

Contributions / Communications

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LANDFORM EVALUATION AS A METHOD OF ROAD CONSTRUCTION INVESTIGATION IN SOUTH AFRICA**L'ÉVALUATION DES FORMES DU RELIEF COMME MOYEN D'ÉTUDE DE CONSTRUCTION ROUTIERE EN AFRIQUE DU SUD****HOWLAND A.F.**, Engineering Geology Division, Department of Geology, Imperial College, London, U.K.***Summary**

An established technique of materials survey for road construction purposes in South Africa is based on landform evaluation.

A direct relationship is assumed between landform and the underlying soil profile for a given geological and climatic situation. By mapping landform units from stereo-aerial photographs, then sampling and testing typical landform units, extrapolation to similar units allows the spatial distribution and quality of material in the mapping area to be estimated. This will only hold true for landforms that are morphogenetic in character where they are a direct consequence of the processes acting. If there is therefore a uniformity of geology and climate over large areas this method of mapping has many advantages.

For long roads in regions of bad access such a map forms a useful tool at all stages of the contract. As an initial survey it indicates suitability and amounts of material available, location of borrow areas and therefore haul distances. At a later stage it could indicate areas that would provide extra material. While by the same reasoning stretches of bad ground could be quantified and likely foundation conditions determined for crossing points.

This procedure lends itself to the storage of data suitable for re-use at a later stage on subsequent projects.

Résumé

Une technique éprouvée pour l'étude de matériaux employés dans la construction des routes en Afrique du Sud est basée sur l'évaluation de formes de relief.

Étant donné une certaine situation géologique et climatique, on suppose qu'il y a une relation directe entre la forme du relief et le profil du sol sous-jacent. En établissant des unités de formes du relief par l'étude de photographies aériennes, suivie d'échantillonnage et de tests sur des unités typiques, l'extrapolation à des unités similaires permet d'estimer la répartition spatiale et la qualité des matériaux dans la zone levée. Ceci sera valable uniquement dans le cas de formes du relief de caractère morphogénétique et seulement aux endroits où ces formes sont dues à l'action des processus de transformation. Ainsi, si l'aire contient de grandes zones de géologie et de climat uniformes, cette méthode de levé est avantageuse.

Pour de longues routes dans des régions d'accès difficile, une telle carte devient très utile à toute phase du contrat. Comme levé initial, la carte indique où l'on peut trouver des matériaux, et en quelle quantité, la situation de balastières possibles et, par conséquent, les distances de roulage. A une étape postérieure, la carte pourrait indiquer des zones de réserves possibles de matériaux. Par le même raisonnement, elle servirait à déterminer la quantité des sections de mauvais terrain et les conditions probables des fondations aux points où la route devra les croiser.

Ce procédé se prête au stockage des informations en vue d'une réutilisation pour une étape ultérieure ou d'autres projets.

Introduction

Environments that are stable, both geologically and climatically, often show a consistent relationship between landform, weathering and soil profile and knowledge of this tendency will be intuitively used by geologists working in such an environment. The concept becomes particularly useful when dealing with road projects where the ground conditions in the upper layers play an important role in providing construction materials, and in determining problem areas, while the requirements for foundations of structures at crossing points may be indicated by the ground conditions encountered before detailed site investigation takes place.

A major part of road construction costs may be related directly to near surface ground conditions. Estimates indicate that the location and winning of materials in the road construction industry in South Africa amounts to 70 per cent of the total construction expenditure (Kantey 1971). This compares in value to the cost of production of the raw materials in South Africa's iron and coal industry (Clausson n.d.).

South Africa's geological setting lends itself to survey and investigation methods based on landform evaluation. This can be readily utilised in the road construction industry where a systematised approach to materials and route investigation for road projects has been developed. The incentive behind this has been the possible cost saving benefits gained by the systematised description of conditions found on routes and the storage of this information for re-use on later projects. Accordingly a data storage and retrieval system has been set up called the National Data Bank for Roads (NDBR) (Clausson and Vail 1975).

This paper discusses in general terms the landform evaluation techniques as used in the South African road construction industry and how the results can be used at all stages of the project. The inherent assumptions on which this approach is based are discussed together with a description of the method of data storage and retrieval in the Data Bank. Finally, an early example of the application of this technique is outlined to illustrate how landform evaluation was used in the preliminary investigation of a road in South Africa. Typical

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retrieval data from the NDBR is compared to the results of the investigation to illustrate a use of the Data Bank system.

