FOUNDATION & FOOTINGS SOCIETY (VIC) LTD
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BUILDING ON FILL

What are the risks and problems?
How to test fill and minimise the risks.

1. BUILDING ON FILL.

Fill comes in 4 basic categories :-

a) Controlled.
b) Shallow - Uncontrolled.
c) Deep - Uncontrolled.
d) Very deep - Uncontrolled.

a). Controlled Fill

Fill that is supervised to comply with the requirements of AS 3798 Geotechnical Testing Authority supervision level 1 & tested at the frequency of Table 8.1. All such work must be documented, otherwise the fill cannot be deemed controlled.

b). Shallow Fill

A depth of fill that does not exceed the minimum founding depth of a standard footing system or a depth that can be compacted in one lift. For a slab foundation this depth is 250mm loose or 200mm compacted. For a footing system a depth that is less than the maximum for the underlying natural material. Say 350mm for 'M' & 500mm for 'H'.

c). Deep Fill

Depth of fill, such that cost of founding through it, is greater than that for a site that is unfilled, but not too deep so that a sophisticated engineer design footing system is required ie. Maximum approximately 1m.

d). Very Deep Fill

Depth of fill such that extensive site investigation, bearing capacity and an engineer designed footing system is required.

2. FOOTINGS FOUNDING IN UNCONTROLLED FILL

Cost Considerations

The classification of naturally occurring soils and prediction of the behaviour of these natural soils is extremely difficult on the basis of a few holes. However, assumptions are made based upon the hypothesis that the Geological Formation of this material can be deemed sufficiently uniform.

The major requirement for boulder fill is that all the voids between boulders must be filled with finer grade material, otherwise pockets of differential settlement can occur as fines collapse into voids between boulders.

In the case of rock fill, strength is not usually a problem as rock is an excellent engineering material, differential settlement is generally the major design concern.

Settlement and bearing capacity need to be considered for both sand and gravel fill.

b). Cohesive material

Compacted clays exhibit residual strengths that are lower than natural clays at the same density. Therefore, to ensure compacted clays are of sufficient strength they must be compacted to at least 95% Standard. Investigation needs to determine;

- plasticity of the material. i.e.: low, medium, high
- Yearly seasonal heave of the material. (Ys value)

AS 2870.2 in this circumstance requires that Ys calculations be carried out without the influence of the cracked zone. This means that the classification for deep fill may jump one level i.e. from M $\Rightarrow$ H or H $\Rightarrow$ E.

This Ys determination is a mandatory requirement of AS 2870.2.
Other parameters must be determined:

- Strength - Based on unconfined compression/triaxial test or insitu strength tests.
- Settlement - Based on consolidation, plate bearing tests.
- Differential Movement. - Based on Engineering Judgement.

Unless the filling has been fully supervised, thoroughly tested for its compaction characteristics and all such work can be fully documented this fill must not be deemed as controlled.

If investigation of areas deemed as controlled fill ;

(a) encounter topsoil either under the fill (ie: site improperly stripped prior to placing fill) or

(b) significant pockets are encountered within the fill, then the compacted fill must be regarded as UNCONTROLLED.

Saturated silts have little or no strength and are unsuitable engineering materials.

	ITEM	CATEGORY		TICK BOX	COMMENTARY
	DEPTH	Shallow	(0 - 200)		If slab compact.
		Medium	(200 - 900)		Suspended slab or compact in layers or footings found through.
		Deep	(900 - 3500)		Suspended slab or pier & beam or footings found through.
		Very Deep	(3500 +)		Suspended slab or pier & beam.
	STATUS	Controlled			Determine Ys value.
		Uncontrolled			See Depth Comments.
DESCRIPTION	COHESIVE MATERIAL (Plasticity)	Low			Softening with water.
		Medium			Controlled-omit crackzone for Ys/Uncontrolled-see depth.
		High			Controlled-omit crackzone for Ys/Uncontrolled-see depth.
	COHESIONLESS MATERIAL	Sand			Usually OK determine.
		Gravel			Settlement potential.
		Cobbles			ie: plate bearing tests.
		Boulders			OK if well filled between.
	COMPACTED	Well	95% - Std		Can still be a problem if well dry of optimum moisture content.
		Medium	85 - 94 % Std		Determine settlement plate bearing etc...
		Poor	< 85%		Found through or compact in layers.
	WASTE	Builders			Can be OK if clean.
		Domestic			Test for decomposition.
		Industrial			Test for pollution.
LONG TERM BEHAVIOR	SETTLEMENT	Low	< 25mm		Plate bearing or consolidation fines washing into voids.
		Medium	< 50mm - 25		
		High	> 50mm		
	Potential to COLLAPSE	Low			Depends upon quantity of hollow objects especially steel drums and car bodies.
		Medium			
		High			
	Potential to DECOMPOSE	Low			Depends upon quantity of timber, rags, grass cuttings and rotting garbage.
		Medium			
		High			
	Potential to DISSOLVE	Low			Depends upon the quantity of chemical wast to dissolve.
		Medium			
		High			
ENVIRONMENTAL	HYDROCARBONS	Low			High quantities can be polluting to ground water, If contained, cover with concrete, otherwise remove & replace.
		Medium			
		High			
	HEAVY METALS	Low			High quantities may be injurious to public health Remove and replace or cover with concrete.
		Medium			
		High			
	INSECTICIDES	Low			High quantities may be injurious to public health Remove and replace or cover with concrete.
		Medium			
		High			
	OTHER DANGEROUS CHEMICALS	Low			PCBS etc Treat as for insecticides.
		Medium			
		High			
	STATUS OF UNDERLYING NATURAL MATERIAL	Poor			If fill better clad, adjustable structure.
		Good			May be OK. See Depth.
		Excellent			See depth smaller footings.

