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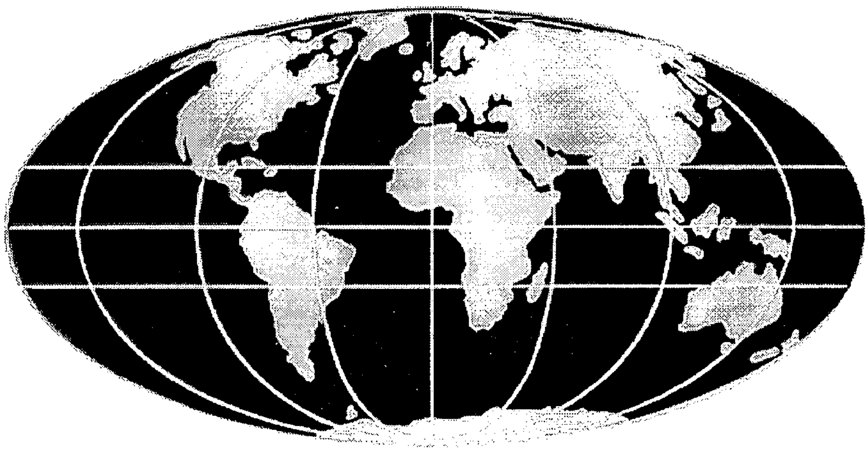

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HIGHWAY EARTHWORK AND SLOPE ASSESSMENT IN MALAYSIA.

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ABSTRACT:

In Malaysia, and most other developing countries, highway earthworks have generally increased in size and complexity in recent years. The very high costs of many earthwork rehabilitation programmes indicate that methods of designing and maintaining such slopes could be improved. In response to this, a joint study between the Transport and Road Research Laboratory (TRRL) and the Jabatan Kerja Raya (JKR Malaysia) is aimed at developing a method of monitoring, by analysing aerial photographs, and evaluating earthwork problems the results of which can be used to provide a progressive upgrading of slopes. This technique has been used to analyse earthwork features on a number of highways in Malaysia and to make a detailed appraisal, for re-habilitation purposes, of earthwork slope problems on the Tamparuli-Ranau highway in Sabah.

INTRODUCTION:

The expenditure on road construction and maintenance in most developing countries has increased significantly during the last two decades. This results from a number of factors including firstly, the need to expand networks in line with rural development; secondly the requirement for roads to have higher geometric standards, and thirdly the increased costs of maintenance and repairs as roads are improved. All three factors are most significant in those countries where considerable areas of the terrain are mountainous, as for example Malaysia.

In such mountainous regions the development of roads has, in the past, been given a low priority because of the inherent difficulties and high costs of earthworks. The roads that were constructed tended to follow contours in an attempt to restrict the need for earthworks and to minimise the disturbance to slopes. It meant that the roads had high gradients, tight bends and were narrow. With more recent highway design strategies favouring roads with a much higher geometrical design it has meant that the size and complexity of many earthwork operations has increased. This has not only added significantly to the cost of constructing roads, where earthworks alone may account for 75% or more of the budget, but provided additional high costs in terms of maintaining and repairing such roads.

The earthwork slopes on many modern roads tend to be very large and have involved considerable alteration and disturbance to the terrain. During their construction the level of protection and drainage is not easy to determine because of the difficulties of predicting what type of deterioration will occur and where it will take place. Consequently there is often a need for a high input of maintenance, to prevent deterioration, after a road is constructed. Such maintenance is not only costly to carry out but, even more important, it is difficult to plan and organise effectively. The latter reflects difficulties in identifying problems because of the large number of slopes, the inaccessibility of much of the terrain and the hidden nature, due to vegetation and ground features, of so many of the slope failure problems. However if adequate maintenance is not provided the slopes degrade and become unstable and this may necessitate an even greater capital expenditure in terms of a large scale rehabilitation programme of remedial work.