The road system in South Africa

The road system in the Republic of South Africa is a well defined network which, although more densely knit around the industrial and urban areas, has an interconnecting system covering much of the country. This network includes all classes of roads from unclassified farm roads up to three-lane national highways. Normally road surfacing consists of a flexible bituminous layer or natural gravel, concrete surfacing being little used. Most South African roads have a structure similar to that shown in Fig. 1 (Weinhert 1968).

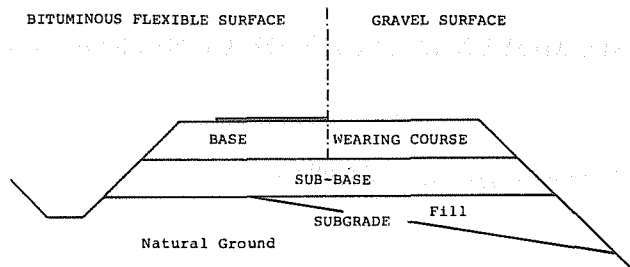


Fig. 1: Typical structure of the two main types of South African roads, with a flexible bituminous surface and a gravel surface. Not to scale. (Partly from Weinert 1968).

The flexible pavement surfacing is formed from selected aggregates, generally crushed rock, with a bituminous binder. The base is the structural layer on which the surfacing rests and is composed of good quality material able to withstand the loads to which it is subjected by running traffic and the destructive influences of environment at changes below the black top surfacing, such as moisture content variation and changes in salt concentrations. Often naturally occurring disintegrated material is used. If nothing suitable exists crushed rock may be substituted. Several Road Administrations often locally require the base to be stabilised, in which case poorer quality material may be considered.

The sub-base supports the base and its lower load carrying requirements mean that its specification is less stringent. A wider choice of suitable material is therefore available.

The subgrade refers to the natural material on the road alignment and this may be improved by reworking or stabilising. It also includes the upper layers of any earthworks before the structural layers of the pavement are placed.

Gravel roads have a wearing surface of natural material which has similar requirements to those of the sub-base. Some materials such as ferricretes and calcretes may have a self-stabilising property and are particularly suitable as they are not susceptible to break-up and erosion. Depending on the materials available differentiation between the wearing course and the sub-base may not be made.

The geological setting of South Africa

An appreciation of the geological setting in South Africa is important when considering the landform evaluation technique used in road project investigations. The geological setting is fundamentally different to that typical of the Northern Hemisphere. It has shown a high degree of crustal stability and lack of climatic fluctuation in the past. This means that soil forming processes have a different degree of influence from those in the Northern Hemisphere. Although the soil forming processes are similar in both Hemispheres, the differing importance of separate processes reflecting the different geological and climatic conditions and their variation, coupled with land use, means that entirely different weightings must be given to the basic assumption used in an investigation such as this.

Briefly the geological setting for much of the younger strata exposed in South Africa may be considered as follows. During the Upper Palaeozoic and Mesozoic a great inland basin was filled with an alternating sequence of siltstones and sandstones of the Ecca, Beaufort and Stormberg Series. These with an underlying series of tillites called the Dwyka Series comprise the Karroo System. The System is generally cyclothemic in character becoming more arenaceous towards the top while more argillaceous sequences include abundant units of coal.

Morphogenetic origin of landform

It has long been recognised that the local surface landform is a direct consequence of processes acting at that locality. For example over

much of the Northern Hemisphere V-shaped valleys are accepted to be a consequence of the downcutting of rivers, while U-shaped valleys are related to the erosive action of glacial ice. It is this same cause and effect idea that has been used to relate particular soil profiles to genetic origins: Kolb and Shockley (1957) have noted a genetic relationship between material type, its mode of formation and its geotechnical properties for the alluvial material in the Mississippi valley. McGowan and Derbyshire (1977) have interpreted variations in glacial tills as being due to variations in their mode of deposition. Therefore a cause and effect relationship exists not only between the processes and the landform, but the processes, the landform and the associated soil profile.