THE FOUNDATION AND FOOTINGS SOCIETY(Vic)

WORKSHOP 95

SECTION 7

SOME CURRENT ISSUES IN BUILDING EDUCATION AND RESEARCH

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SOME CURRENT ISSUES IN BUILDING EDUCATION AND RESEARCH

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INTRODUCTION

The paper addresses issues which , currently , are some cause for concern in the education of practitioners in the building industry involved with foundations . It also looks at topics of interest to Engineers , Builders , Foundation Investigation professionals , Building Surveyors and other Practitioners in the industry .

The concerns of the industry cover some of the following points:

- site characterisation
- structure flexibility
- user acceptability of structure response
- foundation type appropriate to load
- interaction of trees and structures
- moisture management of sites
- public education of crack tolerance
- education level of practitioners
- continuing education programs

EDUCATION

TERTIARY EDUCATION IN BUILDING

The courses which have been accredited by the Australian Institute of Building as providing the academic requirements for Associate or Corporate Membership of the AIB have grown in the past few years . The traditional base has expanded from Melbourne University, RMIT ,VUT and now includes such newcomers as Swinburne University of Technology which was accredited in 1995 .

All of the courses accredited cover such topics as building and construction processes , materials, structures , foundations , hydraulics , materials ,

economics , planning , communication etc. . Few deal with post construction performance , analysis and rehabilitation of damaged structures .

POSTGRADUATE STUDIES

Postgraduate studies by coursework which specifically address the topics raised by other speakers in the workshop are very difficult to find in the current range of programs offered at Tertiary level in Victoria . In 1993 , a serious attempt was made by a group of academics in Geomechanics to introduce a postgraduate course in Foundation Engineering . Unfortunately , the project did not come to fruition ,as there was doubt that the course would be economically viable and that the administration of the course would be too complex as it was designed to be run by a consortium of Universities.

Courses in building and construction management are available and some of these deal with the technical aspects of construction . However ,coverage of the topics which have received emphasis in this Workshop is not to the depth which some practitioners would require .

RESEARCH

Research at the Ph.D. and Masters level in the performance of lightly loaded structures on clay and fill soils has not received much attention in recent times . There are no large Grants from the ARC supporting Research Centres in the areas of interest and ARC Collaborative grants are few and far between.

At Swinburne University, in the School of Civil Engineering and Building , ,currently there are 5 research students , whose topic is somewhat related to the interaction of light structures and soils . The major support for the research comes from the road and transport industry .

CONTINUING EDUCATION FOR PRACTITIONERS

Continuing education has been provided through professional organisations . The introduction of new codes has resulted in the Australian Standards Association in running seminars to bring interested parties up to date . Workshops are very useful but all too rare . The Foundation and Footings Society provide an annual series of talks on subjects of interest to the members and provide a good model for other groups . The Institution of Engineers , Australia has an excellent program of presentations by professionals designed to keep the profession aware of current developments . The Australian Institute of Building has similar programs .

Occasionally , short courses have been mounted for professionals in the Foundation and Footings area . However , there have been too few in recent times .

There is a requirement for any professional to keep knowledge current . This is being reinforced in the courts of the land on a daily basis . The Institution of Engineers has a requirement of 150 hrs of continuing education every three years for corporate membership to be maintained .

EDUCATION FOR THE END USER

The owners and occupiers of light structures who observe the movements of the structures have little frame of reference to determine if any movement is a problem or not . The slightest crack is a cause of great concern . The users of light structures need to be informed of what has to be taken seriously and what should be regarded as within normal limits .

