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THE 3D-SEEP COMPUTER CODE USER'S MANUAL

June 1986

Hideo KIMURA and Susumu MURAOKA

日 本 原 子 力 研 究 所
Japan Atomic Energy Research Institute

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The 3D-SEEP Computer Code User's Manual

Hideo KIMURA and Susumu MURAOKA

Department of Environmental Safety Research
Tokai Research Establishment
Japan Atomic Energy Research Institute
Tokai-mura, Naka-gun, Ibaraki-ken

(Received May 30, 1986)

This report describes the 3D-SEEP computer code and presents the direction to use the code effectively. 3D-SEEP calculates the saturated-unsaturated time dependent or steady state flow of groundwater in permeable geologic media for the safety evaluation of nuclear waste disposal. 3D-SEEP is based on the 3-dimensional Galerkin finite element method. This allows the modeling of complex geometrical shapes and complicated patterns of geologic media. The flow is modeled by single phase flow governed by Darcy's law, and the simplified double porosity model is introduced to consider fractured media. This code can handle non-uniform flow regions having irregular boundaries and arbitrary degree of local anisotropy.

Keywords : Groundwater Flow Model, Finite Element Method, Darcy's Law, Fracture, Double Porosity, Hydraulic Conductivity, Waste Disposal, Safety Evaluation

計算コード3D－SEEPのユーザーズマニュアル

日本原子力研究所東海研究所環境安全研究部
木村　英雄・村岡　進

（1986年5月30日受理）

本報告書は，計算コード3D－SEEPについて述べたもので，本コードを有効に使うためのマニアルである。3D－SEEPは放射性廃棄物処分の安全評価のために，飽和－不飽和，定常－非定常の地下水流解析を行う計算コードである。本コードは，ガラーキン法を用いた3次元有限要素法を用いており，複雑な地形や地層パターンを取り扱うことができる。地下水流はダルシー則にしたがう単相流として取り扱い，フラクチャーを有する地層を考慮するため簡便な二重空隙モデルを導入した。また，本コードは自由水面を有するような領域も取り扱うことが可能である。

東海研究所：〒319－11　茨城県那珂郡東海村白方字白根2－4

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Burial into deep and low permeable geological formations such as crystalline rocks is one of the solutions presently considered for the disposal of high level waste. Transport by moving groundwater is the most likely means of escape for released nuclide transport in geologic media, the modeling of groundwater flow is critically important in the geological disposal. We have developed saturated-unsaturated groundwater flow model using a simple double porosity model by 3-dimensional Galerkin finite element method. The basic parts of this model are based on Neuman's method[1) which can treat both unsaturated and saturated zone.

The pores of rock are assumed to be composed of two parts in the double porosity model[2). The primary pores control the rate of fluid storage and release only, whereas the secondary pores impart the fluid flow capacity. Flow exchange between the two hydraulic elements are determined by the net difference between the primary and secondary hydraulic head. It is difficult to use the double porosity model directly in our model because of 3-dimensional analysis. In order to simplify the calculation, it was introduced the 'Smearing model'. In this model, fractures are not fixed at the specific site but smeared in the element of rock. As permeability of the fracture is given as a function of pressure head, it becomes possible to treat the change of water flow due to elastic change of discontinuous zone.

2. Governing equations

We assume that rock media is uniformly composed of unsaturated zone, and groundwater flow is given by Darcy's law.

$$\vec{u} = -[K_{ij}] \cdot \nabla h \qquad (1)$$

We neglect the compressibility of groundwater and rock in the continuity equation, then

$$-\nabla \vec{u} + Q = c \frac{\partial h}{\partial t} \qquad (2)$$

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where

$\vec{u}(r,t)$: average velocity

$K_{ij}(r,\theta)$; hydraulic conductivity

$h(r,t)$; total head ($h=h_p+h_e$)