Where environmental changes have occurred the relationships are likely to be complicated and difficult to unravel. Since the response to change is not instantaneous but time related, the resulting profile may be very variable particularly if the environmental changes occur on a frequency greater than the time period required to develop a stable profile. The end product will also be a function of initial material condition. That initial material will vary depending at what point in the time dependent response the new processes begin to act.

In the South African situation the environmental changes have been relatively minor during the recent geological past. Landforms and soil profiles have therefore attained a balance with the processes of weathering and erosion. This relation between geology, soil profile, climate and landform has been recognised in soil science and is called a catena (Ollier 1976, 1977 b). Since the same factors which influence the soil profile, that is the mineralogy and grading, also effect the geotechnical properties, it seems logical that materials with similar engineering characteristics will be found on similar landforms in areas with the same geology, the same climate and similar relief.

Much of the geological history since deposition of the Karroo has been terrestrial in nature. The cratonic setting has resulted in little deformation of disturbance other than the intrusion of the Karroo Dolerites into the Karroo System and the extrusion of a series of basalt lavas now best preserved in the Highlands of Lesotho. The present day outcrop of the Karroo System covers some 50 per cent of the country. To the north and east the Precambrian Basement outcrops comprising a series of granites and metamorphic rocks. Folded Lower Palaeozoic rocks are found to the south. Rocks younger than the Karroo System are relatively rare and are found only as localised fold sequences at a few coastal localities, while Tertiary deposits may be found as wind blown sand flats which have spread south from Botswana.

Climatic fluctuations over the last 5 million years have been minimal other than to produce minor fluctuations in the amount of rainfall and the length of the seasons (Weinhert 1968). Therefore, the land surface of Southern Africa has existed in its present form for a considerable length of time. The drainage system has been established since the Jurassic. Consequently, the land surface may be considered as mature.

Accumulations of fluvial material do not exist because of the high elevation of the country resulting in non-depositional flow regimes. The long term stability also results in little sediment input. Therefore, the soil profile is generally related entirely to the weathering of the underlying rock. Where transported materials are found they are generally the result of prevailing conditions such as wind blown sand.

The soil profile can be related systematically to the local geological setting since it and weathering determine the development of the soil profile.

The factors influencing the soil profile in South Africa

If the soil profile is considered to consist of a unit or series of units of material with similar mineralogy and grading the factors influencing the soil profile can be discussed by considering those factors which affect the mineralogy and grading.

The degree and type of weathering to which material is subject is probably the most important factor. If it is accepted that the two extremes are pure mechanical and pure chemical weathering and that these are not mutually exclusive, then their balance will determine the mineralogy and grading in the weathering products of any one rock type. Moisture generally assists chemical breakdown, however the moisture available is not governed by the total rainfall falling on an area; evaporation needs to be considered since rainfall in areas of equally high evaporation means that little or none of the water need become available for chemical weathering. Equally the distribution of the rainfall is important. Rainfall evenly distributed throughout the year will have a higher potential for causing weathering than an equal amount falling in a limited season where ground saturation may result in much of it being lost to run-off. The temperature of the water is important since, generally, chemical reactions occur faster in warmer situations.

Weinhert (1974) has used a relationship between precipitation and evaporation to produce a numerical index value N where:

$$N = 12 \frac{E_i}{P_a}$$

where E_i is the potential evaporation during the warmest month (January in the Southern Hemisphere) calculated from the Olivier formula (Olivier 1964)

and P_a is the total annual precipitation.

In South Africa this produces a boundary value $N = 5$ above which rock will mechanically weather due to the scarcity of water and below which rocks will decompose by chemical weathering.

Although this approach is simple, field evidence suggests a good agreement with the predicted form of weathering and indicates that the micro-climatic effects are of little importance compared to the regional climatic setting. The country has been contoured for N -values so that individual values need not be determined for each site. In fact this would be difficult because of the scarcity of recording stations. The contour map itself has been produced from a limited number of recording stations, many having records that only cover a period of a few decades. That this seems sufficient to provide data representative enough to produce the map is possibly related to the continental aspect of the climate and that local variations in micro-climate are insignificant and smoothed out by the long term climatic stability.

This is in contrast to a climatic regime such as that found in Britain where the micro-climatic effects may be on a larger scale compared to the regional trend and the perturbations within that regional trend are on a scale at least as great as the regional variation. In such an environment a method of determining weathering potential similar to that used in South Africa would require a smaller scale measurement of the parameters and a longer period of measurement to determine the representativeness of any results.