Each owner should have a plan to reduce moisture change under the structure to a minimum during the life of the structure . Garden plantings , the watering program and the site drainage all need to be considered by the Owner . The Owner should be able to feel that the cracking of the structure can be controlled .

RESEARCH TOPICS

SITE CHARACTERISATION

The assumption that the characteristics of any site can be determined from one borehole or from an inspection of a geological map have been challenged . From agricultural science sources , it has been found that the distribution of soil can not be expected to be uniform .The figure attached to this paper (Fig 1 , 2) illustrates the differences which have been measured in a particular fields . The proportion of the clay was not found to be uniform throughout the site and hence movement prediction could also not be uniform . Depending on the location of the boreholes different site classifications could be possible .

In 1994 , a series of individual sites were examined to determine the proportion of expansive clays at various locations and depths , using the Methylene Blue test . In one site , the movement of the structure was recorded and correlated with the proportions of clay found in the laboratory tests . The diagrams below show the results of that investigation . (Fig 3 , Fig 4 , Fig 5)

This topic is worthy of further investigation to see if limits of variability can be established which would give a better prediction of differential movement than the current mound theory can render .

REHABILITATION OF DAMAGED HOUSES ON EXPANSIVE SOILS

If a structure has been subjected to movement caused by change in the volume of expansive clay , normally the structure has the damaged panels replaced together with some underpinning of the foundation . If the cause can be sheeted home to tree root penetration or a broken water pipe then the cause would be remedied .

It has been very unusual to find that the plan to rehabilitate has been based on stabilisation of the moisture regime . This option is available in expansive clay soils which have dried out . Those clay soils which have high swelling pressures (usually the Montmorillonitic clays) which exceed the applied load can have moisture added which would lift the structures back to the desired levels .

Research into this approach has been carried out in a pilot study and is now the subject of a Master's thesis in progress

The rehabilitation of a two storey full brick federation dwelling in Abbotsford using water recharge wells resulted in the recovery of cracking displayed in the diagram below . The present research indicates that the recovery is seen to be slow when compared with the current techniques of water recharge (Fig 6).

FLEXIBILITY OF HOUSES AND WALLS

The more flexible a structure the more tolerant it is to movement . The flexibility of a light structure depends on the material of construction , the complexity of the plan view and the ability of the walls to absorb movement without any obvious sign of distress .This concept is reflected in AS2870 but it is not well articulated .

Where the possibility exists of expansive clay producing substantial movement of light structures , the option of providing a more flexible structure which is tolerant of relative movement must be considered .The designer should be in a position to offer advice on the degree of flexibility required in the proposed structure and how that might be provided .

The table below gives some broad guidelines concerning flexibility of light structures :-

	STRUCTURAL FLEXIBILITY		
FACTOR	**FLEXIBLE**	**SEMI - FLEXIBLE**	**STIFF**
Construction Material	Timber	Brick Veneer	Cavity Brick
Plan View	Square	Rectangle	H shape
Wall length	Short	Medium	Long
Wall Openings	Floor to Ceiling	Normal Door and Window Openings	No Openings or Joints
Number of Storeys	One	Two	Three or more
Tolerance to Movement	Tolerant	Tolerant to Some Movement	Not Tolerant
Foundation Requirements	Required to support load only	Required to support load and to resist some movement	Required primarily to resist movement

Little research has been carried out locally to determine a " Flexibility Number" which could be determined for a particular structure which would lead designers to seek combinations of the factors in the table above which would result in foundations designed primarily for structural support.

PUBLIC EDUCATION OF CRACK TOLERANCE

The public become alarmed at a level of cracking in structures which is far below the limit at which the Engineer becomes concerned about structural integrity and safety . Engineers have been caught up in court cases for " failure" of structures which have been sound , and which could be fixed with the garden hose and some flexible filler .

The owners and occupiers of existing structures need to understand the movement which could occur , the likely extent and what role they can play . Structures require maintenance and so do the foundation systems to ensure satisfactory behaviour . The provision of foundation systems which are guaranteed to resist all movement has become prohibitively expensive .

Little work has been done to set up an educational program for owners . There is no research on crack tolerance levels by the population or the extent of cracking which produces high anxiety states in people who occupy dwellings which are cracked .

APPROPRIATE FOUNDATIONS

The presence of the structure has an effect on the change of volume of the expansive soil due to the pressure exerted by the structure .For the highly expansive clays , the uplift pressure due to swelling of the clay from the dry to the wet state exceeds the applied pressure and causes the structure to move . Any shrinking of the clay also results in associated movement .

