

differ significantly from small scale laboratory results. In addition, it is not possible to model or even map all the faults, dykes and joints present in the rock mass.

Very often, therefore, it is necessary to select a range for each of the above parameters and to try to assess their influence on the final results. In addition, analyses are often carried out to compare the relative stability of a number of different geometries or to assess the effect of different primitive stress conditions on a particular geometry rather than to predict categorically the stability of a given excavation. Confidence in the method is obtained once predictions have been observed in the field.

The above uncertainties are imposed by the particular problem at hand. These have to be considered together with the numerical uncertainties imposed by the particular numerical technique being used. When boundary element or finite element analyses are carried out, one of the first questions concerns the size of the grid or mesh. One rule of thumb which has proved particularly useful is described in some detail below.

It is not advisable to attempt calculating stresses within one element width of each element, where the width is defined as the square root of the element area. This restriction arises primarily from the assumption that displacements and tractions are constant over any one element. As a result a displacement jump or discontinuity arises at each element boundary resulting in localised stresses which are infinite. The tractions, however, usually vary much more slowly than displacements except of course at edges or corners, where the true tractions are discontinuous. If it is necessary to calculate stresses within one element width, then these should be calculated over the element centroid rather than above the element boundaries (Diering, 1980b).

This simple rule leads to numerous other rules of thumb which assist the user in drawing up a boundary element mesh.

- (i) The aspect ratio of these areas of adjacent elements in the same plane should not exceed 4 or 5 to 1.

- (ii) When a tabular excavation is being modelled, elements on opposite surfaces of the excavation should be separated by at least one element width.
- (iii) Elements on opposite sides of solid material should be separated by at least three element widths. This enables a reasonable stress distribution to be obtained within the intervening solid material.
- (iv) The angles between elements at corners or edges should exceed sixty degrees, if possible.
- (v) At least two and preferably three elements should be used to span the side or edge of an excavation.

The following factors contributed towards drawing up and explaining the above rules.

- (a) The use of numerical integration of limited accuracy can be expected to break down if elements are too close to one another.
- (b) Considerable experience has been gained from the use of the two-dimensional programme MINAP (Crouch, 1976) and three-dimensional displacement discontinuity formulations for tabular excavations (Starfield and Crouch, 1973).
- (c) The use of the programmes to model problems for which analytic or other solution were available.

In addition, it was found that a badly specified boundary element mesh usually produced a set of equations which was divergent or converged very slowly.

The above rules were used in drawing up the meshes for the practical examples which are described below. It should be borne in mind at all times that the computer programmes described here are merely tools which provide the engineer with stress and displacement information about a real problem. Interpretation of the results to predict failure or select pillar sizes etc must still rely on engineering judgement and experience.

9.1 Programme BEM

9.1.1 Underground excavations close to surface

A nickel mine in Southern Africa is at present mining two major ore bodies in close proximity. The larger and smaller are here termed orebodies A and B respectively. Collapse of the 18 m thick crown pillar above the workings in orebody A prompted a stress analysis of the situation to determine whether further failures could be expected. The complexity of the situation required a three-dimensional analysis. Even so, the geometry was considerably simplified as shown in Fig 9.1 for the analysis. The situation was modelled as a homogeneous elastic problem using 300 boundary elements and stresses and displacements were determined at numerous points in and around the crown pillars of the two excavations.

From the displacements it was apparent that overall surface uplift occurred as a result of mining but that the immediate hangingwall of excavation A subsided under its own weight. An extensive zone of horizontal and vertical tension was revealed by the calculated stresses and this can be attributed to the surface deformation pattern. A representative example of the tensile zone is shown in Fig 9.2 as a NE-SW section through the centre of the excavation. Because rock is weak in tension and because of extensive weathering of the near surface rock, it was possible to delineate a potential zone of failure around excavation A. In this zone, failure would typically result from the combination of tensile failure close to surface and shear failure extending down to the excavation. Calculated shear stresses in this region exceeded measured values of cohesion. The modelled and observed failure zones are shown in Fig 9.3. The actual failure zone extended approximately 40 m to the north of the modelled failure zone, this difference being due to the presence of a weak geological contact (between the talc carbonate host rock and neighbouring greestone). Calculations show that it is also possible that

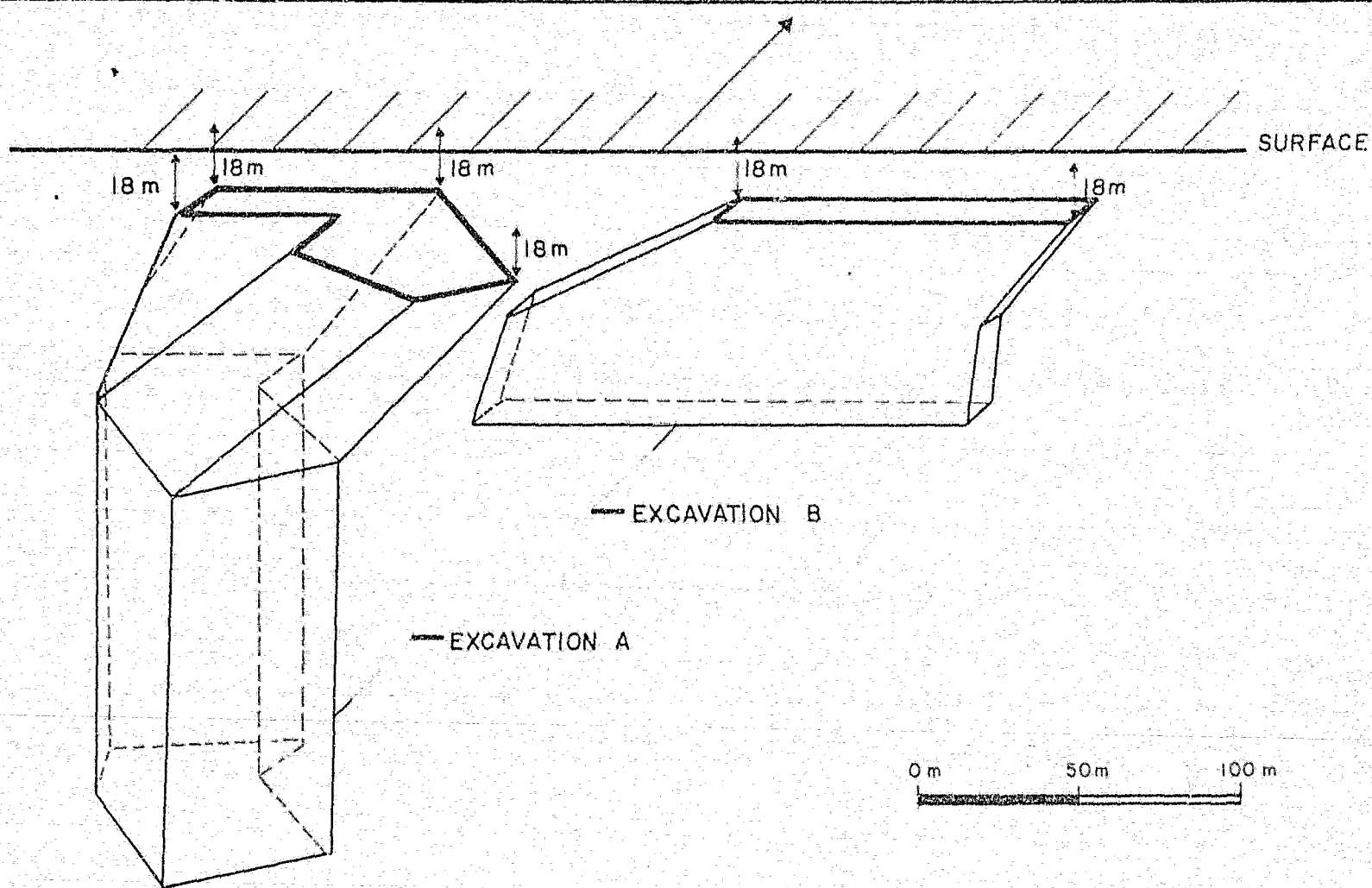


FIG. 9.1 GEOMETRY USED TO MODEL FAILURE OF CROWN PILLAR ABOVE EXCAVATION A

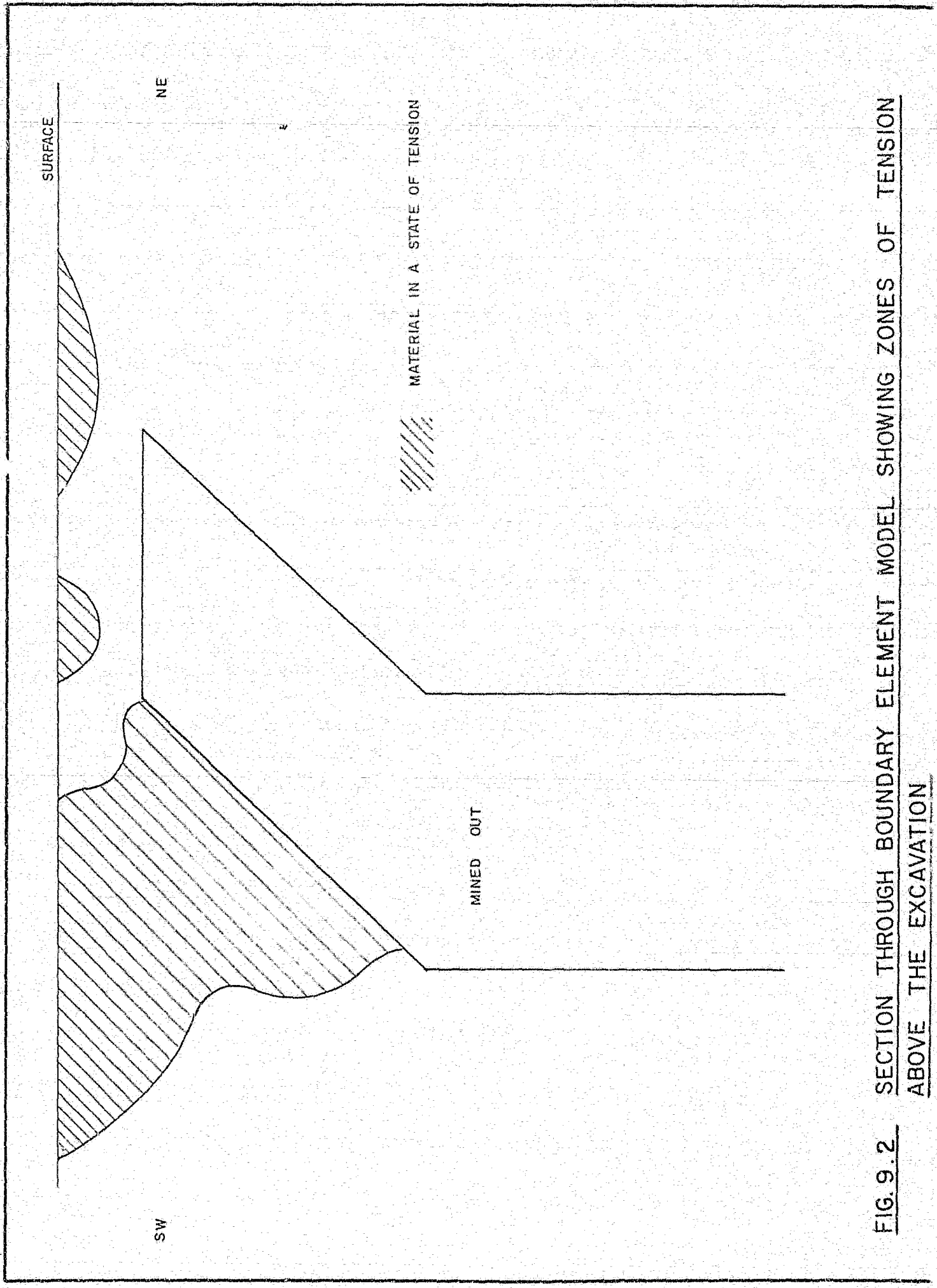
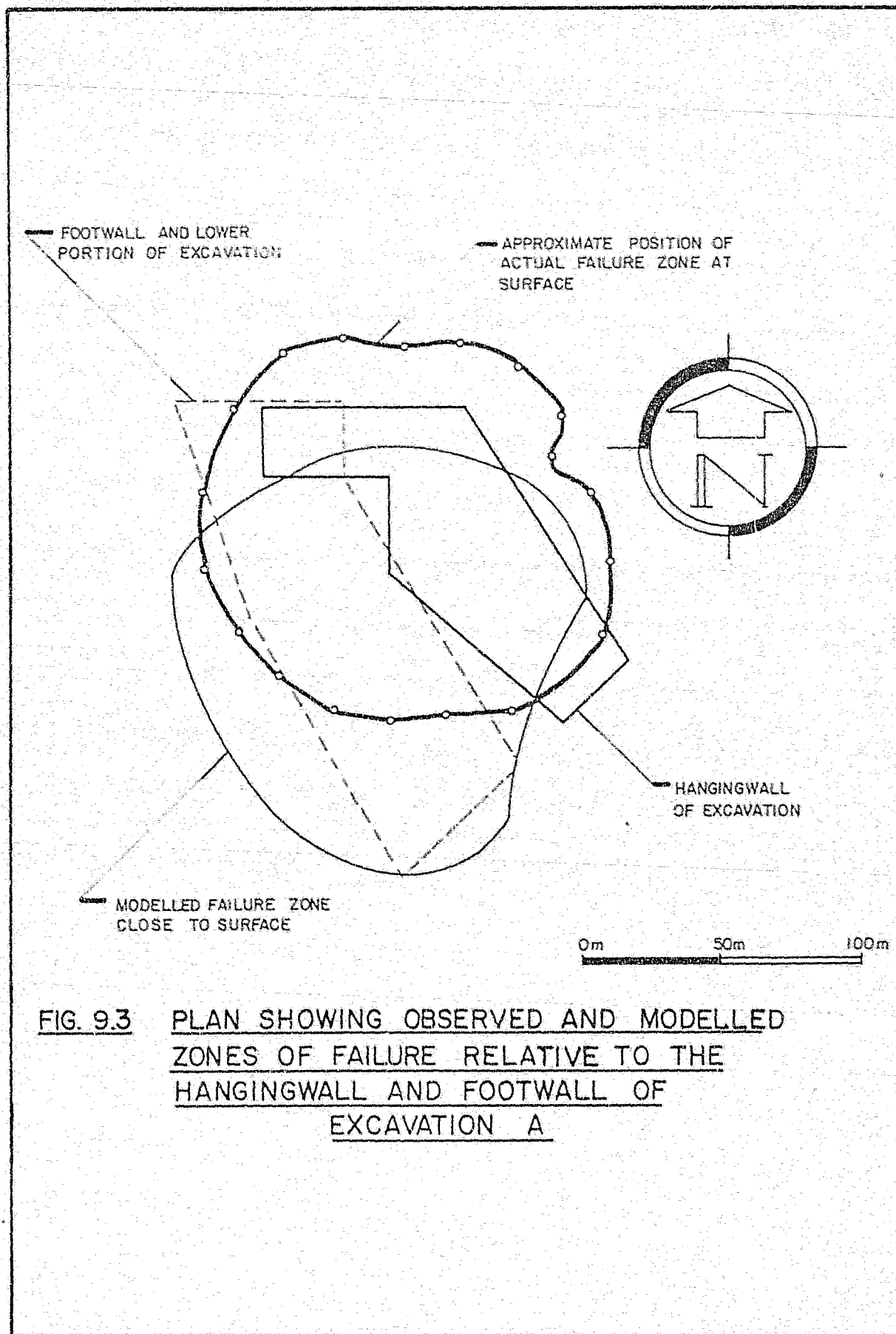


FIG. 9.2 SECTION THROUGH BOUNDARY ELEMENT MODEL SHOWING ZONES OF TENSION
ABOVE THE EXCAVATION



further collapse of the crown pillar will take place south of the present zone. This corresponds with future mining at depth which will be further to the south as shown by the plan outline of the lower portion of excavation A in Fig 9.3.

It is important to emphasize that this analysis was carried out using a bare minimum of boundary elements and after making several simplifying assumptions about the excavation geometry. Thus failure of excavation A was able to be modelled by a simple elastic boundary element analysis while excavation B, which has a smaller span, was shown to be stable due to the absence of any extensive tensile zone.

9.1.2 Interaction of underground and open pit excavations

Fig 9.4 shows a schematic representation of the geometry for this problem. A number of items were of interest, the most important being:

- (i) the stability of the crown pillar between the underground and open pit excavations,
- (ii) the stability of the hangingwall above the larger underground excavation,
- (iii) the optimum size and shape for the pillar between the stope and larger underground excavation (Fig 9.4), and
- (iv) the stresses below the stope, since this is where ore-passes and service excavations are located.

Use was made of one plane of symmetry to reduce the total number of elements, but more than 350 elements were required for the problem. Unlike the previous example, stresses and displacements were required at a number of widely separated points, so that a fairly uniform and fine mesh was required. As the primitive stresses were not known with any certainty,

crown pillar will take place south of the present zone. This corresponds with future mining at depth which will be further to the south as shown by the plan outline of the lower portion of excavation A in Fig 9.3.