The soil profile developed is also related to the slope of the ground since many of the weathering products are mobile. Therefore the three important variables to be considered when interpreting a soil profile are, the rock type, the climate and the relief.

Landform evaluation for road construction purposes

If an area of sufficient uniformity is investigated, mapping of the landform types is a viable way of mapping the material types throughout that area.

Since many of the factors in road projects are related to ground conditions landform mapping, if suitable, becomes an economically attractive form of investigation. This has many advantages where large projects involving inaccessible terrain are being investigated since it can greatly reduce the field time.

The mapping is best done from stereo-aerial photography of a suitable scale. Appropriate field checking and testing will enable a rapid appraisal of the availability and spatial distribution of material types within an area. This approach has uses at all stages of the project. During the same testing programme bad ground can be quantified by relating it to landform units. As the cost of structures at crossing points is often related to the type of foundation required rather than to the detailed design, preliminary cost estimates can be made at a very early stage. The costs of excavation and winning construction materials for roads determine the haul distance over which they can be economically carried. The haul distances may be easily determined from the spatial distribution of the landform units and the economic distance determined from the quality of the materials in the area.

Updating the evaluation as the project proceeds enables it to continue being a useful tool.

Data banking of materials for roads

The use of landform evaluation has long been appreciated and used for a variety of purposes under a variety of names (Ollier, 1977a). Nowhere has the systematic approach been developed to the same extent as used in South Africa. It was realised that if significant cost saving could be made on individual road projects with this method then re-use of the data on different projects would produce a further cost saving. Accordingly the National Data Bank for Roads was set up by the National Institute for Road Research in 1971 to collate and make available data collected during separate road projects. Since its formation a standard approach to materials investigation has been developed. Test data are submitted to the Data Bank for storage together with any other storable information (Figs. 2, 3, 6). The system allows retrieval of data according to any material specifications required.

For the purpose of the Data Bank it is assumed that only climate, geology and relief determine the material properties. These three variables define the 'material analogue'. Subclasses of each analogue are linked to the surface landform unit since it is these landform units which exhibit a close uniformity of engineering characteristics.

The main requirement for a comparison of results is that all workers use the same terminology when submitting data. The specification (NITRR 1978) requires that bedrock be determined with respect to the 1 : 1,000,000 geological map of South Africa produced by the Chamber of Mines. The relief is described in terms of standardised categories (Fig. 4). Climate is described in terms of Weinert's N -value, while the landform units are chosen according to a standard list (Fig. 5).

Thus by ensuring that information is recorded in a suitable manner, that is in the sequence (a) the material analogue, (b) the landform units encountered, (c) the soil profiles and geotechnical properties in each