$h_p(r,t)$; pressure head

$h_e(r,t)$; elevation head

$Q(r,t)$; nodal flux

$c(r,h_p)$; specific moisture capacity

$\theta(r,h_p)$; volumetric moisture content

We assume so that

$$K_{ij} \equiv K_{ij} \cdot k(h_p, \theta) \tag{3}$$

where

K_{ij} ; saturated hydraulic conductivity

$k(h_p,\theta)$; reduction coefficient of unsaturated zone

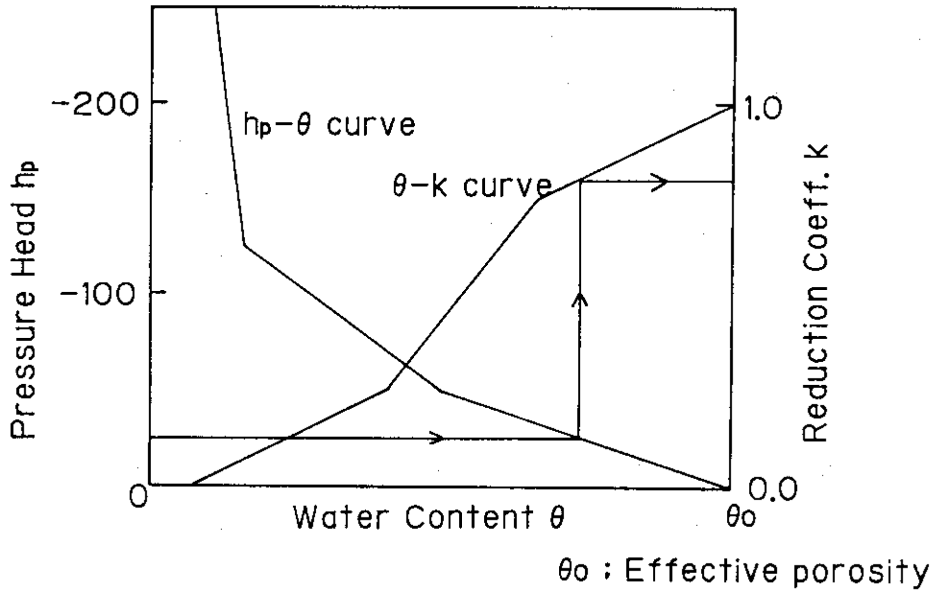

Fig. 1 Hydraulic Property of Unsaturated Zone

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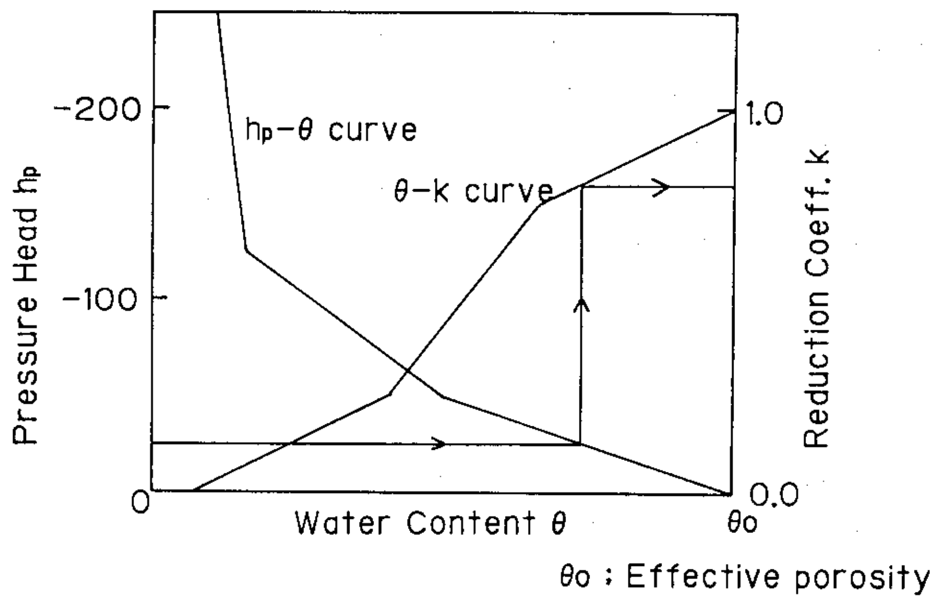

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i) Hydraulic boundary where the pressure is prescrived ;

$$h_p = \overline{h_p} \qquad (4)$$

ii) Internal boundary where normal flow is prescrived;

$$u_n = \overline{u_n} \qquad (5)$$

iii) Atmospheric boundary where the relationship between velocity and moisture is prescrived ;

$$u_n + q_r = 0 \qquad \text{(unsaturated)} \qquad (6)$$

$$h_p = 0 \qquad \text{(saturated)} \qquad (7)$$

4. Discretization by finite element method

For arbitrary value of h_p, the following equation must be satisfied from eq. (1) and (2).

$$\int_v \left(\nabla \vec{u} - Q + c\frac{\partial h_p}{\partial t} \right) \delta h_p \, dV = 0 \qquad (8)$$

The pressure head is assumed to be the linear combination of known shape function $N_i(r)$.