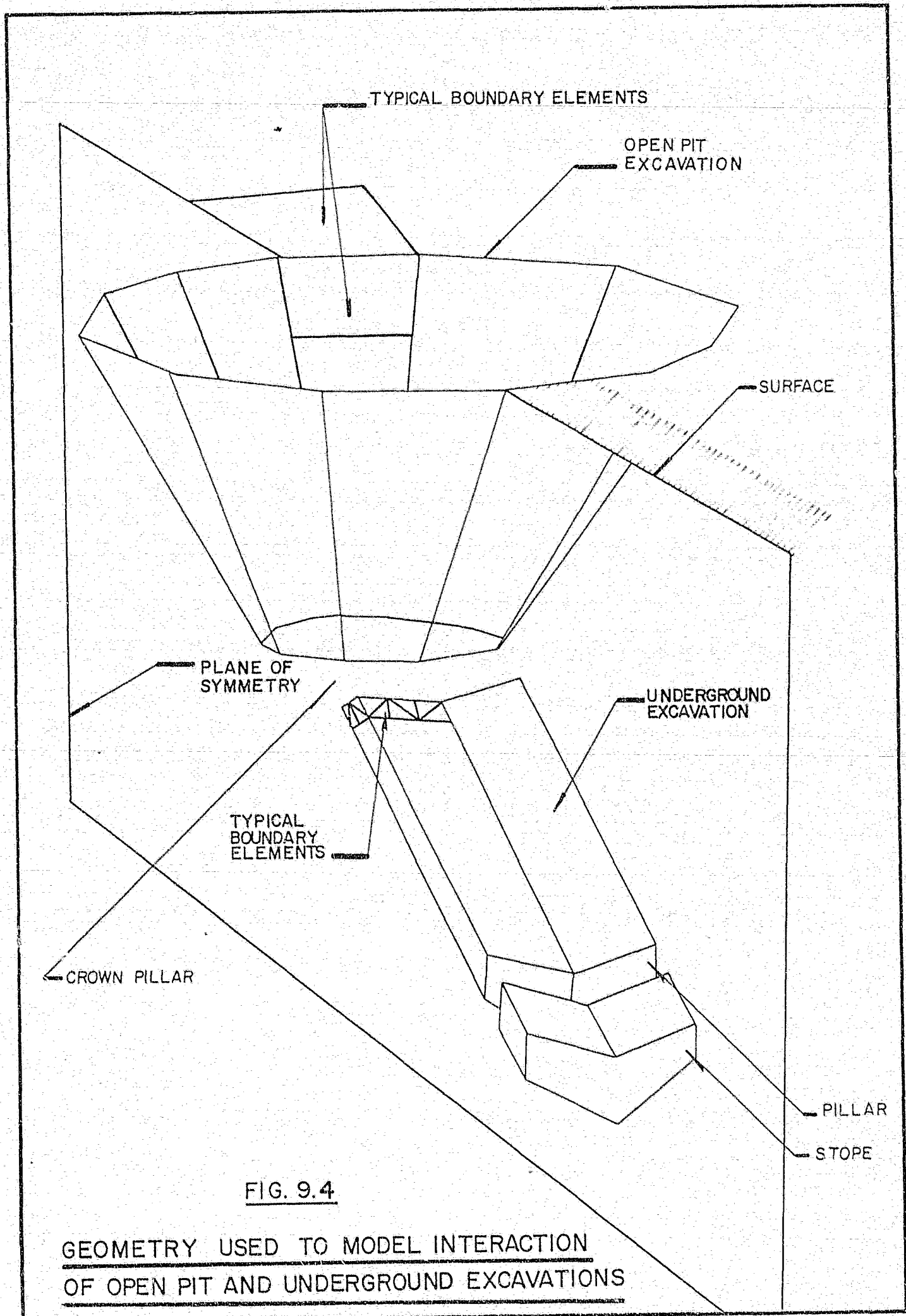
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it was necessary to do a number of different runs to check the effects of different primitive stress states.

It proved worthwhile to write a small programme which generated a line or plane of points or benchmarks at which stresses were to be calculated. For example, three planes of benchmarks were inserted into the pillar between the stope and underground excavation and three in the stope footwall.

Typically, from two to four hundred points were selected as benchmarks and again it proved worthwhile to write a small programme to analyse the points. This programme highlighted areas of high tension, or high shear on specified planes. It also described the position of each point, ie five metres in the footwall of the stope or fifteen metres in the hangingwall etc. It is felt that this type of "post processing" facility should form an integral part of the analysis cycle.

Thus a fairly simple analysis was able to provide adequate information to the design engineer enabling him to answer the above questions with increased confidence.

9.1.3 Circular pile in sandstone

Although this is not a mining problem, it is included here since it demonstrates the interaction between subregions with different elastic properties as well as the effects of slip across the vertical interface between pile and sandstone. 186 elements were used together with 2 planes of symmetry. The pile diameter was 1,8 m and the vertical pile load equivalent to 5,28 MPa (Fig 9.5). Table 9.1 gives a comparison of vertical stresses and displacements at various points and it is seen that the load shedding characteristics of the pile depend significantly upon the choice of cohesion and angle of friction. The pile and sandstone moduli were:

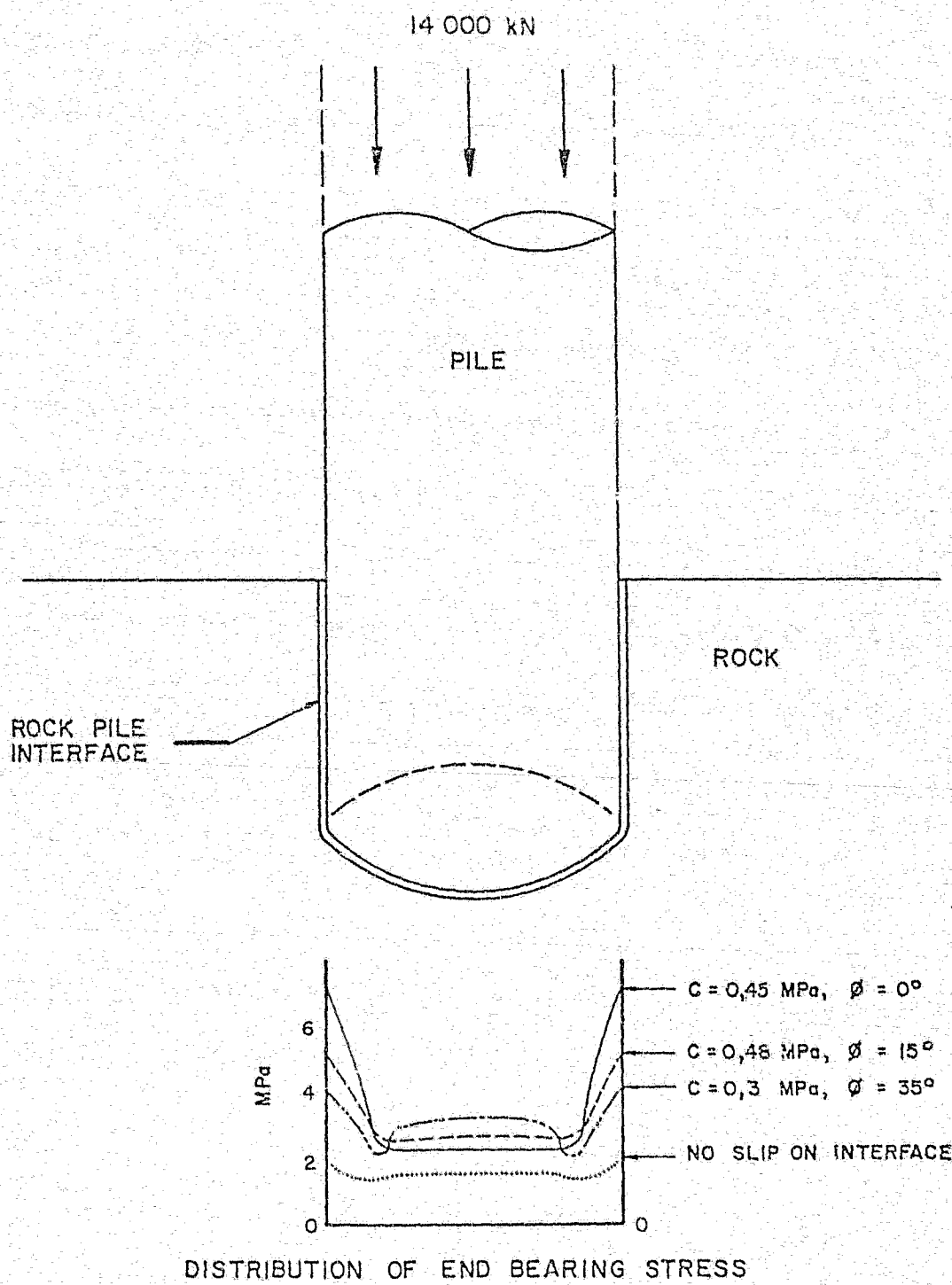


FIG. 9.5

PILE SOCKETED IN SANDSTONE

$$E_1 = 26\,000 \text{ MPa}$$

$$\nu_1 = 0,22$$

$$E_2 = 20\,000 \text{ MPa}$$

$$\nu_2 = 0,25$$

respectively.

TABLE 9.1: LOAD SHEDDING OF CIRCULAR PILE AND SETTLEMENTS FOR VARIOUS COHESIONS AND ANGLES OF FRICTION

Item	Run 1	Run 2	Run 3
Cohesion (MPa)	9999	0,48	0,45
Angle of friction	30°	15°	0°
Settlement (mm)	0,95	1,07	1,10
Vertical stress below centre (1)	1,40	2,40	2,60
Resisting stress at surface (2)	3,00	0,90	0,45
Pressure at base edge of pile(3)	1,40	3,80	4,0
Vertical stress at radial distance of 1,5 m 0,25 m below pile (4)	0,50	0,31	0,28

In particular, Table 9.1 shows how the load is transferred directly below the pile as cohesion and angle of friction of the pile/sandstone interface are reduced. The load distribution at the end of the pile is also shown in Fig 9.5. It should also be noted that no other boundary element formulation has been found in the literature capable of modelling this particular situation.

9.2 Programme MBEM

9.2.1 Tabular underground excavation close to an open pit excavation.

A copper mine in Central Africa is currently mining two tabular ore bodies, the upper by open pit and the lower by underground block caving. As the two excavations approach one another, the stability of the open pit slopes is gradually being reduced. The problem was well suited to an analysis

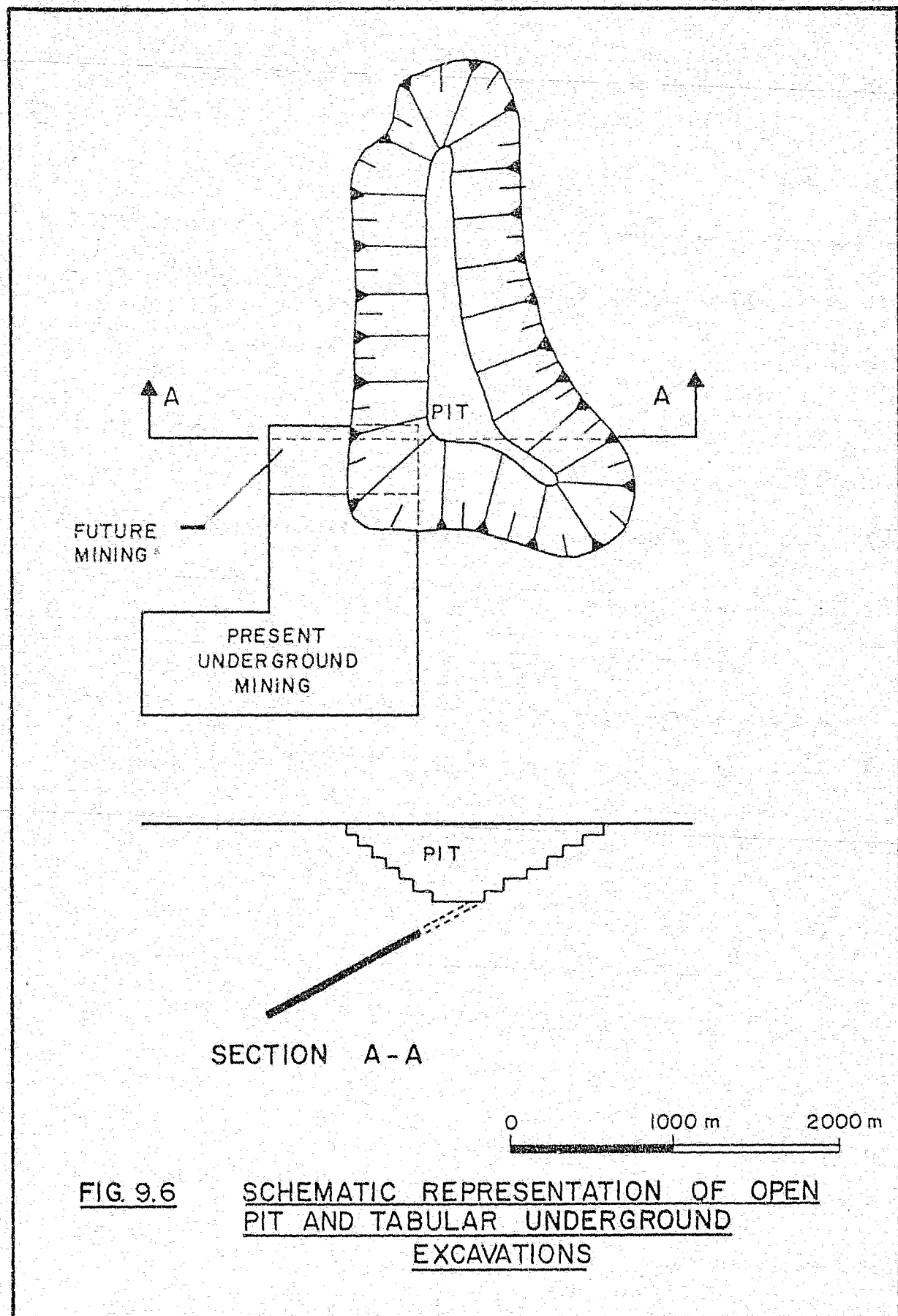
using the mixed boundary element programme. Some 220 boundary elements were used to model the open pit and surrounding ground surface, while the underground excavation was initially modelled with a 12x12 and subsequently with a 20x24 grid of displacement discontinuity elements. A schematic representation of the situation is shown in Fig 9.6.

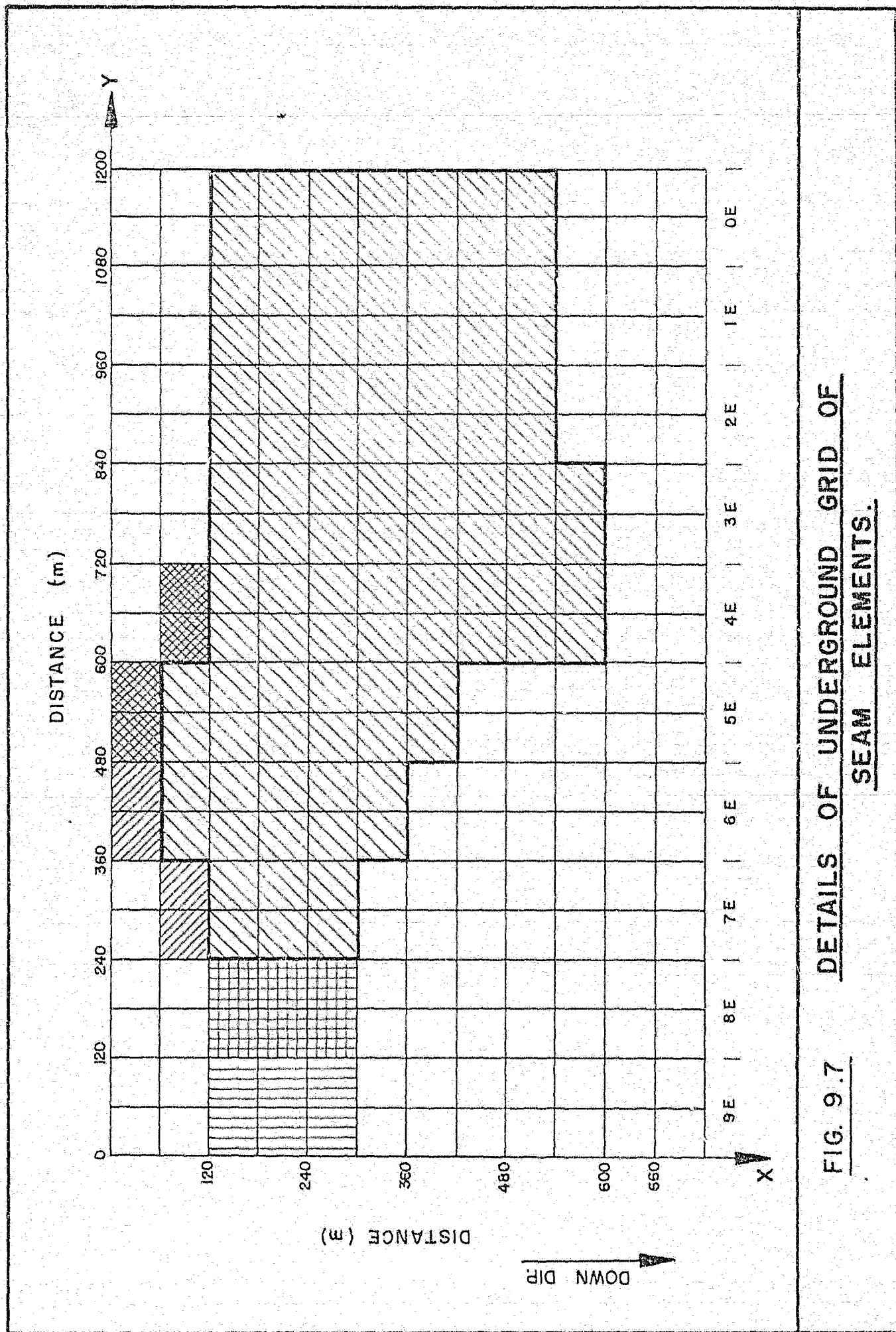
This example differs from the previous examples in that displacements, not stresses, were of interest. Although the surrounding rockmass is grossly non-homogenous, this simplified homogeneous elastic analysis was carried out with the aim of correlating surface elastic deformations with observed cave cracks. Since the boundary element method gives displacements more reliably than stresses, it was felt that the rather coarse mesh of 220 elements was adequate.