None of the movement described above is related to shear failure of the soil supporting the foundations . As a minimum , the foundations have to be designed to accommodate the loads of the structure . There is no fundamental reason to provide foundations to do any more than that .

There is a requirement to devise design philosophies to account for the support required by the structure and the movement generated by soil volume change . Research is needed which addresses each of the requirements separately so that the most efficient solution for each problem can be found .The table below illustrates some of the options .

NO.	FOUNDATION OPTIONS	ACCOMMODATION OF MOVEMENT
1.	Shallow Strips	Flexible Structure
2.	Shallow Piers	Adjustable Pier Heads
3.	Slab Foundations	Flexible Structure
4.	Deep Foundations	Flexible and Adjustable Pier Heads

HOUSES AND TREES

Where movement on an expansive clay site has been attributed to the moisture content change due to tree roots , the conventional wisdom has been to remove the tree or to install " root barriers " of somewhat questionable efficiency . Other options have rarely been investigated . Management of the tree moisture uptake by pruning and pollarding has not normally been considered by the Engineering or Building Consultant . Provision of an assured water source away from the affected structure has not often been suggested in the past as a solution .

Advice about planting of trees and shrubs has been part of the Australian Standard for some time . However , few , if any reports , contain advice on tree type , shrub type for planting on sites with expansive soil . There has been little interaction between the Consultants and the Aboralculturalists to produce such plans .

One of the great attractions of the Melbourne urban regions has been the high density of tree plantations . This environment needs to be preserved into the future but in such a way that it does not interfere with the structures and urban infrastructure . More research is required to establish guidelines for future planting in new or reestablished subdivisions .

SITE MOISTURE MANAGEMENT

One approach to reduce movement on expansive clay sites is to manage the soil moisture content so that it varies little throughout the seasons . With movements reduced to minimal levels , the option of providing light shallow foundations for light domestic structures could be taken up .

There is little in Engineering literature which deals with this concept . Passive methods of preserving moisture levels using surface seals and vertical moisture barriers have been used in the past and have been the subject of recent and continuing research at Swinburne University of Technology .

Active techniques of raising moisture levels in dry soils in a systematic fashion to restore existing structures or to prepare a site for construction have been examined and are under research presently at Swinburne University .

FUTURE NEEDS FOR EDUCATION

The current undergraduate programs in Civil Engineering and Building are already heavily loaded with difficult concept and subject matter . Although difficult , space must be found to introduce the concepts of the behaviour of lightly loaded structures on expansive soil in an integrated approach . Very little else would be possible in the core of the course , but further elaboration may be possible in an elective and certainly could be provided as an undergraduate research topic .

There are no coursework postgraduate programs in Geomechanics and Structure and Soil interaction available at present . Discussion was held amongst the interested academics in 1992/3 and it was concluded that a need existed . Some course outlines were prepared , but no further action has been taken . It would be useful to encourage this group to continue their work with a view to offering the program in the near future .

It is some time since a set of short courses has been offered in Foundation Engineering and Geomechanics . There is a need to offer such courses to service the continuing education needs of the interested parties .