To overcome the difficulties of carrying out effective site investigations a method is being developed, in a joint study between the Transport and Road Research Laboratory (TRRL) and the Jabatan Kerja Raya (JKR Malaysia), which involves the use of helicopters to gain access to positions where developing slope problems can be seen and recorded. Then, through a process of analysis, information management and evaluation, each specific slope problem is identified, given a priority and recommendations are made relating to the maintenance or remedial work necessary. Providing the monitoring is carried out on a regular basis it is expected that the risks associated with failure can be minimised until the earthwork slopes reach a mature enough stage to be considered completely stable. The project is being undertaken on roads which cross the main North-South mountain range in Peninsular-Malaysia and the Crocker-Range in Sabah, East Malaysia.

1. PROCESSES OF SLOPE DESIGN AND MAINTENANCE:

SLOPE DESIGN: Because of the complexity of many interrelated processes the stability of a particular slope is difficult to determine and failure is generally impossible to predict with any degree of accuracy. In Britain and some other countries, considerable experience about terrain conditions, slope materials and stability is available, and this provides a good basis for empirical slope design. It solves many of the design problems in terms of selecting safe slope gradients and applying sufficient protection and drainage. Slope failure in Malaysia and other South-east Asia countries has been reviewed in detail; Brand E.W. 1983, however the amount of information which is available to engineers on factors which are connected with slope failure is extremely limited.

Consequently, in countries such as Malaysia, slopes are generally designed using simplified specifications, see Table 1. However, the larger earthworks now being constructed are resulting in more and larger slope problems and the need for greater preventitive measures in terms of slope design. The possible need in the future to provide earthworks with better drainage and protection and, in some instances, lower gradients, will give rise to difficulties because failure mechanisms and the need for these higher specifications cannot always be predicted. It means that there will be a significant increase in the cost of earthworks and that a proportion of the additional work may have no beneficial effect.

TABLE 1. Basic outline of earthwork design in Malaysia.

NATURAL SLOPE FAILURE:	1) Avoiding landslide-prone areas by using a route selection strategy with slope stability being one of a number of factors to be considered.
CUT-SLOPE ANGLES:	2) Cut slope angles, in soil, being approximately 1:1, this being a nominal angle for stability. Rock slopes are cut at steeper angles.
SLOPE HEIGHT:	3) No allowance is generally made for slope height in terms of slope angle.
DRAINAGE & PROTECTION:	4) In most cases drainage and protection is restricted to berms, often at 6 m intervals up the slope.
EMBANKMENTS:	5) Specifications call for embankments to consist of a reasonably uniform fill compacted at optimum moisture content to a relative compaction of about 80%.

SITE INVESTIGATION DIFFICULTIES: It is clear that many of the slope failure problems can be seen developing shortly after roads are constructed and that, as an alternative to leaving such slopes to deteriorate and eventually require very high repair costs, these problems should be dealt with immediately.

However, investigating slope problems for maintenance purposes has generally proved difficult. The problems are as follows;

1) There is a lack of resources to deal with the very large number of potential slope failure problems throughout Malaysia.

2) There is no strategy for handling the vast amount of information involved.

3) The high costs of conducting site investigations in remote regions, where there are few facilities, would be prohibitive.

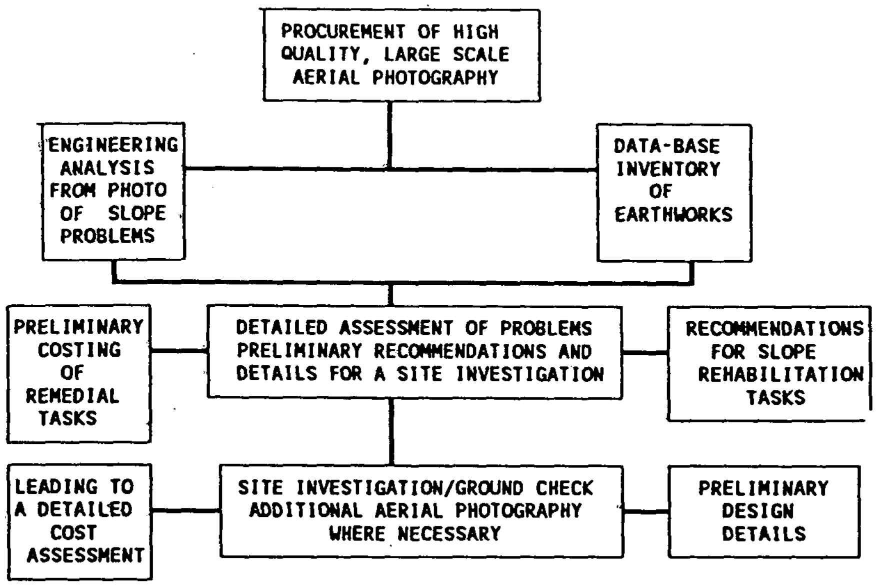
4) There are considerable difficulties in gaining access to steep slopes and embankments in rugged and jungle covered mountains.