A major advantage of the displacement discontinuity element formulation is that it is easy to alter the underground mine layout without having to re-draw the entire mesh. Contours of surface displacements for various underground mine layouts were used to assess relative influences of open pit and underground mining in each case. Details of the grid used to model the underground mining are shown in Fig 9.7. Different shading patterns show the extent of mining for various alternatives. A typical contour map of vertical displacements for the "present" mining layout is shown in Fig 9.8.

9.2.2 Tabular excavation close to a vertical fault

The presence of major faults in the gold mines of Southern Africa gives rise to numerous rock mechanics problems. In particular, large amounts of energy may be released as the mining approaches a fault. As the energy released sometimes manifests itself in the form of rockbursts and often results in adverse mining conditions, the manner in which the fault is approached is of considerable importance. Two-dimensional modelling of this type of situation has been well described by Crouch (1976). Usually, however, the mining and fault make up a fully three-dimensional problem.





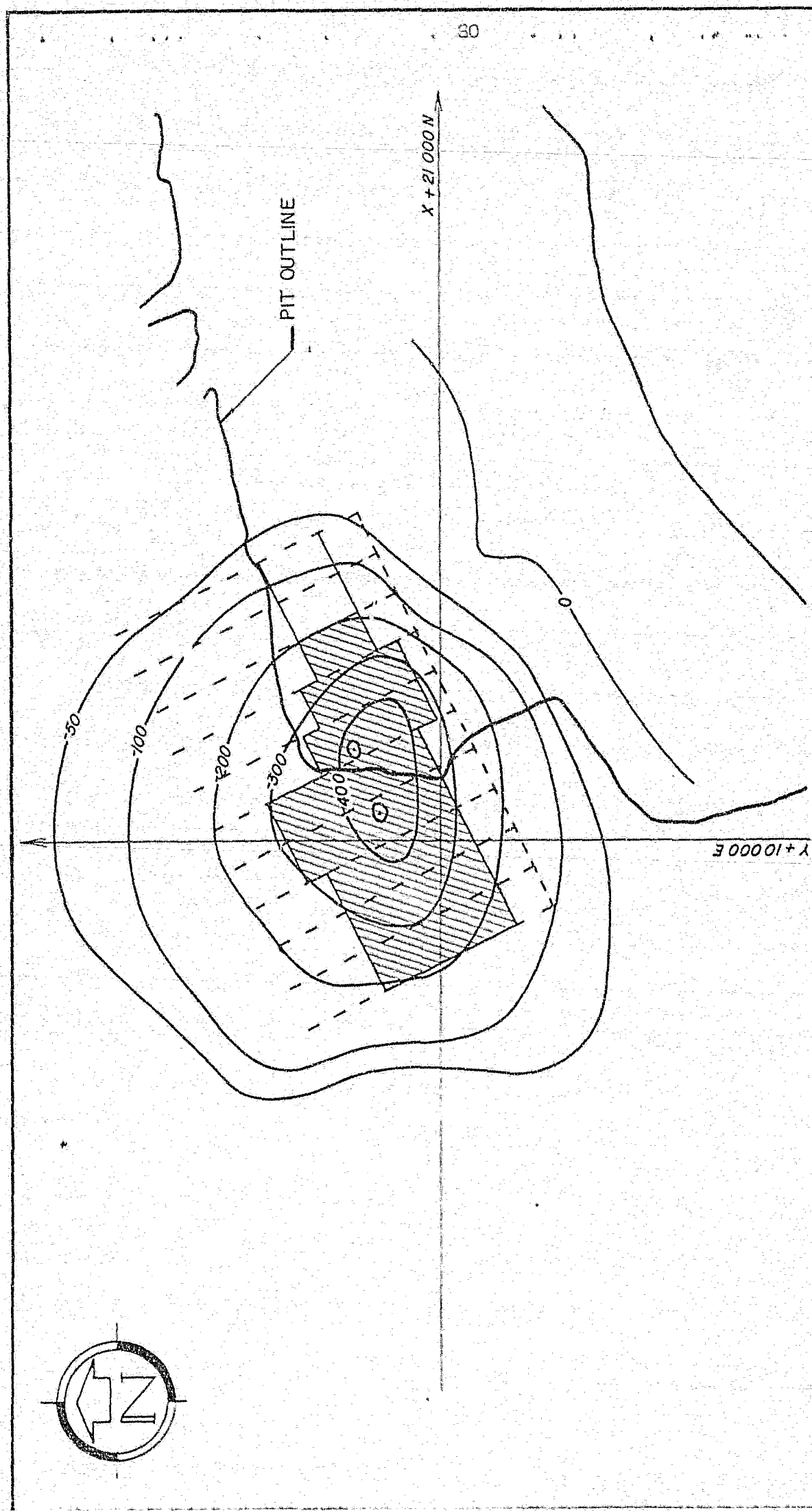


FIG.9.8 : CONTOURS OF VERTICAL DISPLACEMENT (Z DIRECTION)

— PRESENT MINING SITUATION UP TO 7E

A simple test problem was devised to test the MBEM programme. A six by six array of displacement discontinuity elements was placed perpendicular to a ten by ten array of double or interface boundary elements (Fig 9.9).

Two mining steps were carried out and in the second step, the amount and extent of slip occurring along the fault was much greater than for the first step. Material properties and loading for the analysis were:

Young's Modulus	=	60 000 MPa
Poisson's Ratio	=	0,2
Fault Cohesion	=	0
Fault Angle of Friction	=	10 degrees
Vertical Primitive Stress	=	60 MPa
Horizontal Primitive Stress	=	30 MPa

Table 9.2 shows variation of closure vs distance from the fault along a section normal to the fault through the centre of the excavation. The three-dimensional programme RIDE was used to obtain check values for the case in which no fault was present. (ie no fault slip allowed). Maximum fault shear displacements are also shown in each case.

TABLE 9.2: FLAT REEF INTERSECTING A VERTICAL FAULT

Programme	Step	Fault Slip	Fault Shear (mm)	Closure (mm)					
				15 m	45 m	75 m	105 m	135 m	165 m
RIDE	1	NO	0	63	90	103	103	91	64
MBEM	1	NO	0	61	88	102	102	89	63
MBEM	1	YES	30	81	96	105	104	90	63
MBEM	2	YES	53	125	127	130	125	110	83
MINAP	-	NO	0	120	163	181	181	163	120
MINAP	-	YES	125	268	258	245	224	192	136

Although this is a very simple analysis in which a bare minimum of fault interface elements and displacement discontinuity elements were used, it demonstrates the marked difference between equivalent two and three-dimensional analyses.

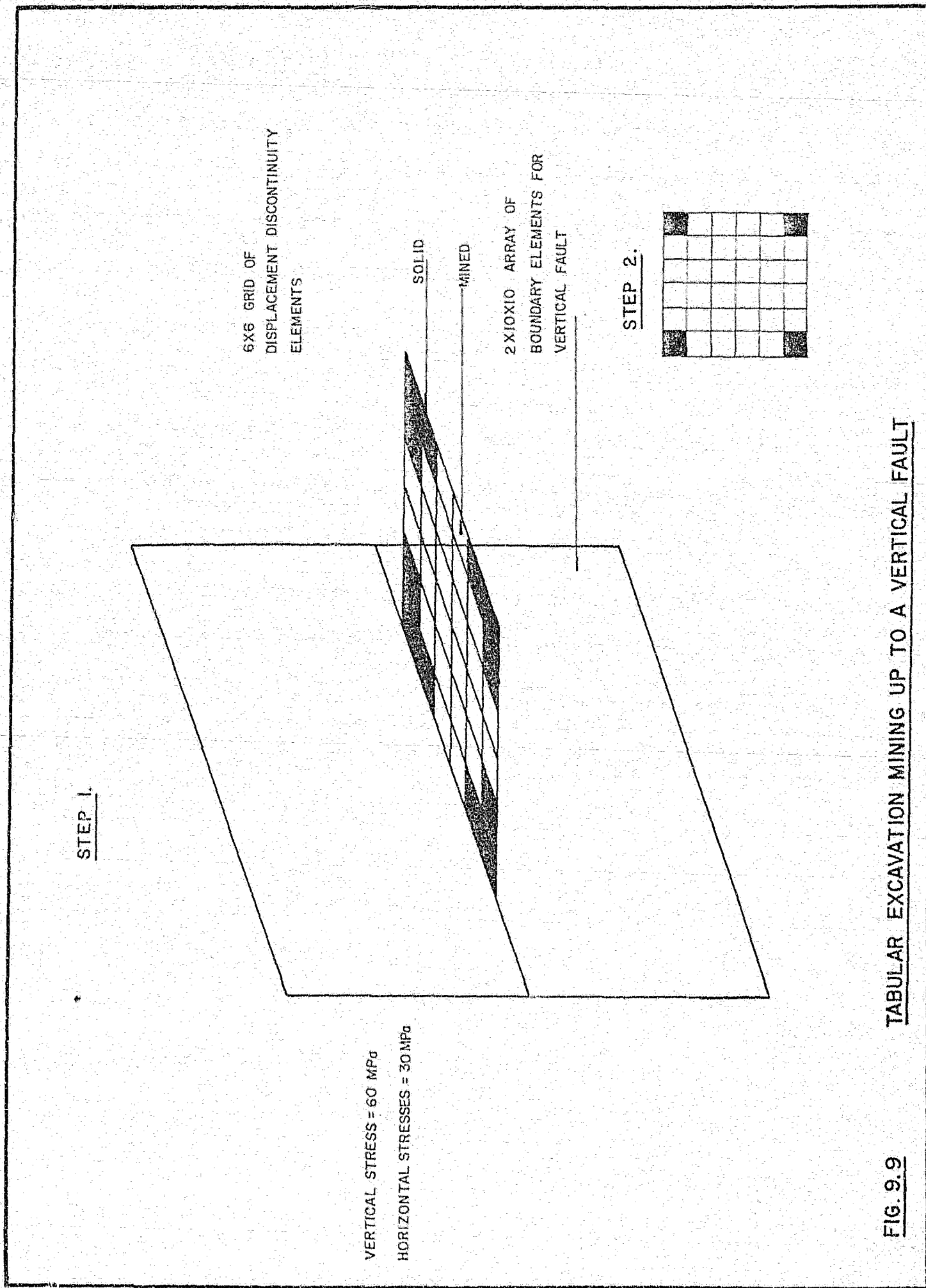


FIG. 9.9 TABULAR EXCAVATION MINING UP TO A VERTICAL FAULT

It also shows that thousands, rather than hundreds, of elements are required to model this type of problem realistically in practice. The simple type of analyses is nevertheless useful for studying representative problems and for modelling general effects.

9.3 Programme MINAPH

9.3.1 Mining of a coal seam below a dolerite sill

Many South African coal mines have coal seams which are overlain by fairly thick dolerite sills. The stresses in these sills and their effect on stresses in and around the coal seams are of considerable interest. Fig 9.10 shows an example selected to test the MINAPH programme for this type of problem. The stresses and displacements for the 12 reference points in Fig 9.10 are given in Table 9.3. These values are compared with an equivalent homogeneous run.

TABLE 9.3: COMPARISON OF STRESSES AND DISPLACEMENTS FOR NON-HOMOGENEOUS AND HOMOGENEOUS ANALYSES

Reference points	Non-homogeneous model			Homogeneous model		
	u_y (m)	σ_x (MPa)	σ_y (MPa)	u_y (m)	σ_x (MPa)	σ_y (MPa)
1	-0,043	0,6	1,1	-0,039	1,0	0,4
2	-0,044	0,5	1,4	-0,040	0,8	0,1
3	-0,044	-6,4	0,3	-0,042	0,3	-0,1
4	-0,044	-2,1	0,0	-0,044	-1,0	-0,1
5	-	-	0,0	-	-	0,0
6	0,011	-1,4	0,3	0,013	-0,2	0,2
7	-0,035	0,5	1,3	-0,032	0,4	1,6
8	-0,034	-5,9	2,8	-0,030	0,0	2,9
9	-0,034	-5,0	6,4	-0,023	-0,4	4,6
10	-0,029	0,3	10,7	-0,023	0,8	9,4
11	-0,011	-	12,9	0,010	-	12,0
12	-0,006	-0,5	0,2	-0,003	0,7	8,6

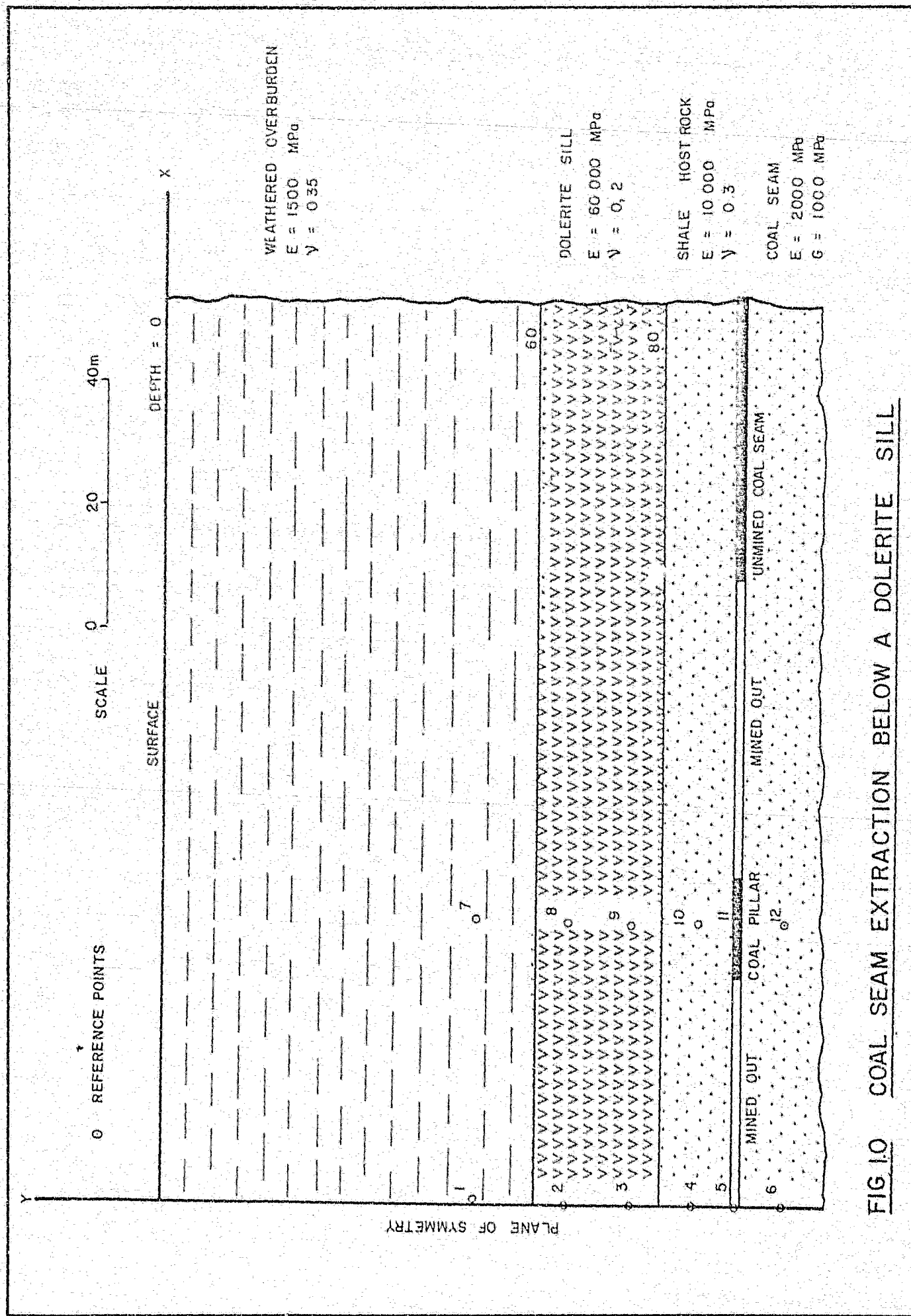


FIG 10 COAL SEAM EXTRACTION BELOW A DOLERITE SILL

Although the displacements are similar in each case, the homogeneous model fails to detect the very high horizontal tension in the sill while over-estimating the extent of induced tension above the excavation. As rock (especially jointed rock) is weak in tension, it is important to know where zones of tension occur since this demonstrates if and where failure is likely to initiate. The non-homogenous linear analysis cannot model the complete failure path, but is at least an improvement over the equivalent linear homogenous analysis.

9.3.2 Tabular excavation with different footwall and hangingwall properties

This problem was selected to see how different hangingwall and footwall materials might affect the behaviour of a fault in close proximity to a tabular excavation (Fig 9.11). Constant field stresses of 30 MPa and 60 MPa were applied in the horizontal and vertical directions respectively. Elastic parameters for the hangingwall and footwall were as follows.

Hangingwall:	E_1	= 50 000 MPa
	ν_1	= 0,35
Footwall:	E_2	= 80 000 MPa
	ν_2	= 0,20

The analyses showed that the normal stresses and hence the shear strengths along the fault were the same, within a few percent, in both the hangingwall and footwall rocks. The shear displacements were about 1,5 times greater in the hangingwall than in the footwall. Consequently, to a first degree of approximation, some 60% of the energy dissipated along the fault would be in the hangingwall.