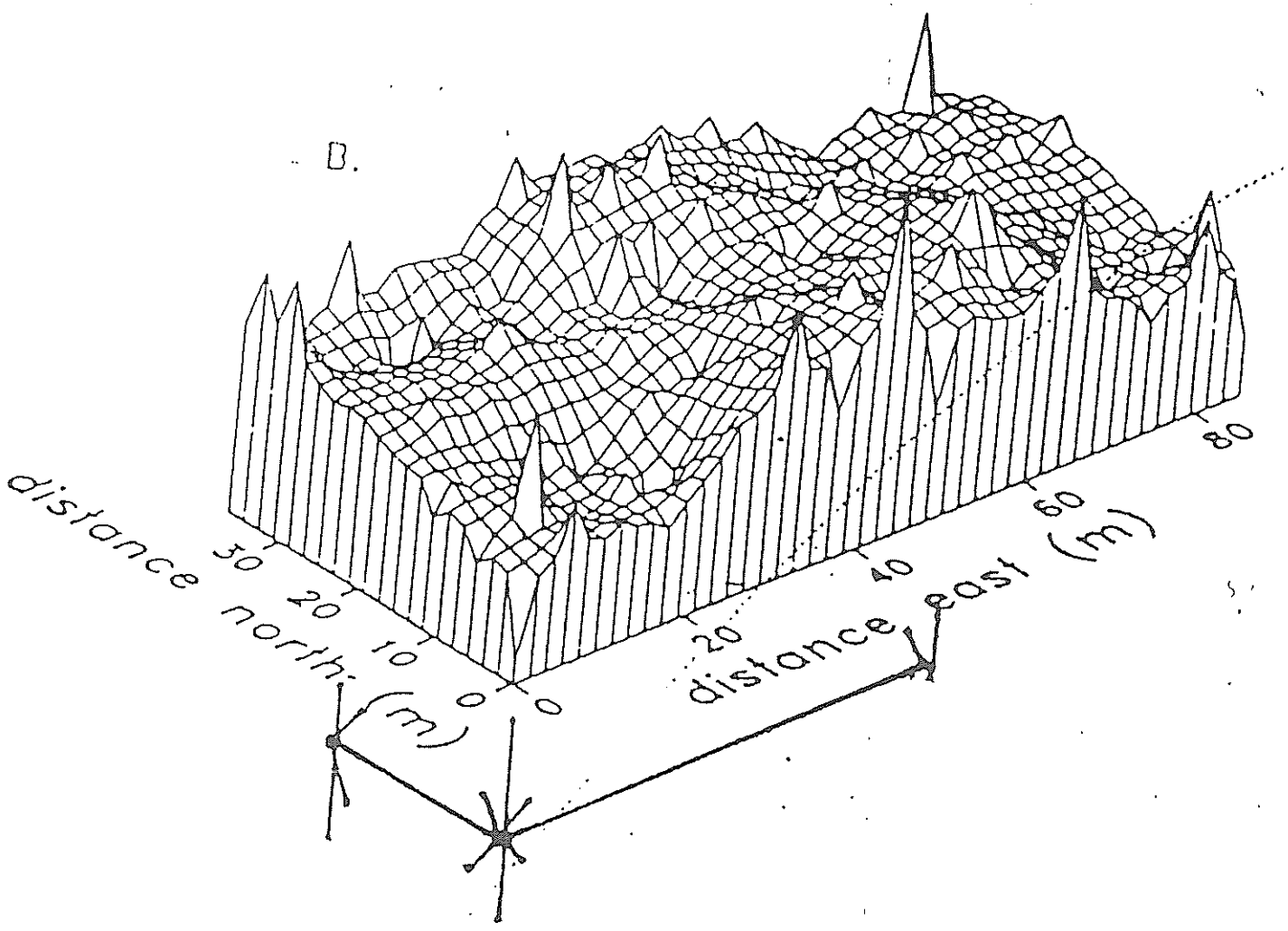
The area which needs most attention is in applied research . Some of the topics of interest have been discussed in this paper . This can only be encouraged by supporting postgraduate students with funding . At least $ 20 000 per annum is required to support a postgraduate student and the Master's degree normally takes a minimum of 3-4 semesters . For the industry to have such research , the funds must come from the industry .

f: scandata/ conworks.doc

FIGURES

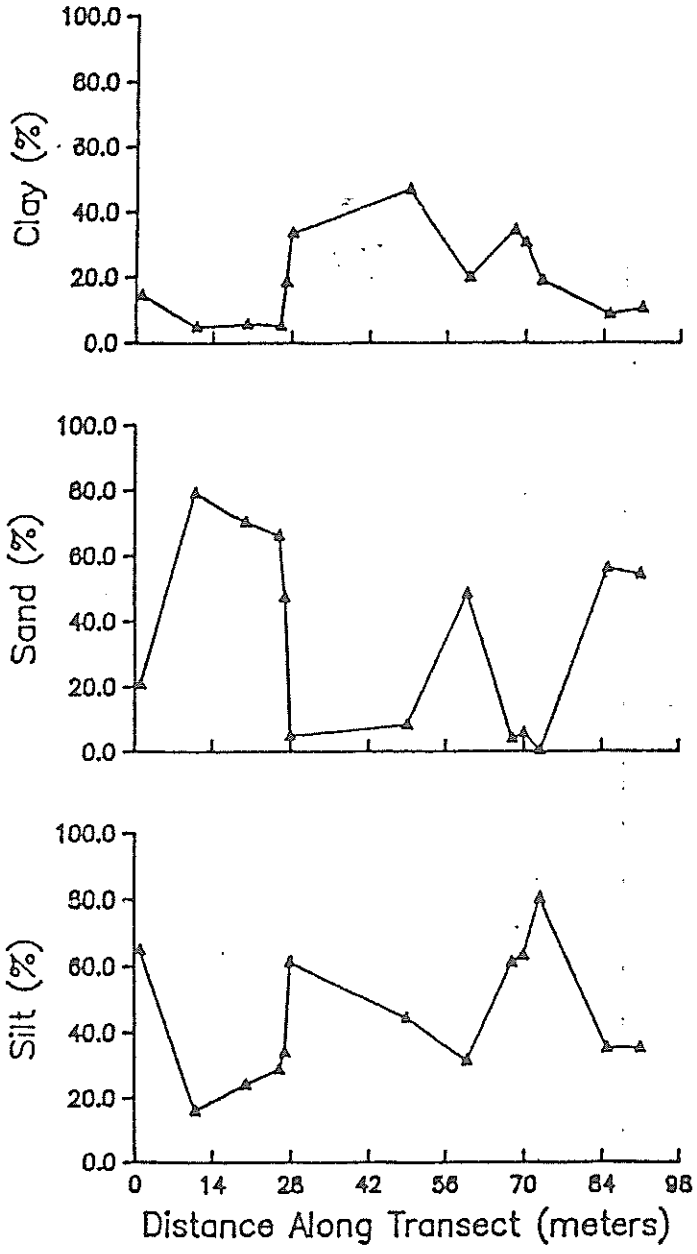
1. Clay Content Distribution in a Field.
2. Variations in Clay , Sand and Silt content at m with distance along the transect.
3. Apparent Surface Area of Soil at Keilor Sites.
4. Apparent Surface Area VS Depth.
5. Movement at Wyndham Vale Site.