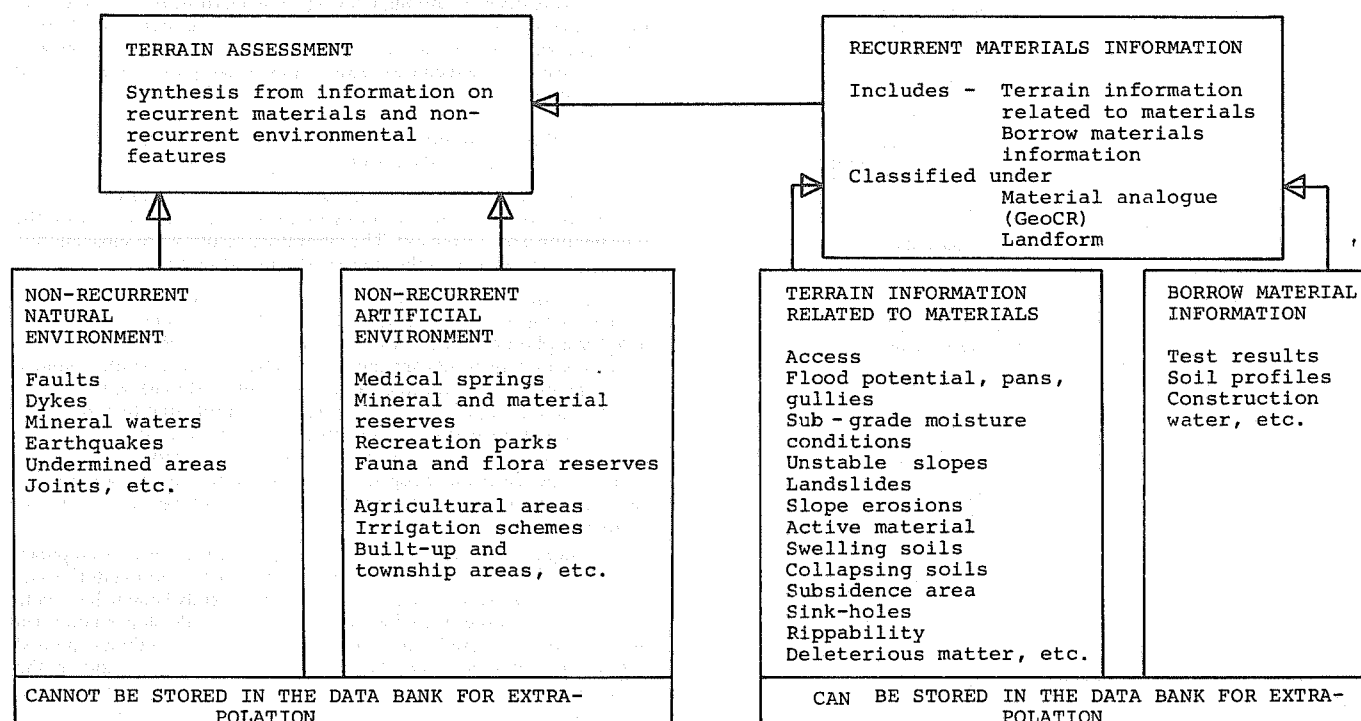


Fig. 2: Some environmental and material aspects affecting road construction and design arranged according to their banking potential (NITRR 1978).

MATERIAL ANALOGUE:		
PROBLEM (underline those encountered)	LAND FORM	REMEDY RECOMMENDED AND REMEDY APPLIED
Access		
Flood potential		
Sub-grade moisture conditions		
Unstable slopes		
Landslides		
Slope erosion		
Active material		
Swelling soils		
Collapsing soils		
Subsidence area		
Sink-holes		
Rippability		
Material contamin- ation encountered		

Fig. 3: Format for inclusion of construction problems in the Data Bank (NITRR 1978).

RELIEF CLASS	PHYSIOGRAPHIC DESCRIPTION	RELIEF (m)
1	Nearly flat plains - low relief, much of it nearly level	<5
2	Rolling and irregular plains - fairly low relief with high percentage of near-level land; no high steep slopes	5 - 100
3	Low hills - moderate relief; low percentage of near-level land	100 - 200
5	High hills - moderate to high relief; low percentage of near-level land	200 - 300
7	Low mountains and escarpments - high relief; low percentage of near-level land	300 - 1000
8	High mountains and escarpments - very high relief; little near-level ground	>1000

Fig. 4: Standardised categories describing relief for the materials analogue (NITRR 1978).

LAND FORM GROUP	DESCRIPTIVE TERMS
1 Crest	1.1 Mountain crest 1.2 Hill crest 1.3 Ridge crest 1.4 Plateau crest 1.8 Bump
2 Free face/cliff	2.1 Free face/cliff
3 Slope	3.1 Talus slope 3.2 Convex side slope 3.3 Concave side slope 3.4 Constant slope 3.5 Pediment 3.6 Dissected pediment 3.7 Landslide 3.8 Fan
4 Plains and dunes	4.1 Plain 4.2 Shifting dunes 4.3 Stabilised dunes 4.4 Dune sheet
5 Drainage features	5.1 Gully head 5.2 Gully 5.3 Pan side 5.4 Pan floor 5.5 River terrace 5.6 River bank and/or levee 5.7 Flood-plain 5.8 Swamp 5.9 Delta 5.10 Sand-bank 5.11 River channel
6 Solution features	6.1 Subsidence area (doline) 6.2 Sink-hole
7 Surface water	Dams, springs, lakes
8 Coast	8.1 Lagoon 8.2 Raised beach 8.3 Beach

Fig. 5: Descriptive terms for landform units (NITRR 1978).

landform unit, (d) the landform unit in which borrow areas were sited, (e) the methods required to win the materials (f) the engineering problems encountered in each landform unit, a store of data is accumulated which may be quickly retrieved and is suitable for use in a number of ways by the road construction industry.