$$h_p = \sum_i h_i(t) \cdot N_i(r) \qquad (9)$$

We use the Galerkin method for eq. (8), considering eq. (9). Then,

$$[K] \cdot \{h\} - \{f\} = -[C] \cdot \{\frac{dh}{dt}\} \qquad (10)$$

where

$$[K] = [K_{ij}] \qquad K_{ij} = \int_v (\nabla N_i)^T \cdot [K] \cdot \nabla N_j \, dV \qquad (11)$$

$$\{f\} = \{f_j\}$$

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$$\{f\} = \{f_j\}$$

$$f_i = \int_v N_i \, QdV + \int S N_i \, q_n \, dS - \int_v (\nabla N_i)^T \begin{Bmatrix} K_{xz} \\ K_{yz} \\ K_{zz} \end{Bmatrix} dV \qquad (12)$$

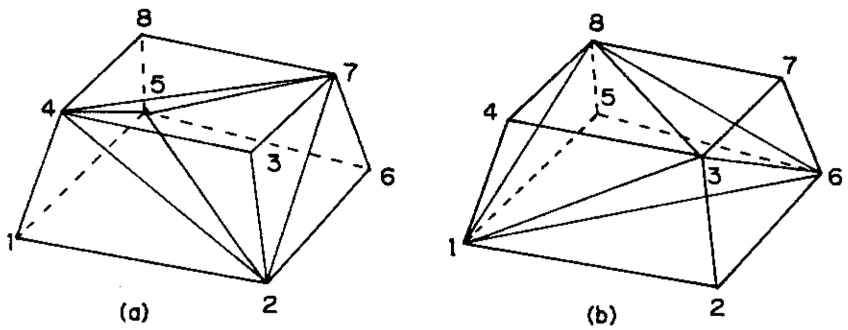
$$[C] = [C_{ij}] \qquad C_{ij} = \int_v c N_i N_j \, dV \qquad (13)$$

5. Complex elements

The basic element of this model is tetrahedral element. If the specified element is pentahedron or hexahedron, the specified element is divided into several tetrahedrons, and the physical values of specified element are given by superposing those of each tetrahedral element.

i) Hexahedral element

In this model, hexahedral element is divided into 10 tetrahedral elements to save the computational time as shown in Fig. 2.



(a)	(b)
1) 1-2-4-5	1) 1-2-3-6
2) 2-3-4-7	2) 1-3-4-8
3) 2-4-5-7	3) 1-6-3-8
4) 2-5-6-7	4) 1-5-6-8
5) 4-5-7-8	5) 3-6-7-8

Fig. 2 Hexahedral element

ii) Pentahedral element

Pentahedral element is divided into 12 tetrahedral elements as shown in Fig. 3.

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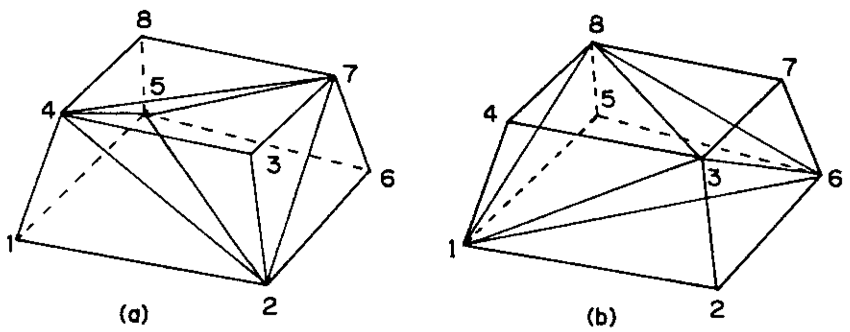

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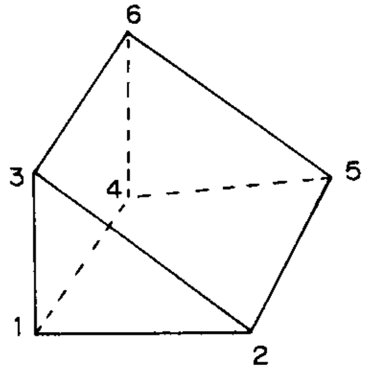
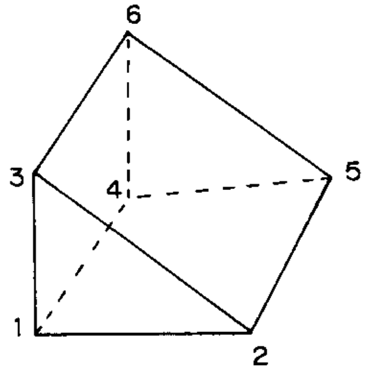