2. EVALUATION AND MONITORING OF EARTHWORKS:

A technique of earthwork and slope evaluation is being developed which overcomes these problems and provides engineers with better information than that gained by more traditional site investigation techniques. The method is based on the use of helicopters to evaluate slopes from a visually ideal position and to take photographic records which can be analysed in laboratory conditions. The organisation and evaluation of information, using database systems, is another important aspect of the technique being developed.

Figure 1 illustrates the overall strategy of the technique beginning with the inspection and recording of earthworks from the helicopter. There are then two stages of analysis of details from the aerial photographs followed by the assembly of information into a database and in reports. These can then be used to make an evaluation of problems by dividing the slopes in terms of hazard risk, priorities, remedial work recommendations and the most relevant approach in terms of design and construction. At this stage, with a breakdown of the number and scale of problems, a preliminary estimate of repair costs can be made. The evaluation also provides information about each slope ready for ground checks to be made. These lead to more detailed cost estimates and preliminary design details.

FIGURE 1. Procedure for assessing earthwork and slope problems.



AERIAL PHOTOGRAPHS: Recommendations for planning highway site investigations have always emphasised the important role of aerial photography. The role of such photographs in assisting engineers to view the overall extent of large scale earthworks from a good visual angle, which is unobscured by trees, etc., is equally relevant.

When obtaining new photography it is possible to specify the photographic image scale that is ideal for the task. In this respect existing topographic survey photography, which is generally at small image scales of 1:30,000 to 1:50,000, cannot even be considered. Table 2 provides guidelines on the correct scale of aerial photographs for different engineering tasks.

TABLE 2. Scale/type of aerial photographs for different tasks.

TASK	SCALE	TYPE	COLOUR/BW
GENERAL TOPO MAPPING 1:25,000	1:50,000	METRIC (V)	USUALLY B/W
INITIAL ROAD ALIGNMENT SELECTION.	1:30,000	(V)	B/W
ROAD ALIGNMENT/GEO-ENGINEERING STUDIES.	1:20,000	(V)	B/W. COLOUR
ROAD CONSTRUCTION PLANNING.	1:10,000	(V)	COLOUR
HIGHWAY UPGRADE AND WIDENING.	1:2,500	(V) & (O)	COLOUR
HIGHWAY MONITORING AND EVALUATION.	1:1,500 TO 2,000	(O)	COLOUR
HIGHWAY REHABILITATION.	1:1,000	(O)	COLOUR
SITE INVESTIGATION PLANNING FOR REMEDIAL TASKS	1:500 TO 1:1,000	(O)	COLOUR

NOTE: B/W = BLACK AND WHITE. (V) = VERTICAL. (O) = OBLIQUE.

An important requirement in obtaining suitable aerial photographs is that engineers, with their knowledge and experience of what to record in terms of earthwork engineering features, should assist in positioning the helicopter and obtaining appropriate photographic records.

ANALYSIS OF AERIAL PHOTOGRAPHS: On a typical section of mountainous road in Malaysia there may be up to 200 earthwork slopes per 50 kilometre of road. For the whole of Malaysia the total number of slopes on highways is likely to be in excess of 5,000. Producing aerial photographs and subsequently referencing the slopes is a relatively modest task. However analysing this number of slopes and storing the information is a more time-consuming and demanding task. Two methods of analysis have been developed.

