OVERVIEW OF DESIGN AND CONSTRUCTION PROBLEMS

COQUIHALLA AND OTHER ROUTES

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COQUIHALLA AND OTHER ROUTES

I have been asked to speak to you about some of the construction problems encountered on the Coquihalla Route.

As the title indicates, I have chosen to include both design and construction since many, in fact probably the majority of construction problems, begin at the design stage.

I would also like to broaden the discussion to take examples from two other mega-projects completed in the last decade. They are the Revelstoke - Mica highway relocation for the Revelstoke dam development, and the highway development to serve the Northeast Coal project.

I do not intend that this paper will discuss the technical solutions to specific problems. These could be the subject of many interesting and informative papers themselves and hopefully some of them will be written in the future to pass on the experience gained.

Instead I want to talk more about the problems caused by the design, or as so often is the case, a design omission, and their impact on the project, the contractor, and the budget. At the same time I hope I can leave with you some thoughts at least, on how some of these can be avoided.

I have chosen the three mega-projects because all three were essentially designed by the consulting industry and all examples used in the discussion will be actual ones which occurred on a project on one of these developments. My comments also are intended as constructive criticism and it is hoped they will be taken in that spirit.

As you know there is a trend in the Ministry to increase the use of consulting firms for highway design. I do not quarrel with that philosophy as I think it will probably be beneficial, in several respects, in the long term. However in the short term it has been less than satisfactory.

I have been directly involved with all three of the mega-projects mentioned and I hesitate to say there has not been, with the odd notable exception, any significant improvement in the quality of highway design from the first to the most recent.

I think that is unfortunate because all of the companies involved are good reputable and competent engineering firms. If you gave any one of them a site specific problem, a bridge foundation or a structure or a dam, they would analyze it fully, bring in the necessary specialists as required, and come back with a complete solution and design.

However, as soon as a linear design, a highway or railway, is involved, there seems to be more generalization and perhaps even less experienced professional attention, and I think that is where the problem lies.

I would suggest to you that a highway design is simply a whole series of site specific problems, each one requiring that it be properly addressed. That means an assessment and solution for every cut and every fill, every drainage course, every available alternate, every sensitive area, etc. In short, it should come as close as possible to having portrayed every activity necessary to build the route, and for all the design recommendations to be compatible with the site conditions.

A highway design is made of four principal parts:-

1. Geometrics
2. Soils
3. Drainage
4. Specifications

The greatest emphasis is usually placed on the first of these and yet once the route is chosen geometry is the easiest to delegate to a technician. There are many people who understand the geometric parameters and there are many manuals available to them. There are also computer programs available for alignments, profiles, earthwork calculations, and graphics.

In fact for a period when computer graphics were first developed it was being used as a symbol to indicate highway design experience. Computer graphics unfortunately only replace your draughtsman.

The other three component parts of a design - the soils, drainage, and specifications, cannot be delegated. They must be addressed by the experienced designer or specialist initially and the appropriate decisions made before delegating the mechanics to others.

Let's look at each of these. Again it would not be possible in this time frame to cover all the facets of these topics, but we will try to give a general statement and then point out some of the most frequent problems encountered.

SOILS

Soils tend to cause the majority of problems. This is understandable since the entire roadway structure is constructed from soils of various and diverse types.

Accordingly it is extremely important - no, "mandatory" is a better word - that all soils to be excavated be assessed and classified as to type for payment and as to suitability and stability for incorporating into the roadway. All embankment areas in turn also need to be assessed for stability or the existence of a possible problem.

In addition, major features such as potential slides or large areas of unsuitable materials need to be identified and either avoided or a solution for them be included.

SOILS (continued)

This sounds simple, but recognizing at the outset that there is a practical limit to the amount of preliminary information that can be obtained, it means that the preliminary information program be tailored to suit the project to obtain the maximum amount of information in the most important or critical areas.

To demonstrate what I am saying, there are two types of soils information. The first of these is available without field exploration and is obtained from geological studies of the area and usually augmented by air photo interpretation. Both of these can give a general overview of the route and perhaps assist in identifying such things as slides, etc. They cannot, however, provide site specific information and should never be relied upon in themselves for design purposes.

The second type is the physical field exploration by drilling, seismic, test pits, visual examination, or a combination of these methods which provides the site specific information.