An example of the use of the NDBR system

A preliminary investigation for the upgrading of a short section of existing gravel surfaced road in District Fochville, Transvaal was carried out in 1975 (Howland 1975). The investigation was carried out according to the procedure laid down in the TRH 2 specification (NITRR 1971), a former edition of the current specification (NITRR 1978). Although the specifications have changed in detail, the basis remains the same. By comparing the results of the early investigation with a computer print-out from the Data Bank on a similar material analogue it is intended to illustrate the worthiness of the system in situations similar to this.

The investigation was carried out as part of a preliminary design for the upgrading of the road. The purpose of the investigation was to assess the suitability and availability of materials within the area, without proving borrow areas, and outline any bad ground likely to be encountered. Finally, the test results were to be stored at the NDBR. Using existing stereo-photographic imagery on a scale of 1 : 30,000 a plan was produced dividing the relevant area of investigation into its component landform units. The geology was determined as Archaean Granite with surrounding sediments of the Witwatersrand System. Weinert's N-value had a value of 3 to 4. The relief was determined as one of 'rolling and irregular plain' (5-100 m). The geology and climate was determined from published data and the relief assessed from the aerial photographs. The majority of the investigation was carried out on the materials analogue Archaean Granite 2 : 2. Twelve landform units were found to be present namely

- 1.2 Hillcrest
 - 1.3 Ridge crest
 - 1.6 Tor
 - 1.7 Bornhardt
 - 2.1 Free face/cliff
 - 3.2 Convex side slope
 - 3.3 Concave side slope
 - 5.1 Gully head
 - 5.2 Gully
 - 5.5 River terrace
 - 5.11 River channel
 - 7 Dam
- 1.8 Bump in the present nomenclature (NITRR 1978)

A field check was carried out and a series of hand-dug trial pits were opened to log the soil profiles and sample material for testing. Twelve trial pits were opened although only in those landforms which the road line crossed or those which might provide suitable materials. Two or three pits were opened in the landform units of more special interest such as the convex and concave side slopes as likely sources of material and the gully and gully head since these were likely to provide bad ground conditions at crossing points. The initial series of pits were sited each in a different landform unit, the second series being sited while in the field on the basis of the results of the first set.

At the time of the investigation no data had been stored with the NDBR for this analogue, so no likely results were known before the investigation was carried out. The laboratory results were subsequently submitted for storage on the standard format (Fig. 6).

If these results are compared to an example of computer print out for a similar analogue Transvaal Belt Granite 2 : 2 relevant to the design code for asphalt pavement for National Roads (NITRR 1975, Fig. 7), it can be seen that good correlation exists between the results found at Fochville and those indicated in the print out. It should be noted that specification changes in TRH 2 and a different granite type make comparison of the two sets of results not strictly valid according to the procedure as laid down. However the method of analogue description for Fochville has been changed to conform to the current practice and the two granite types are considered not dissimilar and valid for comparison.

When comparing the two sets of data it will be noted that a discrepancy exists in the landform unit in which suitable construction material was found. The print out indicates landform unit 5.1 gully head will provide material while in the Fochville investigation the side slopes landform units 3.2 and 3.3 were found to provide material. Nonetheless a good correlation exists between the results in the print out and in the Fochville investigation. A number of reasons may account for this discrepancy in the landform unit. Since the print out is incomplete, information on the landform units 3.2 and 3.3, may indicate that they