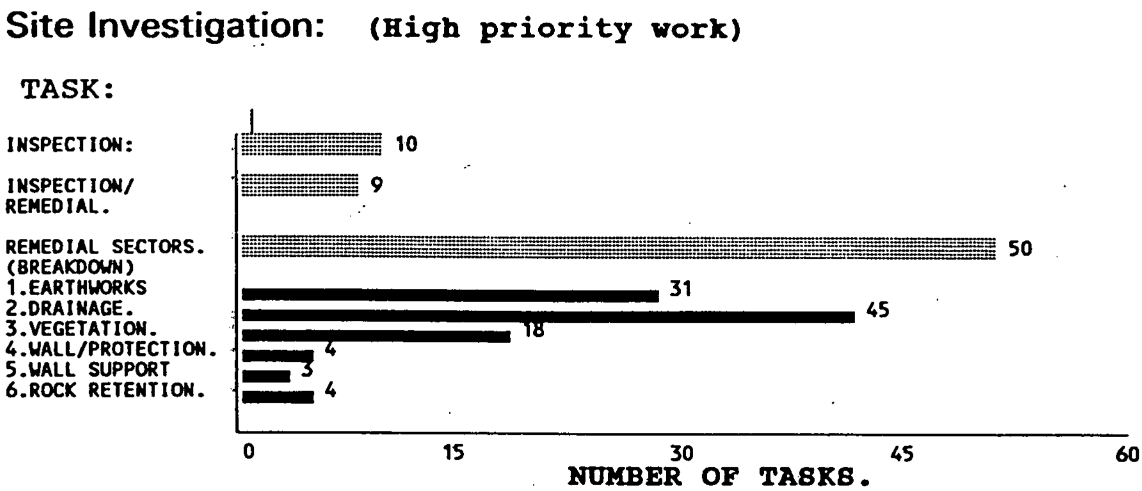
1. Questionnaire analysis: The first relies on a questionnaire form, containing up to 75 parameters. This is designed to be completed by unskilled staff who have been given appropriate training. The parameters consist of features which provide an indication of the scale and type of cut-slope or embankment as well as its present condition. Information from the questionnaire is entered into a computerised data-base and forms an inventory of slope features. To date (Dec 1991) this contains data on approximately 550 earthwork/slopes.

2. Detailed engineering analysis: The second approach is to consider each aerial photograph as representing a sector of road, and to ask questions about the condition of the road in terms of the earthwork cut-slopes, natural slopes and embankments on either side of it. This removes the restrictions of the first method of looking only at features listed. This analysis, by engineers, is entered into computer-stored records in the form of engineering notes for evaluation and presentation in reports. The method provides the main source of information to be used for making ground checks at the earthwork sites.

From the two sources of information the earthworks and slopes are classified into three groups, 'High Priority or A-Slopes', 'Moderate Priority or B-Slopes' and 'Low Priority or C-Slopes'. Priorities relate to the estimated risk of failure, the anticipated hazard to traffic, and the increase in the scale of the problem if the deterioration is allowed to continue. In most cases the cause of failure can be determined from the aerial photographic analysis and this is described together with recommendations for remedial work. When the cause of failure cannot be identified, or only part of the cause is apparent, the sectors are marked for further inspection. Otherwise the objectives of the site check are to confirm the proposals for remedial work.

An example of the technique is its application on the Tamparuli-Ranau highway in Sabah described in a JKR/ILP report (Nik Ramlan N.R., Heath W.G. and Mardiana S. 1990). It involved 232 sectors of road with earthworks and slopes from which more than 80 were classified as requiring urgent repairs and a similar number as requiring repairs within the next five years. Figure 2 provides a breakdown of an investigation showing sectors where further inspection was required and sectors where remedial action was proposed and needed to be confirmed in the field.

FIGURE 2. Outline of tasks for main phase of site checks.



SITE CHECKS: The 'High Priority' or 'A-Slopes' were checked immediately after the analysis, using information from the aerial photograph to instruct engineers what to look for at the site. This is to determine the seriousness of the problems and to check whether site conditions correspond to the analysis of the aerial photograph in terms of the recommendations for remedial work.