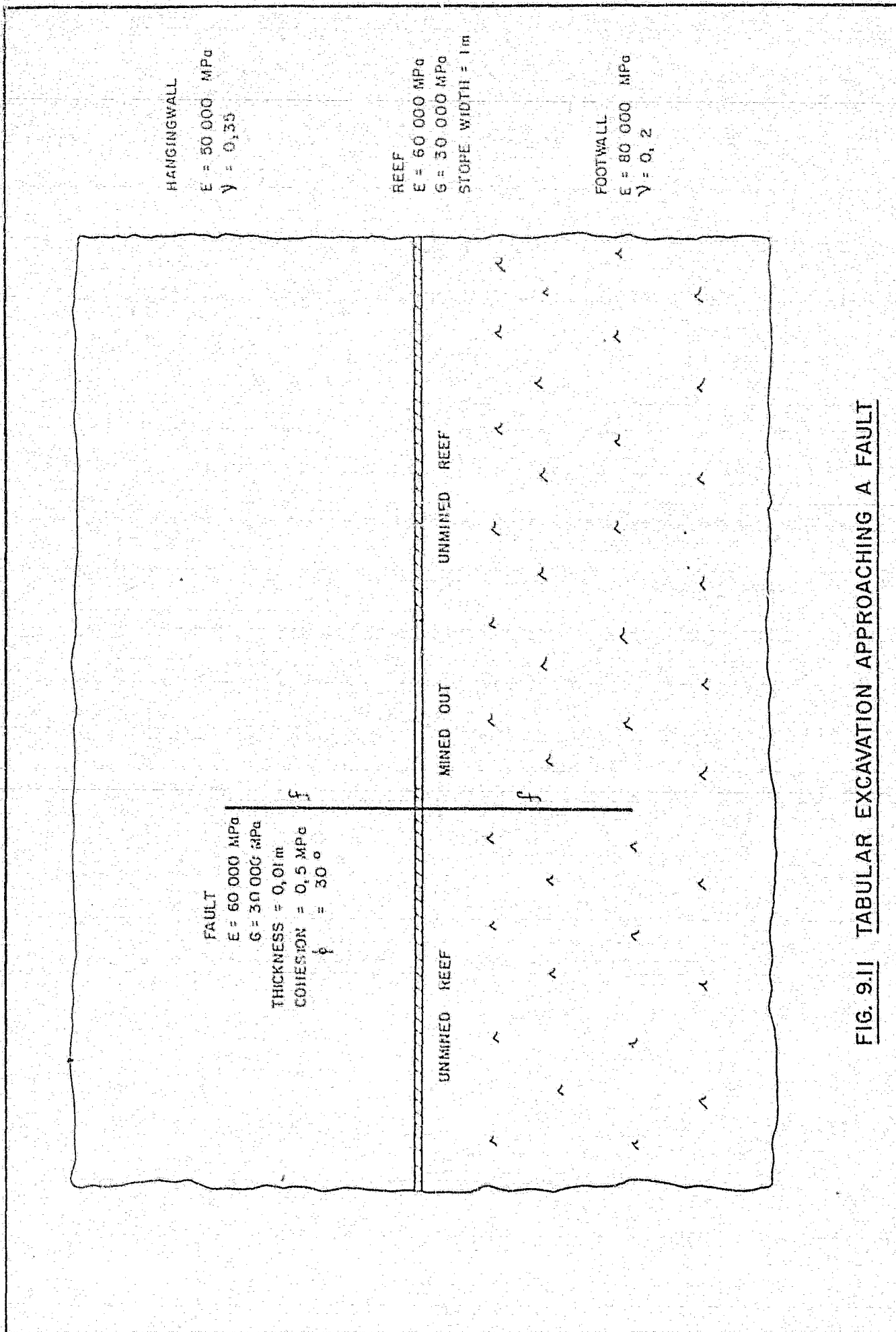


FIG. 9.II TABULAR EXCAVATION APPROACHING A FAULT

CHAPTER 10 GENERAL DISCUSSION AND CONCLUSIONS

It is difficult to evaluate the utility of the formulations described in this dissertation when the range of boundary, displacement discontinuity and finite element formulations already in existence is so large. When considering three-dimensional elastostatic formulations directly applicable to mining engineering problems, then the finite element method becomes very inefficient in most cases as large numbers of elements are usually required.

The displacement discontinuity method has found wide application for the modelling of tabular excavations in homogeneous ground and in two dimensions has been extended (Crouch, 1968) to enable realistic modelling of mining in homogeneous faulted ground. The extension of the displacement discontinuity method described here which enables mining in non-homogeneous ground to be modelled is therefore a logical and useful extension.

In three dimensions, the main applications of the displacement discontinuity method in South Africa have been the modelling of tabular excavations. In the coal mining industry, multiple coal seams at relatively shallow depths are often encountered. The "multi-reef" MINSIM or SHAMIP programmes developed by the Chamber of Mines of South Africa are well suited to this type of problem in most cases and it is only when outcropping coal seams or very irregular ground surfaces are encountered, that the mixed boundary element method of this dissertation would prove useful. The multilayered stratigraphies in many instances are not well suited to any type of three-dimensional analysis since a very large number of finite or boundary elements is normally required. Such problems are probably best modelled by a three-dimensional finite element analysis, especially if use can be made of numerous planes of symmetry or repetition.

A wide variety of displacement discontinuity formulations exist for modelling the tabular excavations encountered in the gold and platinum mines of South Africa including the SHAMIP, MINSIM and "Multi Reef MINSIM" programmes of the Chamber of Mines and the FREEF, DREEF and MREEF programmes of Crouch. These programmes do not allow for different

hangingwall and footwall material or for the presence of faults or dykes. The formulations of this dissertation provide means of modelling these situations. Practical problems of this type would require a large number of elements, probably in excess of two thousand. A computer larger than the Data General Nova 3 on which these programmes were developed would be required. This should not detract from the utility of the programmes, however, as the Data General Nova 3 is a very small mini-computer by modern standards.

Perhaps the best applications for the programmes of this dissertation arise from the interaction of open pit and underground excavations or for underground caverns such as are encountered in underground hydro electric power stations and massive underground mining operations for example. The three-dimensional boundary element programmes of the Chamber of Mines and of Lachat and Watson are also well suited to this type of problem. These formulations are not designed to run on small mini-computers and as such are not as readily available to the rock mechanics practitioner and other users.

Finally, a brief summary of the good points and shortcomings of the formulations of this dissertation is given. In addition, scope for future development is high-lighted.

The main advantages of the formulations of this dissertation may be summarised as follows:

- (1) The combination of boundary and displacement discontinuity elements in a single programme is demonstrated to be both possible and practical.
- (2) The lumping scheme described here forms an essential part of the formulations for the following main reasons:
 - (i) Reduction of disk storage and execution time.
 - (ii) Reduction of core storage requirements.
 - (iii) Numerous checks for user input errors.
- (3) The facility for allowing non linear behaviour on interface boundaries should prove extremely useful in the future. This has

already been demonstrated by the two-dimensional programme MINAP of Crouch (1976).

- (4) The use of an iterative solution technique as opposed to a direct technique has the following main advantages:
 - (i) Reduction in execution time by at least an order of magnitude for most problems.
 - (ii) It enables the lumping mechanism to be implemented.
 - (iii) It enables non-linear behaviour of displacement discontinuity or interface boundary elements to be modelled fairly efficiently.
- (5) The formulations are designed for and execute on a small mini-computer making them both more accessible and cheaper to run for those users who have in house mini-computers and previously had to rely on a computer bureau for this type of analysis.
- (6) Both the boundary and displacement discontinuity elements are the constant displacement/traction type so that their accuracies are very similar. This, the simplest element type, has the following advantages:
 - (i) It is well suited to the development of formulations such as have been described here.
 - (ii) Failure of boundary interface elements poses no special problems.
 - (iii) In mining problems, negligible errors are introduced by the assumption of constant tractions over each element, since the primitive or virgin stress field which gives rise to the tractions on each element usually varies slowly with depth.

The main disadvantages of the BEM and MBEM programmes are as follows:

- (1) The use of constant displacement/traction elements often necessitates the use of a large number of elements. Most of the basic ideas

described in the dissertation, however, should be applicable to more sophisticated element types.

- (2) Some problem geometries, especially those involving more than one subregion, produce sets of equations which cannot readily be solved using the method of Successive over relaxation.
- (3) The present MBEM formulation caters only for one regular array of displacement discontinuity elements, so that mining up to a fault could be modelled, but not mining through a fault.

Very considerable scope for further development of and improvements to the BEM and MBEM formulations exists at present.

- (1) A linear or higher order variation of displacements and tractions over each element is desirable.
- (2) The numerical integration and lumping schemes, although efficient at present, can still be improved and optimised, especially for very large problems.
- (3) It is suspected that alternative iterative techniques might perform better than the Successive over relaxation method being used at present. Two methods look fairly promising, the first being the conjugate gradient method (Reid, 1970) and the second, a partial elimination scheme (Tuff, 1981).
- (4) For large problems, it is not only generation of the boundary element mesh that is time consuming but also interpretation of the output data. Current development is aimed at improving the "pre-" and "post-processing" facilities available to the BEM and MBEM programmes. An interface with computer graphics would be particularly useful.
- (5) Problems involving the earth's surface are frequently encountered. A semi infinite formulation based on Mindlin's solution for a point load in a half space seems both feasible and desirable.

- (6) The present MBEM programme has demonstrated the utility of a combined boundary and displacement discontinuity element programme. A computer package allowing for complete mixing of displacement discontinuity and boundary elements with a number of subregions seems to be a logical extension to the current "state of the art" programmes available to the rock mechanics practitioner.

The boundary element method of stress analysis has already been used widely in various rock mechanics aspects of mine design. The formulations described above were written specially for execution on a small mini-computer. This renders them more accessible to the small group user. Limited storage requirements necessitate judicious use of elements and careful choice of simplifying assumptions about excavation geometry and material properties. However, since the type of problem described here is usually so complex as to defy very accurate modelling even using very large computers, a more rewarding approach is to simplify the problem with the aim of evaluating general effects and calculating stresses and displacements which can reasonably be related to the actual problem and used for the purposes of comparison.

The formulations of this dissertation have already been tested and used successfully on a number of practical mining problems and as such it is felt that they constitute useful additions to the tool box of the rock mechanics engineer.

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APPENDIX 1

EQUIVALENCE OF DISPLACEMENT DISCONTINUITY AND BOUNDARY
ELEMENT STRESS AND DISPLACEMENT FUNCTIONS

APPENDIX 1: EQUIVALENCE OF DISPLACEMENT DISCONTINUITY AND BOUNDARY
ELEMENT STRESS AND DISPLACEMENT FUNCTIONS

The stresses and displacements induced at interior points by the displacement discontinuity elements are given (Starfield and Crouch, 1973) in terms of three harmonic functions ϕ_1 , ϕ_2 , and ϕ_3 . It is shown here that these functions are equivalent to the Kelvin solution used for the boundary elements. (This equivalence made combining the two element types much easier from a programming point of view since only Kelvin type solutions were used. The solution in terms of ϕ_1 , ϕ_2 , and ϕ_3 is not as easily programmed as the Kelvin type solution).

The displacement component (in the x -direction of the co-ordinate system chosen for the displacement discontinuity elements) is (Starfield and Crouch, 1973).

$$u_3(p) = 2(1-\nu) \phi_{3,3} + (1-2\nu)(\phi_{1,1} + \phi_{2,2}) - z \phi_{,3} \quad (A1)$$

where: $\phi = \phi_{i,i}$
 $\phi_i = C_i/r$

$$C_i = \frac{a d_i}{8\pi(1-\nu)}$$

a = Area of displacement discontinuity element
 $= 4h^2$ (h is the element half width)

$\phi_{,3} = \phi_{i,i3}$

r = Distance from element to interior point p

d_i = Displacement discontinuity component in the i direction

From (A1)

$$u_3(\rho) = 2(1-\nu) \frac{-c_3 z}{r^3} - (1-2\nu) \left(\frac{-c_1 x}{r^3} - \frac{c_2 y}{r^3} \right) \quad (A2)$$

$$- z \left(\frac{-c_3}{r^3} - \frac{3xz c_1}{r^5} - \frac{3yz c_2}{r^5} - \frac{3z^2 c_3}{r^5} \right)$$

Or in tensor notation

$$u_3(\rho) = \frac{R^2}{2\pi(1-\nu)} \left[-2(1-\nu) \tau_{33} d_3 + (1-2\nu) (\tau_{11} d_1 + \tau_{22} d_2) \right.$$

$$\left. + \tau_{33} (d_3 - 3\tau_{11} \tau_{33} d_1 - 3\tau_{22} \tau_{33} d_2 - 3\tau_{13} \tau_{33} d_3) \right]$$

$$= \frac{R^2}{2(1-\nu)\pi r^2} \left[-(2(1-\nu)-1) \tau_{33} d_3 - (1-2\nu) (\tau_{11} d_1 + \tau_{22} d_2) - 3\tau_{33}^2 \tau_{ii} d_i \right]$$

$$= \frac{-R^2}{2(1-\nu)\pi r^2} \left[(1-2\nu) \tau_{ii} d_i - 3\tau_{33}^2 \tau_{ii} d_i \right] \quad (A3)$$

The equation for $u_3(\rho)$ is found (for a single element) from (3) as

$$u_3(\rho) = -\Delta T_{3j}(\rho, n) u_j(n) + \Delta u_{3j}(\rho, n) t_j(n) \quad (A4)$$

In order to compare (A4) and (A3) the displacements u_j in (A4) were replaced by d_j in accordance with the definition of a displacement discontinuity (11). The second term in (A4) is not present in a displacement discontinuity element since the t_j components have opposite signs on the two displacement discontinuity surfaces and cancel one another. Also in comparing (A4) and (A3) the integration implicit in the T term is evaluated using a one point integral formula so that (A4) may be rewritten as:

$$u_3(\rho) = -a T_{3j}(\rho, n) d_j(n)$$

$$= \frac{-a(1-2\nu)}{8\pi r^2(1-\nu)} \left[\frac{\partial \tau}{\partial n} \left(\delta_{3j} + \frac{3}{1-2\nu} \tau_{13} \tau_{1j} \right) - n_j \tau_{13} + n_3 \tau_{1j} \right] d_j(n) \quad (A5)$$

Now the choice of co-ordinate system is such that

$$n_i = (n_1, n_2, n_3) = (0, 0, 1)$$

A5 therefore reduces to

$$u_3(\rho) = \frac{-a(1-2\nu)}{8\pi r^2(1-\nu)} \left[\tau_{13} \left(\delta_{3j} + \frac{3}{1-2\nu} \tau_{13} \tau_{1j} \right) - \delta_{3j} \tau_{13} + \tau_{1j} \right] d_j(n)$$

$$= \frac{-a(1-2\nu)}{8\pi r^2(1-\nu)} \left[\tau_{1j} d_j(n) + \frac{3}{1-2\nu} \tau_{13}^2 \tau_{1j} d_j(n) \right] \quad (A6)$$

This is the same as (A3)

The equivalence of the displacements u_1 and u_2 and stresses may be derived in similar fashion to that above.

APPENDIX 2

PROGRAMME LISTING FOR PROGRAMME BEM

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C
C
C SOURCE LISTING FOR PROGRAM DEM
C
C PROGRAM WRITTEN BY J. A. C. DIERING 1980/81
C
C COPYRIGHT RESIDES WITH STEFFEN ROBERTSON AND KIRSTEN INC.
C
C SUBPROGRAMS AND SUBROUTINES ARE GIVEN IN ALPHABETIC ORDER
C EACH IS SEPARATED BY A LINE OF STARS (*****).
C
C

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HEADR
DEMFRINT.IND
ARLAF
CELL
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DEM4
DEM6
DEMDO1
DEMINF
DEMLIN
DEMSHAPE
COMMON
DCOSF
DCOSL
DCOSP
DLOSV
DIAGCO
DIS12
DUMPO
ERROR
GENGEN
ILLOAD
INITT
INPUT1
INTEGB
LAPLY
LESET
LGEOM
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LODNOO
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LUMSUM
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MODSET
MODGEN
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FRANK
GETTLE
SON IN
SIBEL
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FUNCTION AREA(I, J, K, X, N)

FUNCTION TO CALCULATE THE AREA OF AN ELEMENT.