At the time the preliminary engineering program is launched, there is usually a route projection with a tentative profile available. Using this information, the designer should tailor

SOILS (continued)

the soils program to concentrate in the important areas. There is little point in drilling deep holes where the work is light with cuts and fills perhaps below 2 - 3 metres, and where visual information would probably suffice. However, think how comfortable the designer would be to have one or two holes to profile depth in the major cuts and drilling in the foundation area of major fills. This could be augmented with lesser depth test pits strategically located to provide other information on organics, moisture, gravel, etc.

Where seismic is used, it should also be aimed at specific areas and not stand alone but be correlated with drill results to refine the seismic interpretations in any particular area.

Where borrow is a major consideration in a design, some investigation should be assigned to that area to confirm quality and quantity of available material. This would also apply to gravel sources.

I mentioned visual information a few minutes ago. I do not think any highway design should be completed without the senior designer having walked the route at least once, making careful

SOILS (continued)

observations and notes of soils, rock, drainage, organics, and general features of the area. He will then be able to make a better assessment of the interpretations of others as well as have a feel for the terrain to better assimilate the design to the conditions of the area.

In short what is needed before any detail design proceeds is a list station by station of the soils in every excavation and embankment area, their characteristics, their classification, and if problematical, their design solution.

Here are some of the things that can happen and as I said before all the examples have been encountered on a project on one of these major developments.

Organic Stripping

The specifications require that all organic materials be removed from materials to be used in embankments and from embankment areas except where special pre-loading techniques are used. The importance of this item cannot overemphasized yet almost invariably it is glossed over in a general way, creating a host of problems.

Organic Stripping (continued)

One project, for example, showed stripping an average depth of one foot and a total quantity for the project of 100,000 cubic yards. The actual depth varied from three feet to 40 feet with the actual quantity totalling 1,070,000 m^3. The extra cost which approached $4 million, was not only the additional stripping but the additional borrow necessary to replace it. The excessive overrun created an administrative problem and the depths a changed condition due to the changed method necessary to remove.

Another project showed a uniform average depth of peat excavation of 1.5 metres over the project. The actual varied from one metre to eight metres in a very irregular manner. Sounding information was available to the designer taken every station at centreline and at 30 feet on either side, yet the average was chosen perhaps because it was easier for the computer to handle that way. The computer which dutifully followed the surface ground line 1.5 metres below it, portrayed to the contractor an operation which could be handled with normal backhoes and dozers. In actual fact because of the deep holes, draglines were required and some of the material handled up to three times. The cost of course more than doubled and the quantities increased while not as dramatic as the last example, by 67%.

Organic Stripping (continued)

A number of other projects all in the same area showed no organic stripping at all, yet we are encountering several hundred thousand cubic metres. In fact the quantities are so large we cannot store it all on our own right-of-way and have had to make arrangements for other property to haul and stockpile.

Borrow Sites and Gravel Pits

Where a project is based on a large amount of borrow it is imperative that the pits be evaluated for quality and quantity.

One project was predicated on 800,000 m^3 of borrow - it was in essence the major part of the project in terms of contract value. The sites were all shown in detail, complete with names, boundaries, and the quantity to remove from each. The only problem was there was no borrow material there. All of the sites without exception had about a metre of rubble and sand overlying solid rock. It meant of course that we had to redesign the project to a rock design and provide the shortfall from quarries. If you consider that you are changing from an approximate $3.00 material to an $11.00 material, the impact or

Borrow Sites and Gravel Pits (continued)

change to the contract value is in excess of $6 million. In addition with such a major change it could only be interpreted as a fundamental change to the contract and consequently the contract was renegotiated in part at least.

You might ask why we did not re-tender the project. Well we relied on the design and allowed the contractor to mobilize his equipment and camp. His clearing on mainline was also well under way before turning to clearing of the borrow pits. At that point we always re-examine the pits for quantity and quality - when we found nothing in the first we checked them all with the same result. To have removed the contractor at that stage and re-tender would have been costly since he would be entitled to his mobilization costs and other unrecovered overhead.