The considerable amount of information about earthworks and slopes generated prior to this stage greatly simplifies the site investigation effort. By making use of the aerial photographs and guidance notes engineers can rapidly gain access to the relevant parts of slopes and go directly to problem areas. The information and aerial photographs also provide a basis for making remedial design decisions on site. This approach removes much of the uncertainty which is often a feature of site investigations in such difficult conditions, and there is a high level of consistency in the data collected about the whole road. In addition, because engineers are able to go directly to problems, considerable time is saved and investigations can be carried out in days rather than the weeks required by more traditional site investigation methods. Table 3 provides a summary of information from site-checks on the Tamparuli-Ranau road.

TABLE 3. Summary of results and remedial work on Tamparuli-Ranau highway.

SCALE OF EARTHWORK:	SMALL. 17	MEDIUM. 66	LARGE. 125	V-LARGE. 25	//////////
PRIORITY RATINGS:	LOW. 68	INTERMEDIATE 89	HIGH. 74	////////////	/////////
TYPE AND NUMBER OF REMEDIAL TASKS:	EMB-DRNS. 11	CUT-OFF DRNS. 52	BERM DRNS. 15	SUB-SURFACE DRN. 5	VEGETATION 10
	CULVERT DRNS. 6	SUPPORT WALLS. 5	PROTECT WALLS. 15	EARTHWORK. 12	GUNITE. 2

PROGRESSIVE DESIGN IMPROVEMENTS: The final evaluation phase, following site checks, is for all high priority 'A' slopes to be divided into four groups. This is based on the need for any further investigation and design before remedial work commences, see Table 4.

The three aims are as follows;

1) To arrest slope deterioration quickly before it becomes a large scale slope problem.

2) To undertake conservative design only on those slopes which impose exceptionally high risks or where the failure mechanism is too complex to deal with progressively.

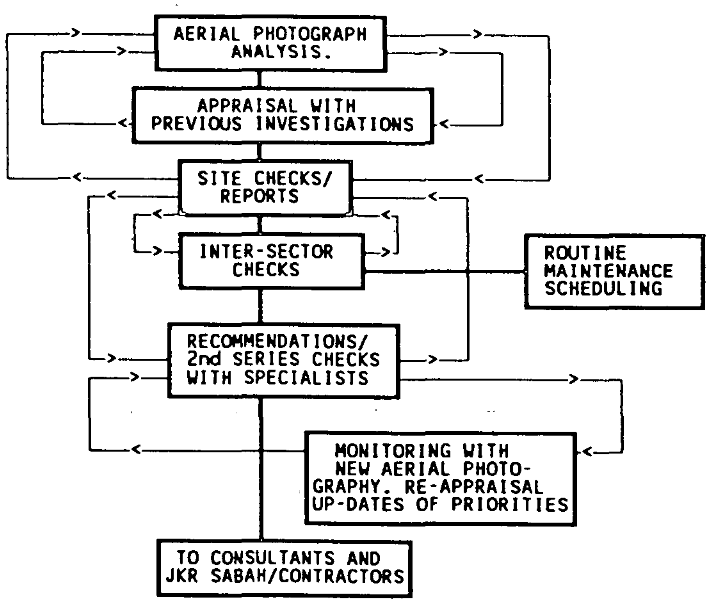
3) On all other failing slopes to carry out sufficient remedial work to reduce the risk of failure to acceptable levels and then to continue to monitor.

TABLE 4. Division of 'A' slopes into four groups.