DIMENSION $X(G, N)$

$$A = \text{SQRT}(\text{DIST2}(X(1,1), X(1,1)))$$
$$B = \text{SUBT}(\text{DIST}2(X(1, J), X(1, K)))$$

C=500T(D1S12)

```

S=0; A[1]=0;
for (i=1; i<=N; i++)

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1. **Mathematics**
 2. **Science**
 3. **History**
 4. **Geography**
 5. **Art**
 6. **Music**
 7. **Physical Education**
 8. **Health**
 9. **Language Arts**
 10. **Social Studies**
 11. **Environmental Studies**
 12. **Computer Science**
 13. **Foreign Languages**
 14. **Business**
 15. **Law**
 16. **Engineering**
 17. **Medicine**
 18. **Psychology**
 19. **Sociology**
 20. **Political Science**
 21. **Economics**
 22. **Philosophy**
 23. **Religion**
 24. **Gender Studies**
 25. **Interdisciplinary Studies**
 26. **Environmental Science**
 27. **Public Health**
 28. **Biotechnology**
 29. **Information Technology**
 30. **Energy Studies**
 31. **Transportation Studies**
 32. **Urban Planning**
 33. **Architecture**
 34. **Design**
 35. **Visual Arts**
 36. **Performing Arts**
 37. **Media Studies**
 38. **Journalism**
 39. **Communications**
 40. **Marketing**
 41. **Management**
 42. **Finance**
 43. **Accounting**
 44. **Business Law**
 45. **International Business**
 46. **Global Studies**
 47. **Development Studies**
 48. **Human Rights**
 49. **Peace Studies**
 50. **Conflict Resolution**
 51. **Disaster Management**
 52. **Climate Change**
 53. **Sustainable Development**
 54. **Water Resources**
 55. **Land Use**
 56. **Transportation Planning**
 57. **Urban Design**
 58. **Architectural History**
 59. **Art History**
 60. **Music History**
 61. **History of Science**
 62. **History of Medicine**
 63. **History of Law**
 64. **History of Philosophy**
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 66. **History of Gender**
 67. **History of Interdisciplinary Studies**
 68. **History of Environmental Science**
 69. **History of Public Health**
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10 SURCOUTLINE TO RING-A-LINGS.

SUBROUTINE BELL

TYPE "A"

1744

[illegible]C
JACD

PARAMETER: JD=13, LJ=63, JY=700

COMMON X(3, JV), ALLIMP(JJ), NLLIMP(3, JJ)

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* IFACE(JU), TLUMP(3, JU), ULUMP(3, JU),
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THEANE TIANZ TIONETI TIOEATZ TIEALL TIEANM I. MEHT(111)-L'JOHNN(3,17) -
ETHELLO(S), PRUSS, G, V, VI, VZ, VS, V4, V3, V8, V/, V8, V7, CK, CM, CONNS, IN

NAME: ATTILIO MARIANO MURIEL - MR. 1 STAR, 7 RUE A 10, NE 113, NIMES, 30000
 INSEE: 13047, 13042, 13041, 13040, 13039, 13038, 13037, 13036, 13035, 13034, 13033, 13032, 13031, 13030, 13029, 13028, 13027, 13026, 13025, 13024, 13023, 13022, 13021, 13020, 13019, 13018, 13017, 13016, 13015, 13014, 13013, 13012, 13011, 13010, 13009, 13008, 13007, 13006, 13005, 13004, 13003, 13002, 13001, 13000, 12999, 12998, 12997, 12996, 12995, 12994, 12993, 12992, 12991, 12990, 12989, 12988, 12987, 12986, 12985, 12984, 12983, 12982, 12981, 12980, 12979, 12978, 12977, 12976, 12975, 12974, 12973, 12972, 12971, 12970, 12969, 12968, 12967, 12966, 12965, 12964, 12963, 12962, 12961, 12960, 12959, 12958, 12957, 12956, 12955, 12954, 12953, 12952, 12951, 12950, 12949, 12948, 12947, 12946, 12945, 12944, 12943, 12942, 12941, 12940, 12939, 12938, 12937, 12936, 12935, 12934, 12933, 12932, 12931, 12930, 12929, 12928, 12927, 12926, 12925, 12924, 12923, 12922, 12921, 12920, 12919, 12918, 12917, 12916, 12915, 12914, 12913, 12912, 12911, 12910, 12909, 12908, 12907, 12906, 12905, 12904, 12903, 12902, 12901, 12900, 12899, 12898, 12897, 12896, 12895, 12894, 12893, 12892, 12891, 12890, 12889, 12888, 12887, 12886, 12885, 12884, 12883, 12882, 12881, 12880, 12879, 12878, 12877, 12876, 12875, 12874, 12873, 12872, 12871, 12870, 12869, 12868, 12867, 12866, 12865, 12864, 12863, 12862, 12861, 12860, 12859, 12858, 12857, 12856, 12855, 12854, 12853, 12852, 12851, 12850, 12849, 12848, 12847, 12846, 12845, 12844, 12843, 12842, 12841, 12840, 12839, 12838, 12837, 12836, 12835, 12834, 12833, 12832, 12831, 12830, 12829, 12828, 12827, 12826, 12825, 12824, 12823, 12822, 12821, 12820, 12819, 12818, 12817, 12816, 12815, 12814, 12813, 12812, 12811, 12810, 12809, 12808, 12807, 12806, 12805, 12804, 12803, 12802, 12801, 12800, 12799, 12798, 12797, 12796, 12795, 12794, 12793, 12792, 12791, 12790, 12789, 12788, 12787, 12786, 12785, 12784, 12783, 12782, 12781, 12780, 12779, 12778, 12777, 12776, 12775, 12774, 12773, 12772, 12771, 12770, 12769, 12768, 12767, 12766, 12765, 12764, 12763, 12762, 12761, 12760, 12759, 12758, 12757, 12756, 12755, 12754, 12753, 12752, 12751, 12750, 12749, 12748, 12747, 12746, 12745, 12744, 12743, 12742, 12741, 12740, 12739, 12738, 12737, 12736, 12735, 12734, 12733, 12732, 12731, 12730, 12729, 12728, 12727, 12726, 12725, 12724, 12723, 12722, 12721, 12720, 12719, 12718, 12717, 12716, 12715, 12714, 12713, 12712, 12711, 12710, 12709, 12708, 12707, 12706, 12705, 12704, 12703, 12702, 12701, 12700, 12699, 12698, 12697, 12696, 12695, 12694, 12693, 12692, 12691, 12690, 12689, 12688, 12687, 12686, 12685, 12684, 12683, 12682, 12681, 12680, 12679, 12678, 12677, 12676, 12675, 12674, 12673, 12672, 12671, 12670, 12669, 12668, 12667, 12666, 12665, 12664, 12663, 12662, 12661, 12660, 12659, 12658, 12657, 12656, 12655, 12654, 12653, 12652, 12651, 12650, 12649, 12648, 12647, 12646, 12645, 12644, 12643, 12642, 12641, 12640, 12639, 12638, 12637, 12636, 12635, 12634, 12633, 12632, 12631, 12630, 12629, 12628, 12627, 12626, 12625, 12624, 12623, 12622, 12621, 12620, 12619, 12618, 12617, 12616, 12615, 12614, 12613, 12612, 12611, 12610, 12609, 12608, 12607, 12606, 12605, 12604, 12603, 12602, 12601, 12600, 12599, 12598, 12597, 12596, 12595, 12594, 12593, 12592, 12591, 12590, 12589, 12588, 12587, 12586, 12585, 12584, 12583, 12582, 12581, 12580, 12579, 12578, 12577, 12576, 12575, 12574, 12573, 12572, 12571, 12570, 12569, 12568, 12567, 12566, 12565, 12564, 12563, 12562, 12561, 12560, 12559, 12558, 12557, 12556, 12555, 12554, 12553, 12552, 12551, 12550, 12549, 12548, 12547, 12546, 12545, 12544, 12543, 12542, 12541, 12540, 12539, 12538, 12537, 12536, 12535, 12534, 12533, 12532, 12531, 12530, 12529, 12528, 12527, 12526, 12525, 12524, 12523, 12522, 12521, 12520, 12519, 12518, 12517, 12516, 12515, 12514, 12513, 12512, 12511, 12510, 12509, 12508, 12507, 12506, 12505, 12504, 12503, 12502, 12501, 12500, 12499, 12498, 12497, 12496, 12495, 12494, 12493, 12492, 12491, 12490, 12489, 12488, 12487, 12486, 12485, 12484, 12483, 12482, 12481, 12480, 12479, 12478, 12477, 12476, 12475, 12474, 12473, 12472, 12471, 12470, 12469, 12468, 12467, 12466

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TT(2), UU(2), IHEAD, IITE, A, B, C, R, KGD, ICHHN, ISSW(20), XCON(3),

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DEL, AKMIN, AKMAX, CLKV, RATT, RATE, ARRAT, ISWAP, R1, R2, R3, R4, K1, K2, K3

COMMON /LM/ INDEX(4, J0), ICEL(3, J0), XCEL(3, J0), T(3, J0), U(3, J0), AREA(J0)

E, IELT (JJO), KOU (JED), LINU (JUD), NUMEL, COH, PHIL, THIRK

130001=1
CALL BACK
STOP
END

C JALD

PARAMETER JU=13, JV=89, JY=700

C OMPON X(3, JV), ALIMP(3, JU), XLIMP(3, JU), DLIMP(3, JU), LKOD(3, JU), LMGU(3, JU),

* JFAC(3, JU), TLIMP(3, JU), LLIMP(3, JU),

2 NUTR(3, 3), NUTL(3, 3), XSYM, ZSYM, ISYM, NSYM(5), PRIMO(3, 3), PRIMI(3, 3),

3 LPMO(3, 3), PRCS(3, 3), E, B, V, V1, V2, V3, V4, V5, V6, V7, V8, V9, CIG, CU, CONS, IEC(3, 3),

4 THRAB, THABZ, THABZ1, THABZ2, THABZ, TRALL, MGH(11), COORD(3, 11),

5 NOCE, NICE, NLIMP, NIMEL, NIML, ISTAB, IBDU, LIM, DELIP, NIMOR, NIMOD,

6 ORE, NIL, TUB, THUK, HALP, ZLRO, I1, I2, I3, P1, ALT(3, 3, 3), DELTA(3, 3), OMEGA,

7 T(3, 3), UH(3, 3), IHEAB, IRIIE, A, B, C, G, ISSG, ICHAB, ISSG(20), XCOM(3, 3),

8 IEL, AKMIN, AKMAX, EURV, BATT, RATE, AIRBAT, ISMAP, RI, RZ, R3, R4, R5, RZ, R3,

C

C OMPON /EN/ INLEX(4, JU), DCEL(3, JU), XCEL(3, JU), T(3, JU), U(3, JU), ARBA(JU)

E, IELT(JU), KOD(JU), LIND(JU), NIMEL, COH, PHI, THIC

C

C OMPON /NE/ INLXK(4, JU), IECLE(3, JU), XCELR(3, JU), TRC(3, JU), ORC(3, JU)

C

R, AREAR(JU), IELRC(JU), KODR(JU), LINDR(JU), NIMELR, CERR, PHIR, THICR

C

LEMA --- SUBPROGRAM TO OUTPUT THE RESULTS.

C

ISMAP=33

CALL OPEN2, "LUMSTOR IE", 1, IER

IF (IER.NE.1) TYPE "LUMSTOR OF ER", IER

WRITE(IRITE, 101)

DO 1 N=1, NIMP

CALL LOOKN(1, 1)

WRITE(IRITE, 102)N

DO 1 N=1, NIMEL

KODE=KOD(N)

CALL JELLOCODE, IEC

1 WRITE(IRITE, 100)N, IELT(N), (XCEL(1, N), I=1, 3), (U(1, N), I=1, 3), (T(1, N), I=1, 3),

1KOD(N), AREAR(N), IFAC(N), IIEC(N), IIEC(N), K=1, 3)

100 FORMAT(13, 15, F7.2, 2(4F9.2, 1X), 3(F9.5, 1X), 3(F9.4, 1X), 16, 4X, F9.2, 16,

*3X, 312, 1X)

101 FORMAT(" ELEMENT X-COORD" T20 "Y-COORD" T30 "Z-COORD" T43 "U-X" T53 "U-Y" T63

1 "U-Z" T73 "T-X" T83 "T-Y" T93 "T-Z" T99 "KODE" T107 "AREA" T114 "IFACE IBC",

*)

102 FORMAT("/" LIMP" T3, /)

1 LIMP=1

CALL BACK

STOP

END

C

PARAMETER JU=13, JV=89, JY=700

C OMPON X(3, JV), ALIMP(3, JU), XLIMP(3, JU), DLIMP(3, JU), LKOD(3, JU), LMGU(3, JU),

* JFAC(3, JU), TLIMP(3, JU), LLIMP(3, JU),

2 NUTR(3, 3), NUTL(3, 3), XSYM, ZSYM, ISYM, NSYM(5), PRIMO(3, 3), PRIMI(3, 3),

3 LPMO(3, 3), PRCS(3, 3), E, B, V, V1, V2, V3, V4, V5, V6, V7, V8, V9, CIG, CU, CONS, IEC(3, 3),

4 THRAB, THABZ, THABZ1, THABZ2, THABZ, TRALL, MGH(11), COORD(3, 11),

5 NOCE, NICE, NLIMP, NIMEL, NIML, NIML, ISTAB, IBDU, LIM, DELIP, NIMOR, NIMOD,

C

PARAMETER JU=13, JV=89, JY=700

C OMPON X(3, JV), ALIMP(3, JU), XLIMP(3, JU), DLIMP(3, JU), LKOD(3, JU), LMGU(3, JU),

* JFAC(3, JU), TLIMP(3, JU), LLIMP(3, JU),

2 NUTR(3, 3), NUTL(3, 3), XSYM, ZSYM, ISYM, NSYM(5), PRIMO(3, 3), PRIMI(3, 3),

3 LPMO(3, 3), PRCS(3, 3), E, B, V, V1, V2, V3, V4, V5, V6, V7, V8, V9, CIG, CU, CONS, IEC(3, 3),

4 THRAB, THABZ, THABZ1, THABZ2, THABZ, TRALL, MGH(11), COORD(3, 11),

```

6  CTIME,NIL,TWO,THREE,HALF,ZERO,11,12,13,P1,ALT(3,3,3),DELTAT(3,3),OMEGA,
7  T(3),U(3),LINEAR,WRITE,A,B,C,D,RSQ,ICHAH,ISSW(20),XC(3),
8  DELTAMIN,ALPHA,CURV,RAT1,RAT2,AKRAT,ISWAP,R1,R2,RS3,R4,K1,K2,K3
9
COMMON /ENP/ INDEX(4,JO),DELT(3,JO),XCDEL(3,JO),T(3,JO),U(3,JO),AREA(JO)
E , TELT(JO),KOD(JO),LIND(JO),NMDEL,CONP,PR1,THIR
R , ANEAR(JO),LITR(JO),KODR(JO),LINDR(JO),NMELR,CONR,PR1R,THIR
COMMON /CO/ AO,BO,M
DEMT --- DEMONSTRATES INTERIOR POINTS FOR STRESSES AND DISPL CALCS)
DIMENSION XX(3),XEL(3),XC(3),RS(3),TRAC(3),DEQ(3),DISP(3)
EQUIVALENCE (STRES,TT)
WRITE(17,100)
100 FORMAT(," OUTPUT FOR FIELD POINTS",/ " *****",/
1/" -VE STRESSES ARE COMPRESSIVE",/
1/" SIG-1 IS THE MAX PRINC STRESS",/
1/" SIG-2 IS THE INT PRINC STRESS",/
1/" SIG-3 IS THE MIN PRINC STRESS",/)
CONSTANTS.
ISWAP=30
CALL OPEN(4,"CONSTOR BE",1,IER)
1F(1ER.NE.1)TYPE "CONSTOR OP ER",1ER
CALL OPEN(3,"LENSTORE",3,1EV)
1F(1ER.NE.1)TYPE "LENSTORE OP ER",1ER
CALL OPEN(5,"LENC1",1,1ER)
1F(1ER.NE.1)TYPE "OPEN ER",1ER
CALL OPEN(5,"TEML IN BE",1,1ER)
1F(1ER.NE.1)TYPE "TEML IN BE OP ER",1ER
CALL OPEN(2,"LUMSTOR BE",1,1ER)
1F(1ER.NE.1)TYPE "LUMSTOR OP ER",1ER
READ BINARY (5) UN
READ(4)TRANL,TRAN42,TRANZ1,TRAN7,TRANS,AO,B0,B0
WRITE(17,100)TRAN42,TRANZ1,TRAN7,TRANS,TRANL,W,AO,B0
303 FORMAT(," TRANSITION VALUE FOR 42 POINT INTEGRATION =",F10.2,/,
1" " " 21
1" " " 7
1" " " 3
1" " TRANSITION VALUE FOR LUMPING
1" " W ( O FOR CONSTANT 1 FOR LINEAR
1" " (A,B) FOR SHAPE FUNCTION
DO 1 KK=1,NMDEL
READ BINARY (6) NMDEL,JOEN,XX,MODUL
TYPE XX,MODUL
CALL MODDEN(MODUL)
RS=NSYS(MODUL)
CALL NULL(DISP,3)
CALL NULL(STRES,9)
DO 66 NL=1,NLUMP
MODL=LKOD(NL)
1F(KODL.EQ.NIL)GO TO 66

```