Another borrow area had been well investigated and an excellent report prepared. The material was a mixture of granular and blue silt-clay tills. Every test pit showed water in the pit bottom at the time of digging. Many of the photographs showed water dripping out of the sides of the pit excavation. The recommendation was that the material was suitable for fill at a

Borrow Sites and Gravel Pits (continued)

certain moisture content. This meant the designer had to make a practical decision whether there was any economical way to remove the water and maintain the schedule. Since the material was super saturated there obviously was not, yet the pit was designated in the design. We lost only the cost of clearing and we changed to a clean gravel source not more than a kilometre away.

Many designated borrow pits in summit areas have also proved unsuitable for the same reason. Small fans at the base of snow slide areas are almost invariably wet year round because of the continuous snow melt affecting them. It is better to look for deposits which do not lie between the snow line and the first creek or in areas where no residual snow exists.

Gravel pits on one of the developments were designated for the most part from a preliminary study of geology and air photographs. All but one of the pits were unsuitable to produce the required product and we had to launch a whole gravel exploration program after contracts were awarded. There was nothing wrong with the report. In fact it was an excellent report and was invaluable to us during our exploration program

Borrow Sites and Gravel Pits (continued)

since it directed us to general granular areas. What was wrong was the preliminary report was used beyond its intent by extending general information to site specific information without sufficient data.

Slides and Major Areas of Unsuitable Material

Features such as these should of course be avoided if the terrain will allow. If not and they must be traversed, they usually require some special design or treatment to ensure their stability. They are also usually very costly items even when included in the design; they are even more traumatic if discovered after award and after the contract has begun, in their effect on cost, on the construction schedule, and on the terms of the contract itself.

On one project before tenders were called we made a helicopter flight over the centreline. We noticed the scarp of a very old but very large earth slide. The magnitude was such that it might well have been missed on the ground but from the configuration of the evidence from the air there was no question a large slide had taken place at some previous time.

Slides and Major Areas of Unsuitable Material (continued)

The design called for a fill about 12 metres high over the area about 1,000 metres in length. This proposed massive weight gave us concern and upon our return we questioned the consultant. They said they had also recognized the slide and had evaluated it. They advised it was down in a stable position and would not be a problem. We cleared the area and began the major excavation to construct the fill. We had placed about one metre when the whole area moved again, breaking up into large moon-shaped wide cracks right back to the original scarp and to the creek below.

The result was a relocation to stable ground but the impact was profound. It meant establishing and designing a new route, redesigning a major culvert already partially built in a large ravine, and it took the site away from the contractor until the following season. In total the additional direct costs to the Ministry were in the order of $600,000.00.

It is interesting to note that the total quantities on the new route were about 100,000 m^3 less than the estimated original.

Slides and Major Areas of Unsuitable Material (continued)

Another slide was encountered which was caused by major drainage at the interface between the rock and the overlying sandy silts and gravels. We detected it at the time it was staked for clearing - there were a number of open cracks up to a metre in width high on the slope. The solution was to determine the rock line, and design a flatter slope which enabled us to reach the rock and to pick up and positively contain the drainage above the roadway. The treatment to date appears successful but the project quantities increased about 300,000 cubic metres.

On one of the routes three flow slides were encountered, all of which had to be unloaded to stable slopes and controlled at the toe with appropriate support and drainage material, in this case blast rock. All of the material was waste and again the project costs were substantially increased.

These kind of wet slopes are often easily identified from existing information around them hence the need for a good visual inspection. In one instance the wet silt material was actually flowing on to the existing tote road immediately below the centreline yet no provision appeared in the design.

Rockwork

Most of the rock designs to date have used one of two general standards suitable for competent rock. These are the 1/4:1 slope or the vertical slope with benches at various intervals.

Unless the rock is so obviously of a poor quality this method works fairly well with changes as necessary being made as the first blast levels proceed. The alternate would be an in-depth study of each rock cut before design and I am not sure the cost would be justified or the end product improved.

However, one should not again generalize and at the very least should classify the rock as good rock or bad rock with the first falling in to the category using the slopes just mentioned and the latter requiring some further consideration and decision to establish practical slope design. This is particularly important where the stability of something above is involved. For example, one design showed 1/4:1 rock slopes breaking out within a metre of the footings of major transmission towers. The rock was a soft coal type which obviously could not be constructed that steeply with the result we had to move the location into a fill situation.