1)	VERY URGENT SLOPES, POTENTIAL FAILURE WITH SERIOUS RISKS.	SLOPES WHICH MAY FAIL BEFORE THE MAIN REHABILITATION PROGRAMME OF REMEDIAL WORK GETS UNDER-WAY. SLOPES IN THIS CLASS ARE DEALT WITH AS IN 2,3 OR 4 BUT IMMEDIATELY.
2)	STRAIGHTFORWARD FAILURE MECHANISM AND REPAIR.	MAINLY ARRESTING FURTHER DETERIORATION AND INVOLVES THE. MINIMAL DESIGN. DIRECTLY TO CONTRACTOR.
3)	COMPLEX FAILURES INVOLVING SOPHISTICATED REMEDIAL WORK.	CAUSE OF FAILURE IDENTIFIED; DETAILED DESIGN STAGE BEFORE REMEDIAL WORK GOES TO CONTRACTOR.
4)	MECHANISMS OF FAILURE NOT FULLY DETERMINED.	A GEOTECHNICAL INVESTIGATION STAGE TO ASSIST WITH THE DETAILED DESIGN OF REMEDIAL ACTION.

The whole process is iterative, see Figure 3, involving the re-examination of aerial photographs as more information becomes available and further site checks on those slopes where extensive repairs are required are carried out.

FIGURE 3. Iterative approach used to check earthwork problems.



During the development of the technique this process is necessary in order to understand the contribution each stage makes to the overall evaluation of slopes, and to ensure that no high risk potential slope failure problems are missed.

The overall objectives are; 1) to ensure that all slope deterioration is identified before it becomes large scale failure. 2) to recommend the most cost-effective remedial action. This last objective involves the use of specialists in different aspects of remedial work, for example drainage, bioengineering etc. in some site investigations. Finally recommendations are passed to consultants who are in charge of the design for remedial work and its implementation. The evaluation stage continues with the process being repeated after twelve months with a re-appraisal of the road and site checks on all 'B' sectors.

3. CONTINUING RESEARCH AND DEVELOPMENT OBJECTIVES:

The work described represents an experimental phase which attempts to define the technical difficulties of carrying out a full-scale appraisal and evaluation of earthworks over a large proportion of Malaysia's road network. Plans to develop a 'Malaysian earthwork monitoring and management system', 'MEMMS' are being implemented with a proposed team of 10 engineers and technical staff. This will lead to the recording, analysis and evaluation of the main highway slopes with the task repeated at 12 month intervals. Cost estimates for the overall programme of monitoring are based on the following brief details, see Table 5.

TABLE 5. Brief outline of some detailed costs of 'MEMMS'

HELICOPTER HIRE.	AERIAL PHOTOGRAPHY.	PHOTO-ANALYSIS	SITE CHECKS
$600 (US)/HOUR	$3 (US)/SECTOR	1 MAN-HOUR/SECTOR	2.5 MAN-HOURS/SECTOR

NOTE: 'Sector' = Earthwork information on one aerial photograph. Sector length variable

Some aspects of the project which are still being developed include;

1) The choice of aerial photograph recording techniques; including the image scale, the processing, the printing and storing of photographs. The latter includes the possibility of digitising photographs and incorporating them into the information database.

2) The identification and labelling of slopes on aerial photographs and methods of using Global Positioning Satellite, (GPS) information for this purpose.

3) Storing and retrieving information on computer database systems and the presentation of this to potential user's of information which include consultants and contractors.

4) The use of the aerial photographs to obtain measurements of slopes by photogrammetric methods which can be used for the preliminary design of remedial work.

In addition to the overall objective of introducing progressive earthwork upgrading, the other aim relates to the advantages of monitoring in detail all aspects of earthwork slope failure over a long period of time. This includes the need to monitor the level of terrain disturbance as new roads are constructed and the collection of data about earthwork failure mechanisms. This will not only lead to improvements in the methods used for slope remedial work but may lead to an even more practical empirically based approach to earthwork design in the future.

CONCLUSION:

In Malaysia the most effective way of reducing earthwork repair costs is to limit slope deterioration quickly and to carry out effective repairs before the scale of a particular problem gets large. Till now this approach has been hampered by the problems of collecting reliable information about the large number of slope problems.

By using helicopters to collect good information quickly and incorporating this into a maintenance management system the present difficulties can be overcome. It is then anticipated that the more efficient methods of investigating problems, based on monitoring and evaluation, will provide a progressive and more optimised repair strategy and this will lead to reductions in overall maintenance and repair costs.

In addition the information collected about slope failure problems is expected to contribute to improved initial earthwork design methods by providing an empirical basis for such design.

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