted should therefore ensure that the damage to the rock behind the final face is minimum. Controlled blasting techniques such as line drilling, cushion blasting, or pre-shear (pre-split) blasting should be contemplated in the designs; before construction as well as during construction. The specification in the contract should clearly stipulate such requirements. The reader is advised to refer to Rock Slope Engineering by Hoek and Bray (1981) for details on principles and techniques of blasting.

Chemicals are also available for blasting. Chemical blasting is expensive and is not practicable for large-scale operations. However, chemical blasting may become essential for small-scale blasting near existing structures and areas susceptible to risks from flying fragments of rock. **Calmmite** is a patented breaking compound developed jointly by Nikon Cement Co. Ltd., Nippon Oil and Fats Co. Ltd., and Nichiya Giken Kogyo Co. Ltd. of Japan. Calmmite is supplied in capsule form. **Bristar** is another breaking agent patented by Onoda Cement Co. Ltd. of Japan. Bristar is supplied in powder form. There may be several other breaking agents manufactured by various companies throughout the world.

25.7.5 *Construction Sequence*

The normal sequence of construction for hill roads should be:

- earthwork, including retaining walls, slope protection, and temporary water management within a working season for a specific road section,
- permanent water management works (drains, culverts, bridges, and erosion control structures),
- pavement layers,
- final stabilization works, and
- maintenance during construction.

The sequence details for earthwork should be:

- cutting of trees and vegetation within the line of construction to secure the stability of the adjoining slope to the maximum; stacking of cut material (whatever cannot be used for construction purposes may still be of use for biotechnical measures (e.g., tree trunks, branches, etc.);
- removal of topsoil within the same strip of land and deposition above the cleared area for re-use (biotechnical measures);
- preparation of temporary footpath (approx. 1m in width) at the future road level to conduct material transport with wheelbarrows (stone, soil, gabion crates, etc.) and to have a last check on the prevailing type of underground material. Based on such findings, the horizontal alignment may need a final local shifting for economisation of construction costs;
- excavation and drainage of retaining wall foundations, if any (surplus material should be safely deposited to avoid erosion). The drainage of the foundation is vital to guarantee dry and stable conditions;
- erection of wall and tight backfill with stones;
- cut and fill of road profile (only appropriate soil should be used for fill). Fill executed in layers of not more than 30 cm (loose) thickness and compacted with hand tampers after adding water to have good compaction conditions in the soil: excavated stones to be nicely stacked for re-use;

- drainage and trimming of mountainside slope;
- excavation of mountainside wall foundation, if any;
- erection and backfill of wall;
- construction of temporary side drains and preparation of sub-grade; crossfall of sub-grade should be 5 per cent towards the mountain side for proper water runoff into side drains;
- distribution of topsoil on road slopes as well as sowing and/or planting of plants shortly before or at the beginning of monsoon (this depends on the type of selected plants); and
- completion of a temporary water management system (temporary causeways at gully crossings, catch- and French drains where necessary, etc).

25.7.6 *Use of Emulsion for Pavement Surface*

Use of cut back or penetration grade bitumen for road surfacing requires heating of the bitumen. The heating can be done by firewood on petroleum products (diesel, petrol, kerosene). Traditional labour-intensive methods most often make use of firewood.

Use of emulsion for surface treatments, or emulsified asphalt concrete, not only serves well for low-volume roads but also minimizes tree cutting and deforestation. Cationic emulsion is applicable in most cases. Emulsifying plants are not very expensive and such plants, if established at selected centres, will greatly minimize the cost of emulsified asphalts since the cost of transportation of the 40 per cent water present in emulsified asphalts is saved.