1) 1-2-3-4	7) 1-2-4-6
2) 1-2-3-5	8) 1-2-5-6
3) 1-2-3-6	9) 1-3-4-5
4) 1-4-5-6	10) 1-3-5-6
5) 2-4-5-6	11) 2-3-4-5
6) 3-4-5-6	12) 2-3-4-6

Fig. 3 Pentahedral element

6. Smearing model

The primary pores (micro crack) control the rate of fluid storage and release only, and secondary pores (fracture) impart the fluid flow capacity in the double porosity model. Smearing model does not share the role of fluid storage and flow capacity to simplify the calculation. The fractures of rock are not fixed at the specific site but smeared in the element of rock, and element including fracture is not treated as plane element. We consider the following element as shown in Fig. 4.



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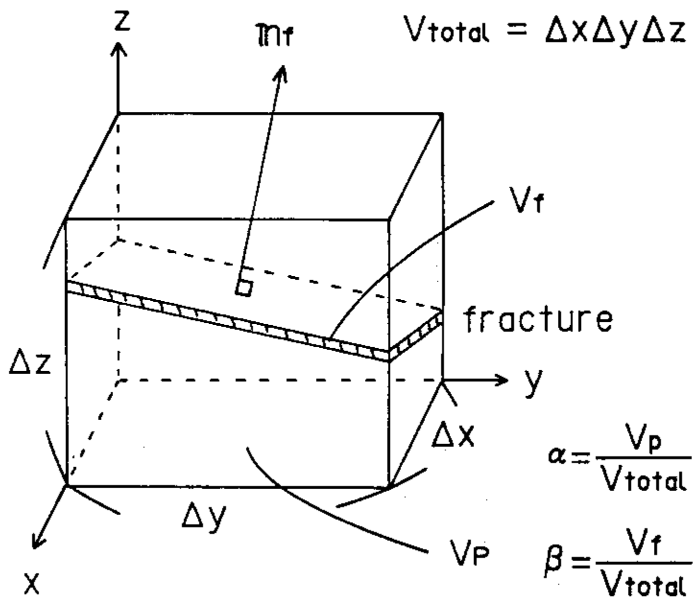

Fig. 4 Finite element including fracture

In this element, the flow-velocity of primary pores and fracture are given by Darcy's law as follows,

$$\vec{u}_p = -\overline{K}_p \cdot \nabla h \tag{14}$$

$$\vec{u}_f = -\overline{K}_f \cdot \nabla h \tag{15}$$

where

$\overline{K}_p$; hydraulic conductivity tensor of primary pores

$\overline{K}_f$; hydraulic conductivity tensor of fracture.

Then, averaged (smeared) flow-velocity of this element is given by summing up each velocity multipuled by volume ratio.

$$\vec{u}_{smear} = -(\alpha\overline{K}_p + \beta\overline{K}_f) \cdot \nabla h \tag{16}$$

where

α ; volume ratio of primary pores to total volume

β ; volume ratio of fracture to total volume,

and coordinate-system of fracture is not always equal to original coordinate-system, then transformation of coordinate is necessary for summing up velocities. It becomes possible to treat the change of discontinuous zone by assuming that permeability of the fracture is a function of pressure head as shown in Fig. 5.

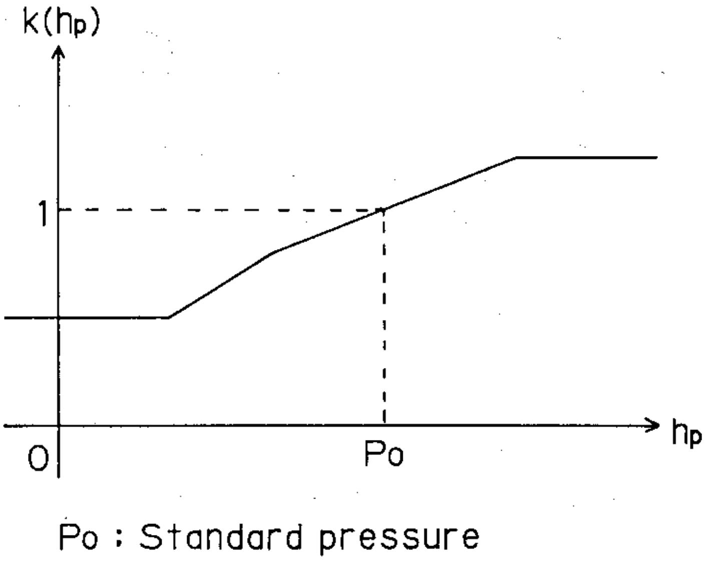

Fig. 5 Pressure dependent hydraulic conductivity of fracture

7. Treatment of boundary conditions in this model

Some modifications are necessary for finite element grids when certain line of elements lies between the boundary where pressure head is prescribed and the boundary where normal flux is prescribed as shown in Fig. 6. These cases occur when the water level moves continuously, therefore the seepage points change.