MATERIAL ANALOGUE		ARCHAEOAN GRANITE 2:2		SUMMARY OF TEST RESULTS																													
HOLE NO.	DEPTH CM	SAMPLE NO.	DESCRIPTION	LAND FORM	SIEVE ANALYSIS (% PASSING)										SOIL MORTAR ANALYSIS			GM	PRA	AASHTO		CBR		STAB WITH	CBR @ %			LL	PI	LS			
					75.0 MM	53.0 MM	37.5 MM	26.5 MM	19.0 MM	13.2 MM	4.75 MM	2.00 MM	0.425 MM	0.075 MM	CS	FS	NAT < 0.075 MM			OMC	MOD	COMP MOIS	SWELL		95	90	90						
5	0-25	366	Silty gravel	1.2	100	84	72	62	57	52	35	22	13	5	42	41	23.1	2.6	A-2-4 (O)											19	8	3.0	
5	25-110	367	Dec granite	1.2				100	99	99	95	76	58	23	34	42	30.8	1.5	A-2-4 (O)											30	10	5.5	
10,11	0-75	369	Fine sand	5.2							100	100	64	17	35	53	16.5	1.2	A-2-4 (O)											NP	NP	NP	
10,11	75-80	370	Lam silty clay	5.2							100	99	73	32	27	44	32.0	1.0	A-2-4 (O)											21	9	3.5	
10,11	0-120	376 384	Fine sand	5.2						100	100	99	76	30	24	56	30.3	1.0	A-2-4 (O)	8.0	1985	7.4	0.1		47	35	23	NP	NP	NP			
7	10-40	368	Dark grey silt	5.1						100	100	67	32	33	41	31.7	1.0	A-2-4 (O)												13	2	0.5	
2	0-15	379 372	Silty gravel	3.3	100	84	61	44	39	36	29	22	16	7	27	49	33.2	2.5	A-1-9 (O)	6.2	2175	5.9	<0.1		72	45	23	19	3	1.5			
2	15	380 373	Dec granite	3.3		100	91	91	91	91	90	73	52	23	29	52	31.0	1.5	A-2-4 (O)	12.5	1900	11.9	0.2		26	16	8	31	11	6.0			
9	15-100	381 374	Ferricrete	3.2				100	93	77	51	44	30	10	32	49	23.0	2.2	A-1-0 (O)	7.8	2091	7.2	<0.1		43	28	15	NP	NP	NP			
9	100-200	382 375	Dec granite	3.2						100	98	90	56	17	37	51	18.6	1.4	A-2-4 (O)	7.8	2050	7.3	0.6		42	35	26	NP	NP	NP			

Fig. 6: Summary of test results for the material analogue Archaean Granite as found in the Fochville District, Transvaal, suitable for storage with the NDBR.

RESULTS OF SEARCH FOR COMBINATION OF GEOLOGY = 51, CLIMATE = 2 and RELIEF = 2
(ACCORDING TO SPECIFICATIONS IN TRH 4)

MATERIALS: 0 9

MATERIAL EXCEPTION: 0

LAYER	NATURAL OR STABILISED	SEL CRIT	LAND FORM	TEST RES	QUANTITY	OCCUR	MEAN	STD DEV	COEFF OF VAR	MIN VALUE	MAX VALUE
BASE	STABILISED 4 4CE	D	5.1	4	LIQUID LIMIT	4	22.0	14.2	64.4	1.0	32.0
					PLAS INDEX	4	3.8	2.6	70.1	.0	6.0
					LIN SHRINKAGE	3	2.4	.6	24.4	1.7	2.7
					GRAD MODULUS	0	.0	.0	.0	.0	.0
					OPT MOIS CONT	4	10.1	1.4	14.3	9.1	12.2
					MAX DRY DENS	4	2032.0	47.7	2.3	1966.0	2080.0
					COMP MOISTURE	4	9.7	1.5	15.4	8.7	11.9
					CBR SWELL	0	.0	.0	.0	.0	.0
					CBR (98%) UCS	4	2200.0	313.6	14.3	1900.0	2550.0
					CBR (95%) UCS	4	1712.5	332.6	19.4	1300.0	2050.0
					CBR (93%) UCS	0	.0	.0	.0	.0	.0
					CBR (90%) UCS	0	.0	.0	.0	.0	.0
SUBBASE	NATURAL	B	5.1	3	LIQUID LIMIT	3	25.3	2.5	9.9	23.0	28.0
					PLAS INDEX	3	5.3	3.2	60.9	3.0	9.0
					LIN SHRINKAGE	3	2.5	1.1	43.7	1.7	3.7
					GRAD MODULUS	3	1.5	.1	3.4	1.5	1.6
					OPT MOIS CONT	3	9.4	.8	8.6	8.5	9.9
					MAX DRY DENSITY	3	2078.0	26.2	1.3	2050.0	2102.0
					COMP MOISTURE	3	9.0	.9	9.9	8.0	9.7
					CBR SWELL	3	.1	.1	66.1	.0	.1
					CBR (98%) UCS	3	55.3	7.5	13.6	51.0	64.0
					CBR (95%) UCS	3	48.7	1.5	3.1	47.0	50.0
					CBR (93%) UCS	0	.0	.0	.0	.0	.0
					CBR (90%) UCS	0	.0	.0	.0	.0	.0
CODE USED:	GEOLOGY = 51 = TRANSVAAL BELT GRANITE						SEL CRIT B = SELECTION CRITERIA: LAYER				
	CLIMATE = 2 = 500 - 800 MM RAIN P.A.						STRENGTH+SWELL+PLASTICITY				
	RELIEF = 2 = 5 - 100 M						ACCORDING TO SPECIFICATIONS				
	TRH4 = TECHNICAL RECOMMENDATIONS FOR HIGHWAYS 4						D = LAYER STRENGTH+SWELL				
	MATERIALS: 9 = WEATHERED GRANITE						ACCORDING TO SPECIFICATIONS				
	LAND FORM: 5.1 = GULLEY HEAD						4 4CE = 4 CASES OF STABILISATION				
							WITH 4% CEMENT ARE ON				
							RECORD				