FIGURE 1



clay content

FIGURE 2



Variation in clay, sand, and silt content at 0.60 m with distance along the transect.

FIGURE 3

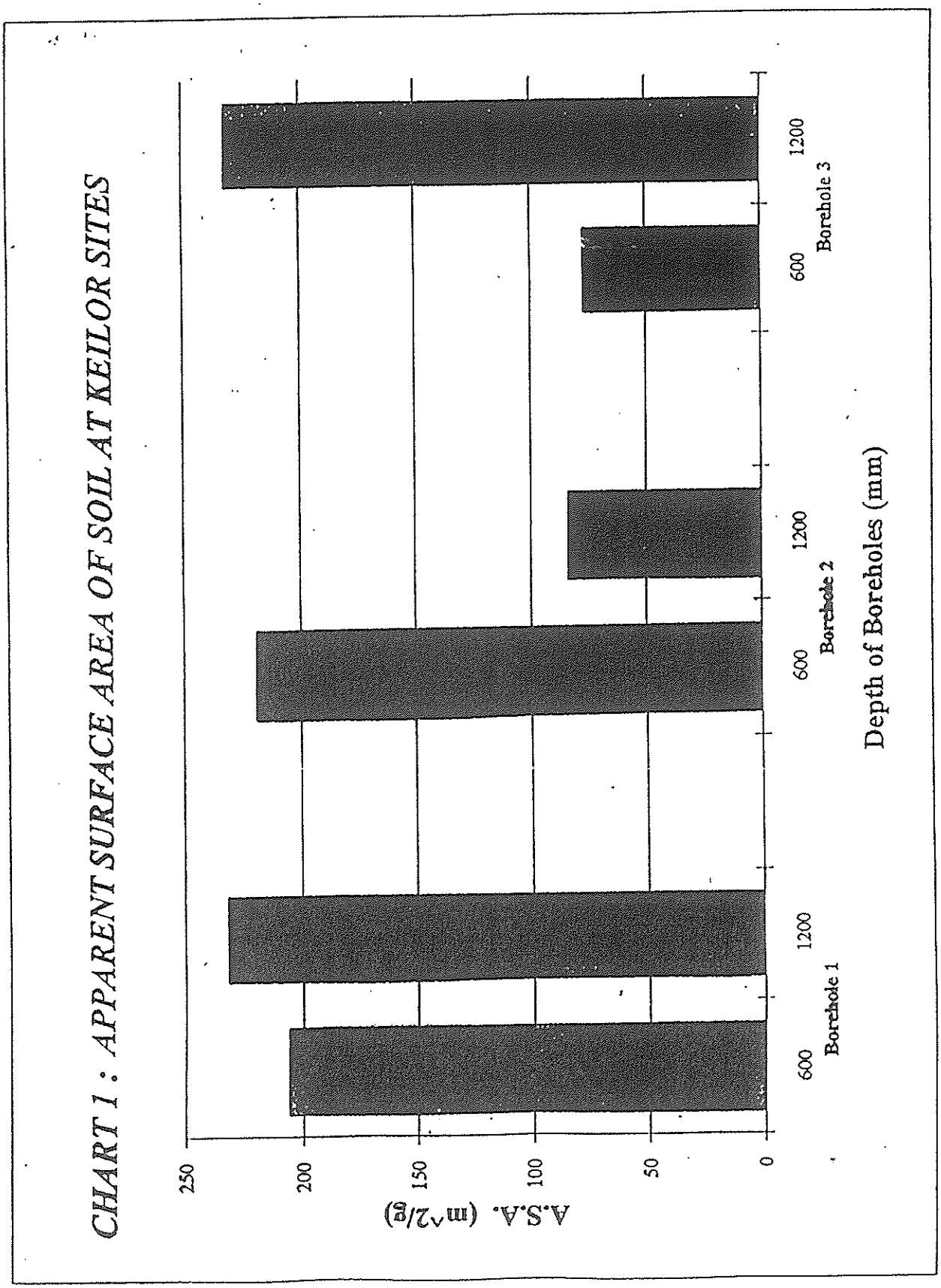


CHART 1 : APPARENT SURFACE AREA OF SOIL AT KEILOR SITES
A.S.A. (m^2/g)
250
200
150
100
50
0
600
1200
Borehole 1
600
1200
Borehole 2
600
1200
Borehole 3
Depth of Boreholes (mm)