```

C DECIDE ABOUT LUMPING
C DO 66 ISYM=1, NS
C
C LOAD SYMMETRIC INSTANTS.
C
C IF (LMOD(NL), NE, MODUL) GO TO 66
C DOIR=DOIR(1,SYN,HS)
C IF (IDIR EQ NIL) GO TO 66
C CALL LSET(1, XC, XLUMP(1, NL), 0, DCO, DLUMP(1, NL))
C AR=ALUMP(NL)
C RSQ=DIS12(XC, XC)
C RATIO=RSQ/AR
C IF (RATIO LT. TRANE) GO TO 60
C CALL LSET(0, TRAC, TLUMP(1, NL), 0, DIS, ULUMP(1, NL))
C CALL INTEGR(1, 1, 12, 13, TRAC, DIS, AR, 1, STRES, DISP, XX, XC, DCO, UN)
C GO TO 66
C CONTINUE
C CALL LDEL(K(NL, 1, ))
C DO 8 N=1, NIMEL
C CALL LSET(0, DCO, DCEL(1, N), 1, XC, XCEL(1, N))
C AR=AREAR(N)
C RSQ=DIS12(XC, XC)
C RATIO=RSQ/AR
C CALL LSET(0, TRAC, T(1, N), 0, DIS, U(1, N))
C IF (RATIO LT. TRANS) GO TO 9
C CALL INTEGR(1, 1, 12, 13, TRAC, DIS, AR, 1, STRES, DISP, XX, XC, DCO, UN)
C GO TO 8
C CALL LCONDD(NOD1, NOD2, NOD3, NOD4, INDEX(1, N))
C IN=NOD1
C IN=NOD2
C IN=NODE+1
C CALL LSET(X(1, IN), XCEL(1, N))
C CALL LSET(UN(1, IN), U(1, N))
C AR=AREAR(N)
C RATIO=RSQ/AR
C IF (RATIO NE. NIL) RATIO=4
C DO 6 NSID=1, NI
C GO TO (361, 362, 363, 364), NSID
C 361 IN=NOD1
C IN=NOD2
C GO TO 365
C 362 IN=NOD2
C IN=NOD3
C GO TO 365
C 363 IN=NOD3
C IN=NOD4
C IF (NO, EQ, 3) IN=NOD1
C GO TO 365
C 364 IN=NOD4
C IN=NOD1
C 365 CALL INTEGR(N, IN, KN, TRAC, DIS, AR, NIL, STRES, DISP, XX, XC, DCO, UN)
C CONTINUE
C CONTINUE
C CONTINUE
C WRITE(INTE, 105)
C 105 FORMAT(1, " IDENTIFY", 114 "X" T22 "Y" T30 "Z" T40 "U" T48 "V" T56 "W" T70 "QXX"
C T60 "OXY" T68 "OZ" T76 "OY" T84 "OYZ" T92 "OZZ")
C WRITE(INTE, 101) MEEN, JEN, XX, DISP, ((SSTRES(1, J), J=1, 3), J=1, 3)
C WRITE(EINTE, 3) MEEN, JEN, XX, DISP, ((SSTRES(1, J), J=1, 3), J=1, 3)

```

[illegible]

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CALL KRONO(2, IRITE, 10N, TINC)
WRITE(UNIT, S00)
CALL SETFILE

START LUMP-LUMP LOOPS

DO 511 MOD1=1, NMOD
CALL MODSET(MOD1)
NS=NSV(MOD1)
DO 511 M=1, NLUMP
LKOR=LKOD(M)
IF(LKOR.EQ.NIL)GO TO 511
IF(LMOD(M).NE.MOD1)GO TO 511
CALL LKOR(M, 1, 2)
TYPE "LUMP=" , M, NMOD
CALL LSET(XIL, XLUMP(1, M))
CALL NULL(TEMP1, 3)
DO 19 M=1, NLUMP
LINDR(M)=NIL
LKODE=LKOD(M)
IF(LKODE.EQ.NIL)GO TO 19
MOD2=LMD(M)
IF(MOD2.NE.MOD1)GO TO 19
ARL=ALUM(M)
NSG=DIST(XIL, XLUMP(1, M))
KATIO=NSG/ARL
IF(RATIO.LT.1E-6)GO TO 14
TYPE "L", M, M
LINDR(M)=1
CALL NULL2(TI, UI, 9)
DO 18 ISYM=1, NS
IDIR=DIR(1SYM, NS)
IF(1DIR.EQ.NIL)GO TO 18
CALL LSET(1, XIL, XLUMP(1, M), 0, D.C, DLUM(1, M))
RS=DIST(XIL, XIL)

LUMP-LUMP COEFFICIENTS.
R=SCRT(NSG)
WCR=C*ARL/RSQ
WIR=ARL*WCR/RS
CALL TIND(XIL, XIL, WCR, WCR, D.C)

18 CONTINUE
CALL LGAD(TEMP1, LKOR, ULUMP(1, M), TLUMP(1, M))
GO TO 19

14 LINDR(M)=3
IF(GAD1D.LT.TRANL OR LKOR.EQ.6)GO TO 19
LINDR(M)=2
TYPE "E", M, M
19 CONTINUE

LUMP-ELT COEFFICIENTS.
DO 1 M=1, NMDLR
MELR=ELTR(M)
TYPE "ELT", MELR, M
LKOR=LKOD(M)
CALL LSET(TLUMP, TEMP1)
CALL LSET(XIL, XCEL(1, M))
CALL LDMG(MOD1, MOD2, MOD3, MOD4, INDEXR(1, M))

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```

CALL ECOSV(NOD1,NOD2,NOD3,ECOSR,X,N1)
DO 3 N1=1,NLUMP
  LNI=LINDR(N1)
  IF(LNI.NE.2)GO TO 7
  LINDR=LINDR(N1)
  AML=ALUMP(N1)
  CALL NLZCTT,OU,9)
  DO 9 ISYM=1,NS
    IDIR=NDIR(1SYM,NS)
    IF(IDIR.EQ.NIL)GO TO 9
    CALL LESETT,XEL,XLUMP(1,NL),O,DLC,DUMC(1,NL))
    R=SDIR(12)(X,XEL)
    R=SDIR(13)(X,XEL)
    WCR=CKR(ARL/RSQ)
    WCR=ARL*CURS/R
    CALL TTRUXEL,XR,WCR,DLC)
  9 CONTINUE
  CALL LOAD1(1EM,LINDR,DLUMP(1,NL),TLUMP(1,NL))
  GO TO 3
7 IF(LNI.NE.3)GO TO 3

ELI-ELT COEFFICIENTS

CALL LDELK(NL,1,1)
TYPE "DET LIMP",NL
DO 6 N=1,NMEL
  MELE=1EL(1,N)
  KODE=KOD(N)

MORE OUT A BETTER SCHEME IN INPUT

IF(LKODE.EQ.(-1))KODE=-1
CALL NULLZ(CT,OU,9)
DO 111 ISYM=1,NS
  IDIR=NDIR(1SYM,NS)
  IF(IDIR.EQ.NIL)GO TO 111
  IF(IH.NE.N)GO TO 30
  IF(1SYM.GT.1)GO TO 30
  CALL DIACG(N)
  GO TO 111
30 CONTINUE
CALL LODNDV(NOD1,NOD2,NOD3,NOD4,INDEX(1,N))
AR=AREAF(N)
NQ=1
CALL LESET(1,XC,XCEL(1,N),O,DLC,DCEL(1,N))
RSG=USSTZ(XR,XC)
NATID=RSQ/AR
NUMTK=1
NINIB=11
NINTE=11
MINI=1
W1=ARX
IF(NATID.GE.16NS)GO TO 50
IF(NOD4.EQ.NIL)GO TO 50
NQ=2
AR=AREAF(NOD1,NOD2,NOD3,X,N1)
50 CONTINUE
DO 11 NIG=1,N1
  IF(NIG.EQ.1)GO TO 53

```

[illegible]

```

40 441 L=1,13
441 X(L,JND)=(X(L,IBU1)+X(L,NCU2))*HALF
GO 10 21
41 IF(NINT(L/4) GO 10 42
DO 442 L=1,13
442 X(L,JND)=(X(L,NCU2)+X(L,NCU3))*HALF
GO 10 21
42 DO 443 L=1,13
443 X(L,JND)=(X(L,NCU3)+X(L,NCU1))*HALF
GO 10 21
43 CONTINUE
IF(NINT(L/4) GO 10 21
IF(NINT(L/4) IN=MOD3
IF(NINT(L/4) GO 10 21
IN=MOD1
JN=MOD3
21 CONTINUE
DO 11 NIN=NINT3, NINTE
N3=MOD3*(NIN)*HALF/IBU1
IF(NINT3 EQ 1) GO 10 64
C1=CUBO(1,NIN)
C2=CUBO(2,NIN)
C3=CUBO(3,NIN)
DO 24 L=1,13
24 X(L)=C1*X(L,IN)+C2*X(L,JN)+C3*X(L,KN)
CALL SYM(X(XSYM,YSYM,ZSYM,NMLT(1,1SYM),XC)
RSD=DISC(X,XC)
IF(ESQ LT RCL) WRITE(1RITE,100)RATIO,MLN,MLE,1ONE
R=SCRT(RSD)
WCR=M1*CL/RSD
WCR=M1*CON/R
CALL FTUB(XC,XR,WCR,WCR,DLC)
11 CONTINUE
111 CONTINUE
CALL LOAD(TEMP,KODE,U(1,N),T(1,N))
2 CONTINUE
3 CONTINUE
WRITE BINARY (3) TEMP
1 CONTINUE
CALL LUB(KML,2,2)
1RM=IBU1-2
WRITE(1RITE,551)ISTAR,IBU1(1),1=1RM,IBU1(1),LINDR(J),J=1,NLUMP)
551 FORMAT(1X,15,2X,3F8.5,2X,9S11)
550 FORMAT(//)
511 CONTINUE
CALL UNFQ(1RM,IBU1,ISTAR,1)
WRITE(1RITE,550)
CALL KRON(CS,1RITE,TON,1INC)
CALL HES1
1SAP=1
CALL BACK
STOP
END

```

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C
C BEM,IN --- AVERAGE NODAL DISPLACEMENTS FROM ELT VALUES (OPTIONAL)
C
C JACD

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PARAMETER JG=13, JI=83, JV=700
COMMON X(3, JV), ALPMP(3, JI), XLSTP(3, JI), DLUMP(3, JI), LKOD(JI), LMOD(JI),
* IFACE(JI), LUMP(3, JI), UIMP(3, JI),
1  IUTR(3, 3), NBU(3, 3), XSYM, VS3B, ZSYM, ISYM, NSYM(5), PJOMO(3, 3), PRIM(3, 3),
3  ENOD(5), EN(5), L, S, V, V1, V2, V3, V4, V5, V6, V7, V8, V9, CK, CD, CONS, IDC(3),
4  TENDS, TENDZ, TENDZ1, TENDZ2, TENDL, WGT(11), CGOR(3, 11),
5  NODS, NUTR, NUTP, NUTBL, NUTL, NUTR, NUTR, NUTR, NUTR, NUTR, NUTR,
6  UDE, NIL, TWO, THREE, FIVE, ZERO, 11, 12, 13, P1, ALT(3, 3, 3), DELTA(3, 3), UDECA,
7  TTS(3), UDE(3), UDEAR, UDETE, A, B, C, R, REG, ICHAN, ISSW(20), XCOM(3),
8  DEL, ARMIN, ARMAX, CURV, RAT, RATIO, ARMA1, ISWAP, R1, R2, R3, R4, K1, K2, K3

COMMON /IE/, INDEX(4, JI), DELTR(3, JI), XCEL(3, JI), TR(3, JI), UR(3, JI)
R , AREAR(JI), DELTR(JI), KOD(JI), KOD(JI), LIND(JI), NIMELR, CORR, PHIR, THIR

DIMENSION UN(3, JV), SUM(JV)
ISWAP=33
TYPE "INITI ELMIN"
CALL OPEN(5, "EELIN.EE", 3, IER)
IF(IER.NE.1) TYPE "EELIN OP ER", IER
CALL OPEN(2, "LUMSTOR.EE", 1, IER)
IF(IER.NE.1) TYPE "LUMSTOR OP ER", IER
ND3=ND+3
CALL NULL(UN, ND3)
CALL NULL(SUM, ND)
DO 1 N=1, NIMP
LECODE=LICOD(EL)
IF(LECODE.EQ. NIL) GO TO 1
CALL LDEK(EL, 1, 1)
DO 2 N=1, NIMEL
DO 3 J=1, 4
NJ=INDEX(J, N)
IF(NJ.EQ. NIL) GO TO 2
WGT=AREA(N)/DISIZ(1, NJ), XCEL(1, N)
DO 3 I=1, 3
UN(I, NJ)=UN(I, NJ)+U(I, N)*WGT
SUM(NJ)=SUM(NJ)+WGT
2 CONTINUE
1 CONTINUE
DO 4 NJ=1, ND
VAL=SUM(NJ)
IF(VAL.EQ. ZERO) GO TO 4
DO 5 I=1, 3
UN(I, NJ)=UN(I, N)/VAL
4 CONTINUE
CALL OPEN(15, "NODEIX.EE", 1, IER)
IF(IER.NE.1) TYPE "NODEIX OP ER", IER
DO 20 N=1, NNODE
READ(15, END=21) NOD, KODE
GO TO (20, 22, 23, 24, 25), KODE
22 UN(1, NOD)=ZERO
UN(2, NOD)=ZERO
UN(3, NOD)=ZERO
GO TO 20
23 UN(1, NOD)=ZERO
GO TO 20
24 UN(2, NOD)=ZERO
GO TO 20

```

```

C 25 UN(3, NOD)=ZERO
C 20 CONTINUE
C 21 CONTINUE
      WRITE (BINARV (5), UN
      TYPE "NEXT BEGIN IN"
      LBAR=1
      CALL BACK
      STOP
      END
*****
C  A=0 FOR FULL NODAL VALUES
C  1 FOR NO NODAL VALUES
C  L=0 FOR NO ELT VALUES
C  1 FOR FULL ELT VALUES
C  W=0 FOR ELT VALUES ONLY
C  1 FOR COMBINED VALUES
C
C  SHAPE FUNCTION FOR 'LAGRANGE TRIANGLE' (OPTIONAL)
C
C  SUBROUTINE LEMSHAP(X1, X2, X3, K0AR, UN, U, N1, N2, N3, DIS, NID)
C  COMMON /C0/ A, B, W
C  DIMENSION UN(3, NID), U(1), DIS(3)
C  GO TO (1, 2, 3), K0AR
C
C  1 K0=1
C  GO TO 4
C
C  2 RHO=4, *X1*X2
C  GO TO 4
C
C  3 RHO=2, *X1*X2*X3
C  RHO=2, *X1*X2*X3
C  RHO=A+RHO*(B-A)
C  RHO=(1.-RHO)*W
C  GO 5, L=1, 3
C
C  5 DIS(1)=RHO*(U(1)+RHO*(X1*UN(1, N1)+X2*UN(1, N2)+X3*UN(1, N3))
C  RETURN
C  END
*****
C  JACO
C
C  PARAMETER JU=13, JV=63, JY=700, JY3=2100
C  (COMMON X(3, JY), ALIMP(4, JU), XLIMP(3, JU), DLMC(3, JU), LKOD(JU), LMGD(JU),
C  * IFACE(JU), LLIMP(3, JU), ULIMP(3, JU),
C  2 NDIR(3,3), NMPLT(3,3), XSYM, YSYM, ZSYM, ISYM, NSYM(5), PRMO(3,3), PRIM(3,3),
C  3 EMD(3,3), F6(3,3), E, G, V, V1, V2, V3, V4, V5, V6, V7, V8, V9, CIG, CD, CONG, IBC(3),
C  4 TRAR, IRAR, THAR21, THAR42, TRALL, TRALL, WGT(11), COORD(3, 11),
C  5 NODE, NDIR, NLIMP, NMPL, MD, ISTAR, IDEF, LIM, NSLIP, NUMER, NMCO,
C  6 ONE, NLL, TWO, THIRU, HALF, ZERO, 11, 12, 13, P1, ALT(3,3,3), DLT(3,3,3), OMEGA,
C  7 TT(3), UU(3), IREAD, IWRITE, A, B, C, R, ISG, ICHAN, ISGM(20), XCOM(3),
C  8 DEL, ARMIN, ARMAX, CUMV, RATT, RATT, ARBAT, ISMAP, K1, K2, K3, K4, K1, K2, K3
C
C  COMMON /C1/ IHDX(4, JU), DCEL(3, JU), XCEL(3, JU), T(3, JU), U(3, JU), AREA(JU)
C  , JELT(JU), KOD(JU), LIND(JU), NMEL, COM, PHI, THIK
C
C  COMMON /C2/ INLEXR(4, JU), DECLR(3, JU), XCELR(3, JU), TR(3, JU), UR(3, JU)
C  , AKARK(JU), DELT(JU), KODR(JU), LINDR(JU), NMELR, COMR, PHIR, THIKR

```


C *****

C SUBROUTINE TO CALCULATE LOCAL COORD SYSTEM ABOUT DC(A,B,C).

C

DC(1,1)=TEMPAC
DC(1,2)=TEMPAC
DC(1,3)=TEMPAC

TEMP=0.00001

DC(2,1)=A

DC(2,2)=B

DC(2,3)=C

AM0=ABS(A)

IF (AM0.LT.100) AM0=TOL

IF (A.LT.0) AM0=-AM0

TEMP=SQRT(AM0*AM0+UB*B)

TEMP=AM0/TEMP

DC(2,1)=B/TEMP

DC(2,2)=0

DC(2,3)=TEMP

DC(2,2)=TEMP

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DC(2,2)=TEMP

一、本行自成立以來，承蒙各界愛護，業務日見發達。茲為擴大服務起見，特在
 本市設立分行，凡在本市及附近地區有業務往來者，均可向該分行接洽。此
 佈。

RECORDED IN THE BUREAU OF COAST AND GEODETIC SURVEY GIVEN THE NUMBER

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0431358

三

一、凡在中華人民共和國境內，凡有違反本條例規定之行為者，均應受本條例之制裁。
 二、凡在中華人民共和國境內，凡有違反本條例規定之行為者，均應受本條例之制裁。
 三、凡在中華人民共和國境內，凡有違反本條例規定之行為者，均應受本條例之制裁。
 四、凡在中華人民共和國境內，凡有違反本條例規定之行為者，均應受本條例之制裁。
 五、凡在中華人民共和國境內，凡有違反本條例規定之行為者，均應受本條例之制裁。
 六、凡在中華人民共和國境內，凡有違反本條例規定之行為者，均應受本條例之制裁。
 七、凡在中華人民共和國境內，凡有違反本條例規定之行為者，均應受本條例之制裁。
 八、凡在中華人民共和國境內，凡有違反本條例規定之行為者，均應受本條例之制裁。
 九、凡在中華人民共和國境內，凡有違反本條例規定之行為者，均應受本條例之制裁。
 十、凡在中華人民共和國境內，凡有違反本條例規定之行為者，均應受本條例之制裁。

100%
 90%
 80%
 70%
 60%
 50%
 40%
 30%
 20%
 10%
 0%

4. HALL, JENNIE. TRAIL TRAIL. 111.

6. ONE: 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846

3. LEE, ANITA, 6. MAX, CLYD, KAT, FATH, ANITA, ISMA, R1, R2, R3, R4, R1, R2, R3

COMMON /E1/ INDEX(4, JN), DECI(3, JQ), XCEL(3, JQ), T(3, JQ), U(3, JQ), AREA(JQ

100

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— 10 —

LEVEL - LEVEL + 1

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1981-1982

CALL 1-800-762-7627 (TOLL FREE)

$$B = \text{tr} \, \text{tr} \, \Gamma(1, 1)$$

C=CELL(3,M)