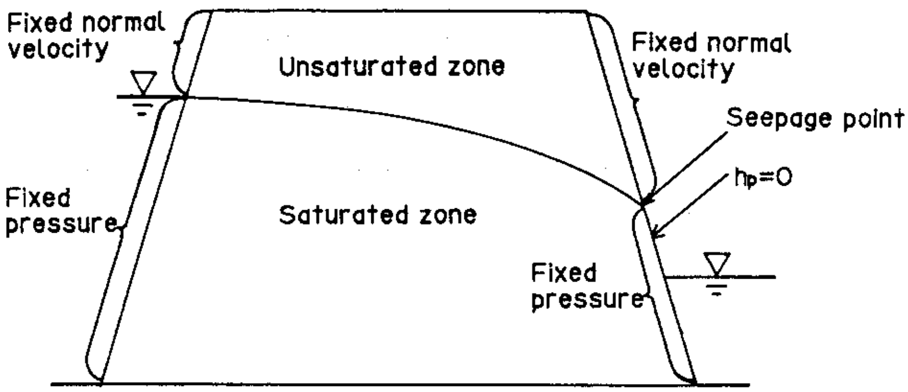

Fig. 6 Boundary conditions of water level

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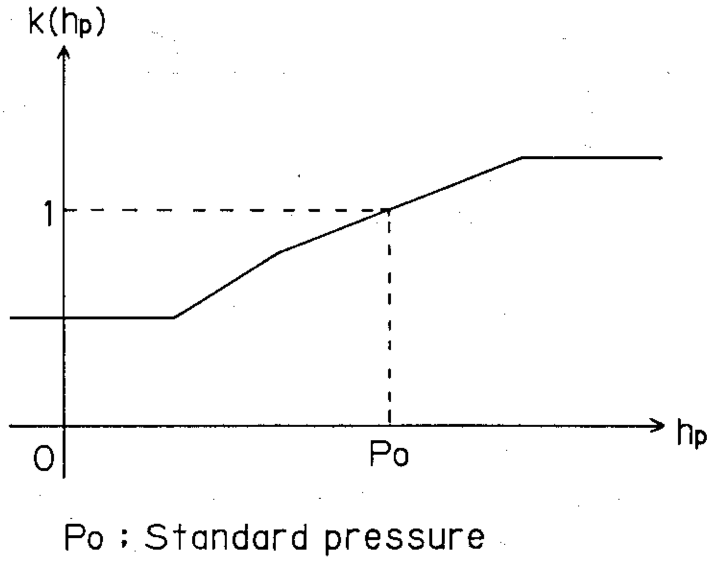

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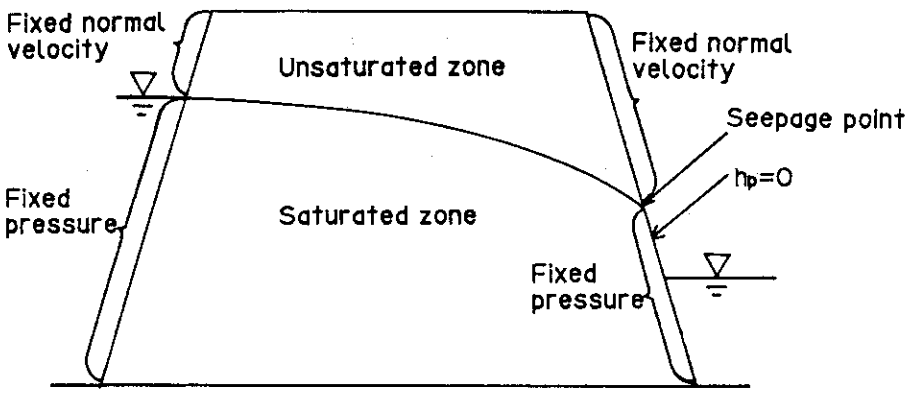


Fig. 6 Boundary conditions of water level

i) Movement of water level

Water level data modifies the grid pattern at the boundary by shifting the nearest nodal point to the water level as shown in Fig. 7.