FIGURE 4

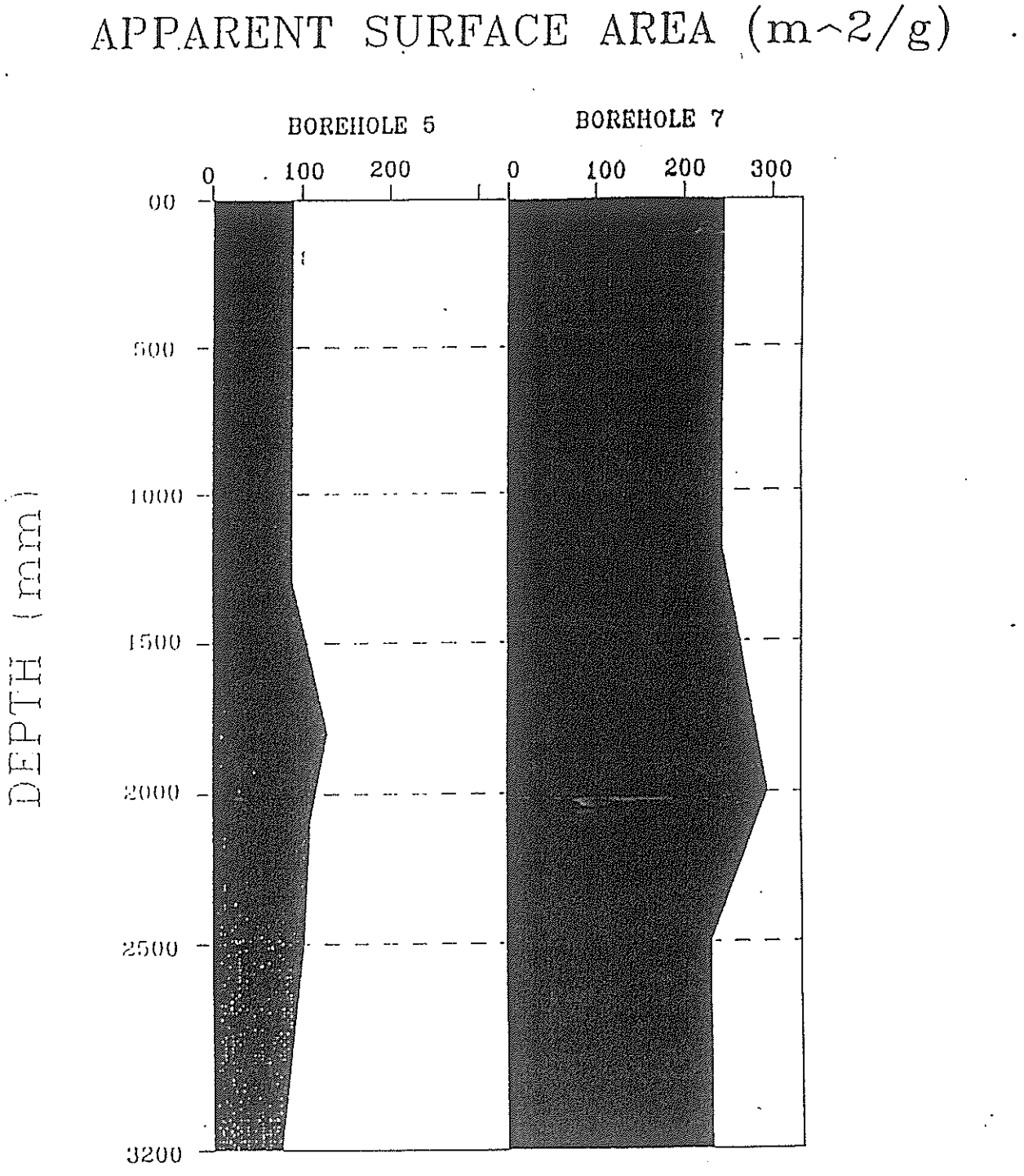
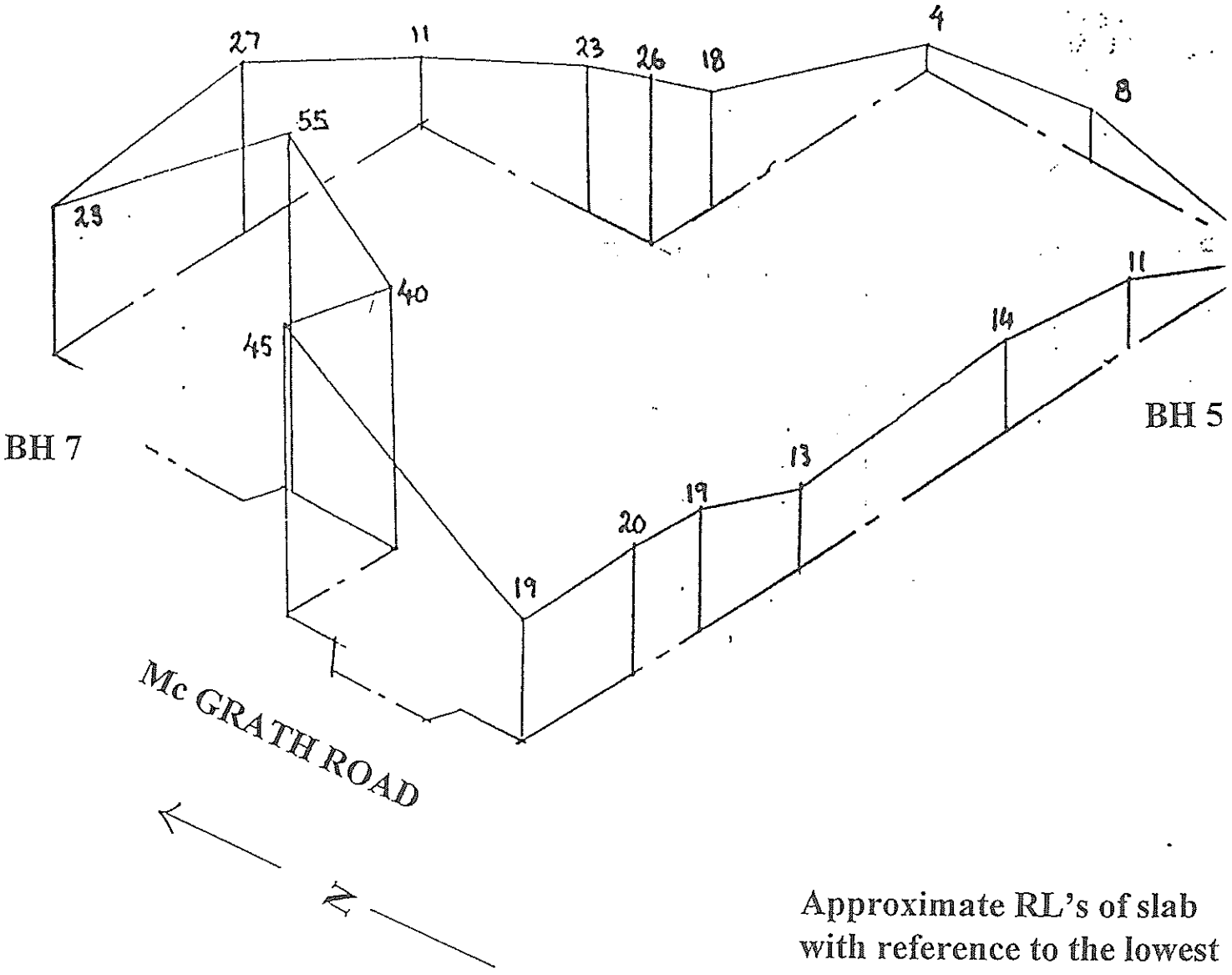

APPARENT SURFACE AREA (m^2/g)
BOREHOLE 5
BOREHOLE 7
0
100
200
0
100
200
300
00
500
1000
1500
2000
2500
3200
DEPTH (mm)

FIGURE 5

SITE :
250 Mc GRATH ROAD ,
WYNDHAM VALE



Approximate RL's of slab with reference to the lowest level of the slab (all measurements in mm)

FIGURE 6

PLOT OF CRACK WIDTH vs TIME
ABBOTSFORD FEDERATION HOUSE