Fig. 7: Example of a computer print out from the NDBR (Claus 1976).

too provide suitable material. Discrepancy may exist in the usage of the terminology for landform units between different workers. Since the Fochville investigation included hand dug trial pits these were terminated when the water table was encountered. In each of the pits in the landform unit 5.1 gully head this occurred after 40 cm as a result only an upper layer of transported silt was sampled. It may also be true that direct comparison between two granites in this manner is not valid.

It seems possible that direct comparison between data gained from reports will not be possible and that a degree of interpretation of the data will be required by someone with an understanding of landform evaluation and the assumptions on which it is based. Nonetheless, from the author's limited contact with it the principle appears sound and valid in particular environmental settings.

Conclusion

The landform evaluation technique for materials surveys and ground investigation for road construction projects seems particularly suited to the environmental situation in South Africa which has a marked geological and climatic stability. Thus few modifications to the ground conditions have occurred from recent climatic or geological changes, or indeed land use changes. The upper weathering and soil profile has therefore often reached a balanced state with the local landform. By mapping in these landforms, if the climate, geology and relief are known the ground conditions can be postulated.

Acceptance of a systematic approach to the investigations enables data to be stored and re-used in a Data Bank System thus enabling con-

siderable cost saving by reducing duplication of effort in subsequent surveys. It seems unlikely that the method will replace the need for an interpretative facility in the form of personnel capable of understanding the assumptions behind the approach.

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REGIONAL GEOLOGICAL AND GEOTECHNICAL SURVEY OF SOUTH ESSEX

LEVÉ GÉOLOGIQUE ET GÉOTECHNIQUE DANS LE SOUTH ESSEX

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Summary

A comprehensive regional geological and geotechnical survey of an area of about 450 sq. km between the Rivers Crouch and Roach in South Essex has been carried out for the Department of the Environment to guide planners in the then proposed urban and industrial development to accompany construction of a third London airport at Maplin. Geological mapping, borehole, pit, trench, core penetrometer and geophysical investigations in the field were supported by laboratory studies of the mineralogy, micropalaeontology and geotechnical characteristics of the superficial, drift and Tertiary deposits of the area. These studies enable geotechnical groups and units to be identified and various presentations of the three dimensional engineering geology, principally in maps and sections at 1:25,000 scale, have been produced, both manually and by computer. The potential engineering problems are associated with landslips in London Clay, variable thicknesses and character of Alluvium and metastability of loessic "Brickearth". An engineering planning map divides the area into zones of engineering significance.

Résumé

Le levé synthétique régional, géologique et géotechnique d'une aire de 450 km² environ située entre les rivières Crouch et Roach, dans le South Essex, a été effectué par le Ministère de l'Environnement, pour guider les planificateurs vers un développement industriel et urbain proposé pour accompagner la construction du troisième aéroport de Londres à Maplin. Les levés sur le terrain, carte géologique, sondages, puits, tranchées, essais au pénétromètre carottier et levés géophysiques furent complétés par des études de laboratoire: minéralogie, micropaléontologie et caractères géotechniques des dépôts superficiels,