```

100 1 NR0T=1, NR
    L1=N1
    L2=N2
    IF (NR0T.EQ.1) GO TO 30
    IF (NR.EQ.4) GO TO 20
    IF (NR0T.EQ.2) L1=N3
    IF (NR0T.EQ.3) L2=N1
    IF (NR0T.EQ.3) L1=N2
    IF (NR0T.EQ.3) L2=N3
    GO TO 30
20 CONTINUE
    IF (NR0T.NE.2) GO TO 31
    L1=N4
    L2=N1
    GO TO 30
31 IF (NR0T.NE.3) GO TO 32
    L1=N3
    L2=N4
    GO TO 30
32 L1=N2
    L2=N3
30 CONTINUE
    CALL ACOSL(L2,L1,A1,B1,C1,X,ND)
    E1(1)=A1
    E1(2)=B1
    E1(3)=C1
    E2(1)=B+E1(3)-C+E1(2)
    E2(2)=C+E1(1)-A+E1(3)
    E2(3)=A+E1(2)-B+E1(1)
    CALCULATE DISTANCES
    D=ZERO
    D1=ZERO
    D2=ZERO
    DO 7 L=1,3
        D=D+E2(L)*X(L,L1)-XCOM(L)
        D1=D1+E1(L)*X(L,L1)-XCOM(L)
        D2=D2+E1(L)*X(L,L2)-XCOM(L)
    7 CONTINUE
    R1=SQRT(DIST2(XCOM,X(1,L1)))
    R2=SQRT(DIST2(XCOM,X(1,L2)))
    IVAL=0
    DO 1 I=1,3
        DO 1 J=1,3
            IVAL=IVAL+1
            UU(IVAL)=UU(IVAL)-UVAL(U,I,R1,D)+UVAL(D,I,R2,D)
            IF (1.EQ.3) GO TO 1
            TV(IVAL)=TV(IVAL)-TVAL(U,I,R1)+TVAL(D,I,R2)
    1 CONTINUE
    RETURN
    ENH

```

```

DIMENSION X(1),Y(1)
R1=X(1)-Y(1)**2*(X(2)-Y(2))*2*(X(3)-Y(3))*2
RETURN
END

```

```

SUBROUTINE TO HANDLE DISK TRANSFERS.

```

```

SUBROUTINE LUMP(110P,BUF,1STAR,1RM)
DIMENSION LBF(1)
N1=0
N2=0
IF(110P.EQ.1)CALL WORK(2,1STAR,BUF,N1,N2,1ER)
IF(110P.EQ.2)CALL WORK(2,1STAR,BUF,N1,N2,1ER)
LBF=0
1STAR=1STAR+N1+N2
IF(1ER.EQ.1)RETURN
TYPE="20721ER,1STAR,1RM",1ER,1STAR,1RM
PAUSE FOR A WHILE
RETURN
END

```

```

SUBROUTINE ERROR(1EL,N,M,1,F)

```

```

IF(1.EQ.2)GO TO 10
IF(1EL.GT.1000)GO TO 10
1EL=1EL*10+1
IF(1.EQ.14)1EL=(1EL-14)*10+1
10 CONTINUE
GO TO (1,2,3,4,5,6,7,8,9,1,1,1,14),1
2 TYPE "ELT",N," SPECIFIED MORE THAN ONCE"
GO TO 1
3 TYPE "NODE",N," NOT IN POSITION",N," AS REQUIRED"
GO TO 1
4 TYPE "ELT",N," IS UNDEFINED"
GO TO 1
5 TYPE "ELT",N," HAS ILLEGAL NODE NUMBER IN POSITION",N
GO TO 1
6 TYPE "NODE",N," IN ELT",N," IS NEGATIVE ?"
GO TO 1
7 TYPE "QUADRILATERAL ELT",N," IS HAS ONLY 3 NODES ?"
GO TO 1
8 TYPE "ELI",N," IS CURVED IN COMPONENT",N," CURVATURE=",F
GO TO 1
9 TYPE "ELT",N," HAS VERY BIG OR SMALL AREA"
GO TO 1
14 TYPE "ELT",N," NOT AT AN INTERFACE (ILLEGAL FOR CODE 7 ELEMENTS)"
1 CONTINUE
RETURN
END

```

```

PARAMETER (J0=13,J1=67,J2=700)

```



```

30 TYPE "PLANE"
DO 31 N=1, NO
N1=NODE+1
N2=NODE+2
N3=NODE+3
N4=NODE+4
READ(1)((X(J,N),J=1,3),N=N1,N4)
READ(1)N12,N14
N1=(-1,-1) N2=(1,-1) N3=(1,1) N4=(-1,1)
N12=NX N14=NY
DYL=1./FLOAT(N12)
DYL=1./FLOAT(N14)
XEL=-1.-DYL
VEL=-1.-DYL
DO 32 NX=1, N12
DO 32 NY=1, N14
XL=XEL+NX*DYL*Z
YL=YEL+NY*DYL*Z
OMX=1.-XL
OPX=1.-YL
OMY=1.-YL
OPY=1.-YL
DO 33 I=1,3
33 XDEFN(1)=0.25*(OMX*OMY*X(1,N1)+OPX*OMY*X(1,N2)
+OF X*OPY*X(1,N3)+OMX*OPY*X(1,N4))
HUBRIS=HUBRIS+1
32 WRITE BINARY (6) NX,NY,XDEFN,ISUB
31 CONTINUE
GO TO 3

40 TYPE "ELT"
EO 41 N=1, NO
READ(1) NL,NEL,DE,DE,NPT
CALL LIOBLC(NL,1,1)
NLM=NLMEL
IF(NEL.NE.NIL)NLM=1
EO 44 NE=1, NOM
NN=NE
IF(NEL.NE.NIL)NN=NEL
CALL LSET(XLOD,XCF(1,NN))
EO 42 NP=1, NPT
PF=FLOAT(NP-1)/FLOAT(NPT-1)
DO 43 I=1,3
43 XDEFN(1)=XLOD(1)-DEEL(I,NN)*(DB+PF*(DE-DD))
HUBRIS=HUBRIS+1
42 WRITE BINARY (6) NP,IELT(NN),XDEFN,ISUB
41 CONTINUE
GO TO 3

N1,N2,N3,N4 DEFINES "SHAPE" QUADRILATERAL
XCDEFN DEFINES OFFSET
N12,N14 = NO OF COLS AND ROWS

```

```

      50 TYPE "VECTOR OFFSET"
      DO 51 N=1,NU
        READ(1) N1,N2,N3,N4
        READ(1) XC,CB
        READ(1) N12,N14
      C
      C
      C
      N1=(-1,-1) N2=(1,-1) N3=(1,1) N4=(-1,1)
      N12=NX N14=NY
      DX=1./FLUAT(N12)
      DY=1./FLUAT(N14)
      XL=-1.-DXL
      YL=-1.-LYL
      DO 52 NX=1,N12
      DO 52 NY=1,N14
      XL=XEL+NX*DXL*2.
      YL=YEL+NY*DYL*2.
      LHX=1.-XL
      LHY=1.-YL
      OPX=1.-XL
      OPY=1.-YL
      EO 53 1=1,3
      53 XLEN(1)=0 25*(OMX+OMY*X(1,N1)+OPX*OMY*X(1,N2)
      1 4OPX*(OPY*X(1,N3)+OMX*OPY*X(1,N4))+XCOM(1)
      52 NUNOR=NUNOR+1
      51 WRITE BINARY (6) NX,NY,XLEN,ISUB
      3 CONTINUE
      TYPE "EXIT GENGEN"
      RETURN
      END
*****
      C
      C
      C
      SET UP IDC WITH BOUNDARY CONDITION CODES
      SUBROUTINE IELGAK(KOD,IBC)
      DIMENSION IEC(3)
      IT=1
      ID=2
      I1=1F
      I2=1F
      I3=1F
      IEC(1)=0
      IEC(2)=0
      IEC(3)=0
      IF (KOD LE 0 OR KOD GT 11) RETURN
      GO TO (20,3,4,5,6,7,8,9,7,7),KOD
      2 I1=1U
      I2=1U
      I3=1U
      GO TO 20
      3 I1=1D
      I2=1F
      I3=1F
      GO TO 20
      4 I1=1T
      I2=1B
      I3=1F

```

```

5 GO TO 20
  11=11
  12=11
  13=11
6 FALSE ILLEGAL CODE 6
  11=3
  12=3
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```

END

PARAMETER JO=1, J1=69, J2=700
SUBROUTINE INIT

C

JACO

```

COMMON X(3,3), ALUM(3,3), XLUM(3,3), DLUM(3,3), LKUM(3,3), LKUM(3,3),
* 1 ALUM(3,3), XLUM(3,3), DLUM(3,3), LKUM(3,3),
2 ALUM(3,3), XLUM(3,3), DLUM(3,3), LKUM(3,3),
3 ALUM(3,3), XLUM(3,3), DLUM(3,3), LKUM(3,3),
4 ALUM(3,3), XLUM(3,3), DLUM(3,3), LKUM(3,3),
5 ALUM(3,3), XLUM(3,3), DLUM(3,3), LKUM(3,3),
6 ALUM(3,3), XLUM(3,3), DLUM(3,3), LKUM(3,3),
7 ALUM(3,3), XLUM(3,3), DLUM(3,3), LKUM(3,3),
8 ALUM(3,3), XLUM(3,3), DLUM(3,3), LKUM(3,3),

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C

SUBROUTINE TO INITIALIZE THE MATRICES.

C

TYPE "INIT INIT"

C

ND=JY-5

C

ND=JY-5

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ND=JY-5

UD 1 1=1,3
DD 1 1=1,3
DELTA(1,0)=ZERO
DELTA(1,1)=ONE
DO 1 I=1,3
1 AL(1,I,0)=ZERO
AL(1,1,2)=ONE
AL(2,3,1)=ONE
AL(3,1,2)=ONE
AL(1,3,2)=ONE
AL(3,2,1)=ONE
AL(2,1,3)=ONE
THIRD=ONE/3.
A1=0.03661587
A2=0.79742699
B1=0.47014206
E2=0.10138651
M1=0.225
M2=0.13239415
M3=0.12593918

COORD(1,1)=THIRD
COORD(2,1)=THIRD
COORD(3,1)=THIRD

COORD(1,2)=A1
COORD(2,2)=B1
COORD(3,2)=B1

COORD(1,3)=B1
COORD(2,3)=A1
COORD(3,3)=B1

COORD(1,4)=B1
COORD(2,4)=B1
COORD(3,4)=A1

COORD(1,5)=A2
COORD(2,5)=B2
COORD(3,5)=B2

COORD(1,6)=B2
COORD(2,6)=A2
COORD(3,6)=B2

COORD(1,7)=B2
COORD(2,7)=B2
COORD(3,7)=A2

COORD(1,8)=HALF
COORD(2,8)=HALF
COORD(3,8)=ZERO

COORD(1,9)=HALF
COORD(2,9)=ZERO
COORD(3,9)=HALF

COORD(1,10)=ZERO
COORD(2,10)=HALF
COORD(3,10)=HALF

```

COPROD(1,11)=THIRD
COCOR(2,11)=THIRD
COCOR(3,11)=THIRD

WGHT(1)=W1
WGHT(2)=W2
WGHT(3)=W2
WGHT(4)=W2
WGHT(5)=W3
WGHT(6)=W3
WGHT(7)=W3
WGHT(8)=THIRD
WGHT(9)=THIRD
WGHT(10)=THIRD
WGHT(11)=ONE

NDI=NDI+3
CALL NML(X,NE3)
DO 3 J=1,8
IF(J,L1,4)NMLT(J,1)=1ONE
NMLT(1,J)=1
DO 3 I=2,8
IF(J,L1,4)NMLT(J,1)=-1
NMLT(1,J)=0
NMLT(1,8)=1
NMLT(J,J)=1
NMLT(2,5)=1ONE
NMLT(2,6)=1ONE
NMLT(3,5)=1ONE
NMLT(3,7)=1ONE
NMLT(4,6)=1ONE
NMLT(4,7)=1ONE
NMLT(2,2)=1ONE
NMLT(3,2)=1ONE
NMLT(1,3)=1ONE
NMLT(3,3)=1ONE
NMLT(1,4)=1ONE
NMLT(2,4)=1ONE
NMLT(3,5)=1ONE
NMLT(2,6)=1ONE
NMLT(1,7)=1ONE
TYPE "EXIT INIT"

RETURN
END

```



```

C      G DEL, ARMIN, ARMAX, CURV, RATT, RATTB, ANRAT, ISLIP, RL, RZ, RS, R4, K1, K2, K3
C      COMMON /EM/ INDEX(4, JO), DCEL(3, JO), XCEL(3, JO), T(3, JO), U(3, JO), AREA(40)
C      E , IELT(40), KOUR(40), LIND(40), NIBEL, COH, PHI, THIK
C
C      COMMON /NEZ/ I, JEXR(4, JO), DCELR(3, JO), XCELR(3, JO), TR(3, JO), UR(3, JO)
C      R , AREAR(40), ELTR(40), KOUR(40), LINDR(40), NIBELR, COHR, PHIR, THIKR
C
C      DIMENSION XE(3), IHED(32), DIS(3), TRAC(3), NIND(20)
C
C      SUBROUTINE TO READ INPUT VARIABLES AND SET CONSTANTS.
C
C      TYPE "INFO INPUT"
C      IREAD = 1
C      100 FORMAT(5E3)
C      CALL SETFILE
C      HEAD(IREAD, 202) ISSM
C      IRITE=12
C      IF(ISSM(5), EQ, 1) IRITE=10
C      READ(IREAD, 100) IHED(1)
C      WRITE(IRITE, 153)
C      153 FORMAT(71X, 128(" ")/)
C      IF(1) IRITE, EQ, 12) WRITE(106) IHED
C      106 FORMAT(71X, " ", 32A2, //)
C      CALL KROUND(7, IRITE, ION, IINC)
C      IF(1) IRITE, EQ, 12) WRITE(107)
C      107 FORMAT(71X, "EQUINARY ELEMENT METHOD 3 D ANALYSIS (MARK Z)")
C      WRITE(107, 153)
C
C      READ AND WRITE INPUT DATA.
C
C      WRITE(107, 254) (ISSM(I), I=1, 7)
C      254 FORMAT(" SWITCH (CONTROLS ARE AS FOLLOWS", /
C      * " ISSM 1 = 1 TO SKIP CALCULATION OF COEFFICIENTS, ", T60, 11, /
C      * " ISSM 2 = 1 TO SKIP CALCULATION OF T AND U, ", T60, 11, /
C      * " = 2 TO CONTINUE CALCULATION OF T AND U, /
C      * " ISSM 3 = 1 TO SKIP OUTPUT OF GEOMETRY, ", T60, 11, /
C      * " ISSM 4 = 1 TO SKIP OUTPUT OF LUMP GEOMETRY, ", T60, 11, /
C      * " ISSM 5 = 1 FOR OUTPUT TO SCREEN, ", T60, 11, /
C      * " ISSM 6 = 1 TO SKIP OUTPUT OF TRACIONS AND DISPLACEMENTS, ", T60, 11, /
C      * " ISSM 7 = 1 TO SKIP PRINCIPAL STRESS ROUTINE, ", T60, 11, /
C      * /)
C
C      READ(1) IREAD) TRANLL, TRANL, TRAN2, TRAN21, TRANZ, TRANS
C      READ(1) IREAD) ARMIN, ARMAX, CURV, RATT, RATTB
C      READ(1) IREAD) NITER, OMEGA, DEL, NSLIP
C      READ(1) IREAD) NUMOR, NLUMP, NPROU
C      READ(1) IREAD) XSYM, YSYM, ZSYM
C      READ(1) IREAD) PRIMO, PRIM1
C
C      202 FORMAT(25I1)
C      WRITE(107, 101) NITER, OMEGA, DEL, XSYM, YSYM, ZSYM
C      101 FORMAT( /
C      4 10X"MAX ITERATIONS      = ", 6X, 14, /
C      5 10X"RELAXION FACTOR      = ", F10, 2, /
C      6 10X"CONVERGENCE RATIO    = ", F10, 5, /
C      1 10X"X PLANE OF SYMMETRY = ", F10, 2, /
C      2 10X"Y PLANE OF SYMMETRY = ", F10, 2, /

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[illegible]