Rockwork (continued)

The most common problem encountered is the adequate identification of the existence of rock both exposed and over-burdened. With the latter it is expected there will be some surprizes unless an extensive drilling or seismic program is undertaken. This relates again to the need to tailor the investigation program to the project. Missing exposed rock is inexcusable.

One project which was displayed as a simple earthwork scraper operation with no rock actually had in excess of 160,000 m^3 of rock involved. The major portion of this quantity was in one 0.5 kilometre area with rock cuts up to 60 feet in depth. Their tops were fully exposed - in fact one was a bald flat rock area about 80 - 100 feet across of the kind that sometimes attract people for a picnic. Obviously the survey crew made no notes, but even more concerning, the designer obviously never walked the job.

DRAINAGE

Generally speaking good careful attention is being given to the drainage, design, and structures and minor differences are usually only personal preference.

DRAINAGE (continued)

There is one area, however, which I would mention and which was overlooked. This is where the route location lies on the steep mountainside in a summit area below the summer snow line but above the first drainage creek. There is a general weeping of melt water along the whole slope even though some of the meltwater is more concentrated in the centre of snowslide tracks. In this instance the design called for a large fill up to 60 metres high lying against the slope. Provision for weep drainage is absolutely necessary in this situation. We therefore constructed the base of the fill one to two metres in depth of permeable blast rock.

SPECIFICATIONS

Simply stated Specifications or Special Provisions need to say two basic things. One describes the intent of the work and the end product and the other the method of payment. If both of these are kept in mind at all times for every item, there should be no problem. Unfortunately one or the other or sometimes both are overlooked. Or sometimes there is ambiguity in the language so the intent is not clear.

SPECIFICATIONS (continued)

Very frequently we find errors in the language, errors in cross-referencing the Schedule items to the Special Provisions, and errors in the Schedule quantities' compatibility with the drawings. All of these are housekeeping items which should not occur with proper final editing of your documents and I urge you to do so.

It should be remembered that the contractor can only bid on the project as portrayed to him. He is expected to evaluate in about two weeks' time what you have had several months or perhaps a year to put together. If the drawings and the specifications do not completely portray the work to the contractor, then the design has failed or at least has a serious shortcoming.

Where these shortcomings occur often claims result and the original portrayal may well become the datum from which the claim will be based. Claims are no longer a dirty word but are merely a means by which the contractor requests payment for a changed condition over which he had no control.

SPECIFICATIONS (continued)

Claims can be categorized into three areas:-

1. Fundamental changes to the contract
2. Changed Conditions
3. Excessive overruns

If you examine each of the examples given you will find they fall into one of these categories and are the basis for a legitimate claim. Contractors are in a very competitive industry and have a right to expect the design is complete in every way. And every designer should have at least a basic knowledge of contract administration and potential claims.

Well I have given you a number of problems most of which were major in magnitude. I would hasten to add that not all project designs are bad. Indeed we have had some very excellent ones but as I mentioned before they are isolated bright lights and because they are in the minority do not reflect the consulting industry as a whole with respect to highway design.

I would hope that these suggestions will play at least a small part in improvements over the whole spectrum.

In closing I would summarize some thoughts or checks that might be worth considering:-

1. Delegate only to junior people those things which they are trained to handle. Soils interpretation and design, drainage design, and specifications should receive the attention of the experienced designer.

2. Understand and evaluate the limitations of the computer and depend on it to that extent only.

3. Design soil investigation programs to the needs of the individual project.

4. Correlate general soils investigation to the specific sites. After all at that point it is no longer important to know how it got there but what's there now and what do we need to do about it.

5. Where a sub-consultant has undertaken the soils investigation and prepared a report, ensure that you use it and recognize any areas where the data is weak.

6. Be innovative and be prepared to look at alternate solutions to achieve the best economic design within the given parameters.

7. Write clear specifications and ensure they are carefully edited.

8. Ensure that the drawings are clear and adequately portray the work. Pay particular attention to the cross-sections.

9. Be inquisitive - the best designs come from designers who will not accept assumptions but continually question every element of the project.

10. And finally, ensure you have on staff at least one senior and experienced highway designer. It should be recognized a highway design, because of its many variables, is probably much more complex than most structure designs, and you wouldn't let an inexperienced junior design a bridge.