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TYPE NL, "LUMP NO"
READ(IREAD) LUMP, NMEL, KOEL, MOD1, MOD2
IF(KEE=1) GO TO 1000
IF(KOEL.EQ.0) NMEL=1
NM=NLMEL
NMEL=1+ABS(NMEL)
IF(KE(NL)=NIL)
  IF(KOEL.GT.5) READ(IREAD) CON, PHI, THIK
  PHI=TAN(PI*PHI/180.0)
  IF(KOEL.LT.(-1)) KOEL=-1
  IF(KOEL.GT.6.AND.MOD1.EQ.MOD2) STOP 'KODE 7 INTERFACE ERROR'
  IF(MOD1.GT.5.OR.MOD2.GT.5) STOP 3
  IF(NMEL.GT.NMEL) TYPE "ERROR 1", LUMP
  IF(LUMP.NE.NL) TYPE "POSSIBLE LUMP ERROR", NL, LUMP
  LKOD(NL)=MOD1
  NTEM=NMEL+3
  CALL MULTI(INDEX, NMEL, 4)
  CALL MULTI(LIND, NMEL, 1)
  CALL MULTI(LIMR, NMEL, 1)
  CALL MULTI(LUR, T, NTEM)
  CALL MULTI(XCEL, XCEL, DCEL, NTEM)
  N=0
  DO 11 NE=1, NMEL
    IF(NO.GT.NL) GO TO 12
    READ(IREAD) NN, NEM, (NIND(J), J=1, NEM)
    IF(NIND(NEM).LT.NL) NO=-NO
    NIND(NEM)=1+ABS(NIND(NEM))
    IF(NEM.GT.9) GO TO 14
    KEL=NEM-1
    DO 17 K=1, KEL
      N=N+1
      IF(N.GT.NMEL) STOP 13
      IELT(N)=NN
      NN=NN+1
      INDEX(1, N)=NIND(K)
      I'=K+1
      IF(IEP.GT.KEL) IP=1
      INDEX(2, N)=NIND(IP)
      INDEX(3, N)=NIND(NEM)
17 CONTINUE
    GO TO 11
14 NIGW=(NEM/4)-1
    KEL=NIGW*3
    DO 15 K=1, KEL
      IFOW=(K-1)/3
      N=N+1
      IF(N.GT.NMEL) STOP 13
      IELT(N)=NN
      NN=NN+1
      NI=IOW+K
      INDEX(1, N)=NIND(NI)
      INDEX(2, N)=NIND(NI+4)
      INDEX(3, N)=NIND(NI+5)
      INDEX(4, N)=NIND(NI+1)
15 CONTINUE
    GO TO 11
12 N=N+1
  IF(N.GT.NMEL) STOP 13
  READ(IREAD) NN, (INDEX(J, N), J=1, 4)
  IELT(N)=NN

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```

11 CONTINUE
  NIMEL=N
  IF (KODE, NE, 6) GO TO 18
19 READ(IREAD)KODL
  DO 22 N=16, 15
    CALL LSET(UT(1, N), DIS)
22 CALL LSET(UT(1, N), TRAC)
  IF (IE LT NIMEL) GO TO 19
  LKOD(N)=KODL
18 CONTINUE
  LKOD(N)=KODL
  IJILL=0
  IF (MOD2, EQ, 0, OR MOD2, EQ, MOD1) GO TO 60
  NLLEN=NLTEN+1
  IF (NLLEN GT NIMEL) STOP 8
  IF (NLLEN)=NLTEN
  IF (KODE, EQ, 7) LKOD(NLTEN)=8
  IF (KODE, EQ, 7) LKOD(NLTEN)=8
  IF (KODE, EQ, 8) LKOD(NLTEN)=7
  LKOD(NLTEN)=MOD2
  IJILL=1
  NIMELR=NIMEL
  COMB=COM
  FHIR=FIR
  TIRIR=TIRIK
60 CONTINUE
  DO 1 N=1, NIMEL
    KODE=KODL
    IEL=NIL
    KOD(N)=KODE
    CALL LINDO(N1, N2, N3, N4, INDEX(1, N))
  END DO
  GENERATE SECOND ELEMENT AT INTERFACE
  IF (IILL, EQ, NIL) GO TO 62
  TYPE "GENERATE INTERFACE ELEMENT", N
  KODR(N)=KODE
  IF (KODE, EQ, 7) KODR(N)=8
  IF (KODE, EQ, 8) KODR(N)=7
  NNN=3
  IF (N4 NE NIL) NNN=4
  NNP=NNN+1
  DO 61 J=1, NNN
61 INDEXR(J, N)=INDEX(NNP-J, N)
62 CONTINUE
  CHECK GEOMETRY OF ELEMENTS.
  DO 10 J=1, 4
    IF (INDEX(J, N), GT, NOUE) CALL ERROR(1EL, N, J, 5, DIFT)
    IF (J LT 4 AND INDEX(J, N), LT, 1) CALL ERROR(1EL, N, J, 6, DIFT)
10 CONTINUE
  CALL LUGSP(N1, N2, N3, A, B, C, X, ND)
  A1=A
  B1=B
  C1=C
  AREA(N)=AREAF(N1, N2, N3, X, ND)
  IF (N4, EQ, NIL) GO TO 7
  CALL DUGSP(N1, N2, N3, A1, B1, C1, X, ND)

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DIFT=ABS(A-A1)
IF (DIFT.GT.CHRV.AND.(ABS(A)$.GT.0.2)CALL ERROR(1EL,N,11,6,DIFT)
DIFT=ABS(B-B1)
IF (DIFT.GT.CHRV.AND.(ABS(B)$.GT.0.2)CALL ERROR(1EL,N,12,6,DIFT)
DIFT=ABS(C-C1)
IF (DIFT.GT.CHRV.AND.(ABS(C)$.GT.0.2)CALL ERROR(1EL,N,13,8,DIFT)
AR=AREA/(N1,N3,N4,X,ND)
RAT=AR/AREA(N)
IF (RAT.LT.(0.2).OR.RAT.GT.(5.))
1 WRITE(1,13E) "INTEGRAL AR QUAD ELEMENT",N,N,RAT
AREA(N)=AREA(N)*AR
7 CONTINUE
DECEL(1,N)=(A+A1)*HALF
DECEL(2,N)=(B+B1)*HALF
DECEL(3,N)=(C+C1)*HALF
AREA(N)=AREA(N)
IF (AREA(N).LT.AMIN.OR.AREA(N).GT.AMAX)CALL ERROR(1EL,N,9,DIFT)
CALL XCEN(1,N,X,XCOM,ND)
CALCULATE B.C.'S
1 = SPECIFIED TRACTIONS.
2 = SPECIFIED DISPLACEMENTS.
3 = " Z-DISP
4 = " Y-DISP
5 = " X-DISP
6 = " B.C
7 = INTERFACE ELEMENTS
8 = FREE SURFACE (ZERO TRACTIONS)
IDC = 1 FOR TRACTIONS, 2 FOR DISPLACEMENTS.
DEPT(1)=XCOM(3)
IF (CODE.NE.9.AND.CODE.NE.1)GO TO 41
DO 42 1=1,3
DO 21 J=1,3
S16=DEPT*PRIM(1,J)-PRIM(1,I,J)
IF (1/PRIM.EQ.33)SIG=0
21 T(1,N)=S16*DECEL(J,N)+T(1,N)
42 CONTINUE
41 CONTINUE
IF (CODE.EQ.2)CALL NULL(U(1,N),3)
DO 6 J=1,3
DECEL(J,N)=DECEL(J,N)
XCEL(J,N)=XCOM(J)
XCELN(J,N)=XCOM(J)
UR(J,N)=U(J,N)
6 TR(J,N)=-T(J,N)
CODE=KOD(N)
CALL IRLoad(CODE,IEC)
180 FORMAT(1/" LUMP" ELEMENT"118"X-COORD"128"Y-COORD"138"Z-COORD"144" NODE "
1," NUMBERS"129"AREA"177"DIR-X"186"DIR-Y"195"DIR-Z",6X,"B-C",
1115/"CODE ERROR CODE"/)
IF (135U(3).EQ.1.AND.1EL.EQ.NIL)GO TO 3
WRITE(1,181)ML,N,1ELT(N),(XCEL(I,N),1=1,3),(INDEX(1,N),1=1,4)
1,AREA(N),(XCEL(1,N),1=1,3),(IEC(1),1=1,3),KOD(N),1EL
181 FORMAT(14,15,15,F10.2,F10.2,F10.2,146,414,161,F10.2,3(F8.2,1X)
1,314,1113,14,8X,15)

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3 CONTINUE
1 CONTINUE
IF(ISSU(1).NE.0.OR.ISSU(2).NE.0)GO TO 191
IF(KODL(5).NE.0)CALL LOKR(NL,Z,1)
IF(IWILL.EQ.1)CALL LOKR(NLTEM,Z,2)
IF(KODL(6).NE.0)GO TO 191
CALL LOKR(NL,1,1)
LPODE=LKOD(NL)
DO 196 N=1,NMEL
TYPE="H,KOD",N,LKODE
196 FORTN=LKODE
CALL LDEL(NL,Z,1)
191 CONTINUE

C
C
C READ IN FIELD POINT LOCATIONS
C
IF(NUMOR.LE.NIL)GO TO 4
CALL OPEN(5,"BENCH",3,IER)
IF(1ER.NE.1)TYPE="BENCH OPEN ERROR",IER
CALL GENDEN
4 CONTINUE
NLNMF=NLTEM
ICHAN=24*NLMP+2
TYPE="EXIT INPUT",ICHAN
RETURN
END

*****
PARAMETER JQ=13,JJ=59,JY=700
SUBROUTINE TO INTEGRATE OVER A TRIANGLE FOR FIELD POINTS
C
C
C SUBROUTINE INTEGRIN,IN,JA,KN,THAC,DIS,ARC,INTE,STRES,DISP,XX,XC,DCO,UNI
C JACTU
COMMON X(3,JY),ALUMP(JJ),XLUMP(3,JJ),BLUM(3,JJ),LKOD(JJ),LMOD(JJ),
* IFACE(JJ),TLUM(3,JJ),ULUMP(3,JJ),
2 INDIR(3,3),NMLT(3,3),XSYM,YSYM,ZSYM,ISYM,NSYM(5),PRIMO(3,3),PRIMI(3,3),
3 ENOU(5),FRI(5),E,G,V,V1,V2,V3,V4,V5,V6,V7,V8,V9,CIC,CP,CONS,IPC(3),
4 TRANS,TRAN2,TRAN21,TRAN22,TRAN2,TRAN2L,WHIT(11),CBOOK(3,11),
5 NODE,NLTEM,NLJEF,NLJEL,NL,ISTAR,IBUF,LJM,NEL,IP,NOMOR,NICOU,
6 QUC,NIL,TWO,THIRD,HALF,ZERO,11,12,13,P1,ALTC(3,3),DELTA(3,3),GREGA,
7 T(3),UU(3),TREAD,IRITE,A,B,C,R,RSG,ICHAN,ISSU(20),XCOR(3),
8 DEL,ANIN,ALMAX,CURV,HAT,RAIT,ALRAT,ISMAP,RI,RZ,IC3,H4,K1,K2,K3
C
COMMON ZEN/INDEX(4,JQ),DCEL(3,JQ),XCEL(3,JQ),T(3,JQ),U(3,JQ),AREA(JQ)
E,IELT(JQ),KOD(JQ),LIND(JQ),NMEL,COH,PHI,THIK
C
COMMON /AE/ INEXR(4,JQ),DELR(3,JQ),XCELR(3,JQ),TR(3,JQ),UR(3,JQ)
R,AREAR(JQ),IELTH(JQ),KODR(JQ),LINDR(JQ),NMELR,COHR,PHIR,THIKR
C
COMMON /CO/ AO,EQ,W
DIMENSION THAC(1),DIS(1),STRES(3,3),DISP(3),XX(3),XC(3),DCO(3)
DIMENSION UN(3,JY),RCOR(3)
NINTB=11
NINTE=11
NI=AR
MINT=1
NUMPRI=1
IF(INTE.EQ.1)GO TO 20

```

```

CALL XCEN(TIN, JN, IN, XC, X, ND)
CALL SYM(X, SYM, VSYM, ZSYM, NMULT(1, 1SYM), XC)
AR=AREAF(IN, JN, IN, X, ND)
RS=DIST2(X, XC)
RATIO=RSQ/AR
IF(RATIO GE. 1RAN5)GO TO 20
MINI=3
NIRI=8
NINE=10
IF(4R110 GE. 1RAN7)GO TO 20
MINI=7
NINE=1
NIRI=1
IF(RATIO GT. 1RAN21)GO TO 20
LM=NDUE+2
DO 444 L=1, 3
UN(L, LN)=(UN(L, IN)+UN(L, JN))*HALF
444 X(L, LN)=(X(L, IN)+X(L, JN))*HALF
MINI=21
AR=AR/2.
NMIRI=2
IF(4R110 LT. 1RAN42)
1 WRITE(1R1E) "ELT", IELT(N), " TOO CLOSE ---- RATIO =", RATIO
20 CONTINUE
IF(MINI GT. 1)TYPE MINI, N, 1SYM
IF(MINI GT. 7)TYPE 1R110, N
DO 6 NIRI=1, NMIRI
IF(NMIRI, NE. 2)GO TO 43
IF(NIRI EQ. 2)IN=JN
IF(NIRI EQ. 2)JN=LI
JN=JN
IF(NIRI EQ. 1)JN=LN
43 CONTINUE
DO 6 NON=NINE, NINE
IF(NINE EQ. 1)GO TO 64
C1=EUORD(1, 1R10)
C2=EUORD(2, 1R10)
C3=EUORD(3, 1R10)
M1=MEAN(NM1)*AR
DO 24 L=1, 3
24 XC(L)=C1*X(L, IN)+C2*X(L, JN)+C3*X(L, KN)
CALL SYM(X, SYM, VSYM, ZSYM, NMULT(1, 1SYM), XC)
CALL BELSHPE(C1, C2, C3, 3, UN, U(1, N), IN, JN, KN, DIS, ND)
CALL SYM(X, ZERO, ZERO, ZERO, NMULT(1, 1SYM), DIS)
RSQ=DIST2(X, XC)
64 R=SQRT(RSQ)
RS=RS/RSQ
BCR=-M1*CL/RSQ
MR=M1*CONS/R
MS=M1*(D/R)
MD=-M1K
ORDN=ZERO
DO 5 L=1, 3
RCOM(L)=(XC(L)-XX(L))/R
5 LCRN=BCRN+RCOM(L)*DEGL
D3=ORDN*3.
RC1=RCOM(1)
RCV=RC1*V3

```



```

5  ONE, NITER, NLUMP, NMDEL, NMDEL, NU, ISTAR, IEUE, LTH, NSLIP, NUMOR, NMOD,
6  QNE, NL, TWO, THIRU, IEUE, ZERO, 11, 12, 13, P1, ALT(3, 3), DELTA(3, 3), OMEGA,
7  T1(3), UUM(3), IEUE, IRITE, A, B, C, R, RSQ, ICHN, ISSM(20), XCOM(3),
8  FEL, ALGIN, ALMAX, CURV, RAT, RATE, ARRAI, ISMAP, RI, KZ, RD, RA, KI, KZ, KS
SUBROUTINE TO LOAD XEL AND DLG.
DIMENSION AI(1), AR(1), AZ(1), ARIZ(1)
DO 1 I=1,3
AI(I)=AR(1)
1AZ(I)=AR(1)
IF(IA1 EQ 1)CALL SYMX(XSYM, YSYM, ZSYM, NMULT(1, 1SYM), AI)
IF(IA1 EQ NIL)CALL SYMX(ZERO, ZERO, ZERO, NMULT(1, 1SYM), AI)
IF(IA2 EQ 1)CALL SYMX(XSYM, YSYM, ZSYM, NMULT(1, 1SYM), AZ)
IF(IA2 EQ NIL)CALL SYMX(ZERO, ZERO, ZERO, NMULT(1, 1SYM), AZ)
RETURN
END
*****
FNAMELER ,NR=13, NR=97, NV=700
SUBROUTINE LGCM
JACL
COMMON X(3, JV), ALLUMP(JU), XLUMP(3, JU), DLUMC(3, JU), LKON(JU), LMOM(JU),
*
1 IFACE(JU), TLUMP(3, JU), ULUMP(3, JU),
2 MEIN(3, 3), NMUL(1, 3, 3), XSYM, YSYM, ZSYM, 1SYM, NSYM(5), PRIMO(3, 3), PRIMH(3, 3),
3 ENMO(5), FIC(5), L, G, V, VZ, VS, V4, VS, V6, V7, VS, V9, CG, CO, CONS, INC(3),
4 TRANS, TRANZ, TRAMZ1, TRAMZ2, TRANL, TRANLL, WGT(11), COORD(3, 11),
5 HODE, NITFO PLUMP, NMDEL, NMDEL, ND, ISTAR, IEUE, LTH, NSLIP, NUMOR, NMOD,
6 ONE, NIL, TWO, THIRU, IEUE, ZERO, 11, 12, 13, P1, ALT(3, 3), FELTA(3, 3), OMEGA,
7 T1(3), UUM(3), IEUE, IRITE, A, B, C, R, RSQ, ICHN, ISSM(20), XCOM(3),
8 FEL, ALGIN, ALMAX, CURV, RAT, RATE, ARRAI, ISMAP, RI, KZ, RD, RA, KI, KZ, KS
COMMON /HE/ INDEXR(4, JU), DCELR(3, JU), XCELR(3, JU), TR(3, JU), UR(3, JU)
R , AREAR(JU), TELTR(JU), KORR(JU), LINDR(JU), NMDELX, CORR, PIIR, THIRU
CHECK LUMP GEOMETRY
N=NMINL*3
CALL NULL4(DLUMC, XLUMP, TLUMP, ULUMP, NJ)
ATOT=ZERO
WRITE(IRITE, 100)
DO 1 NL=1, NLUMP
IER=NIL
IF(LKOD(NL) EQ NIL)GO TO 1
ALLUMP(NL)=ZERO
CALL LOGLN(NL, 1, 2)
DO 11 N=1, NMDELX
11 ALLUMP(NL)=ALLUMP(NL)+AREAR(N)
ATOT=ATOT+ALLUMP(NL)
DO 12 N=1, NMDELX
IER=NIL
IER=AREAR(N)/ALLUMP(NL)
IF(IERR LT RATE)TYPE "ERROR 10", N, NL, RAT, " < ", RATE
IF(IERR GT RATE)TYPE "ERROR 11", N, NL, RAT, " > ", RATE
IF(IERR LT RATE)IER=10
IF(IERR GT RATE)IER=11
DO 2 I=1, 3
XLUMP(1, NL)=XLUMP(1, NL)*XCELR(1, N)*RAT
DLUMC(1, NL)=DLUMC(1, NL)+DCELR(1, N)*RAT

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Author Diering J A C

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