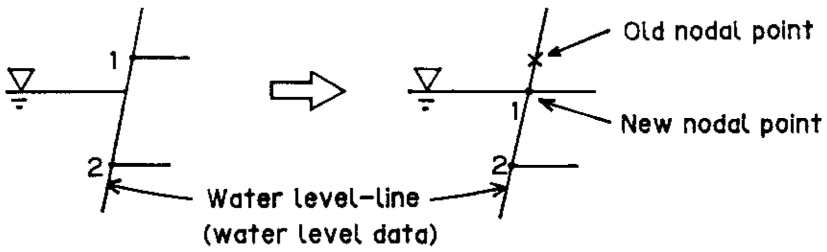


Fig. 7 Treatment of moving surface

ii) Changing of seepage points

As the seepage point is an unknown variable, it should be calculated as follows ; The boundary condition around the seepage point is shown in Fig. 8, and the solving process should be inevitably iterative. First, we assume the boundary condition and the resulting position may slightly differ from the assumption. Then we correct the boundary condition and resume the calculation as shown in Fig. 9. This process is continued until the position is settled using pressure head h_p and following value $\hat{f}$.

$$\{ \hat{f} \} = [K] \cdot \{ h \} \qquad (17) .$$

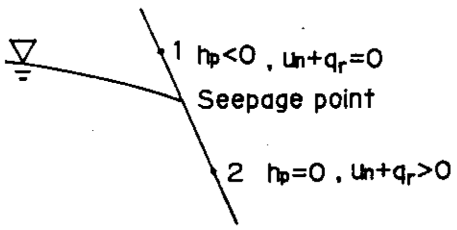


Fig. 8 Boundary condition around the seepage point

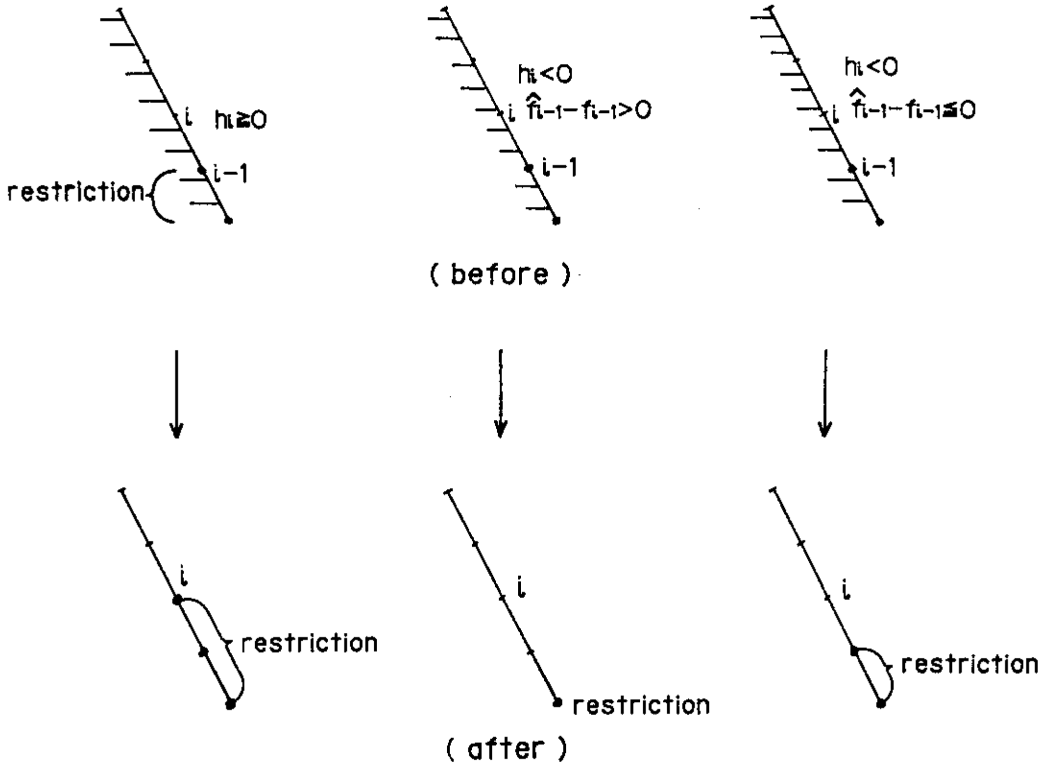


Fig. 9 Changing boundary condition

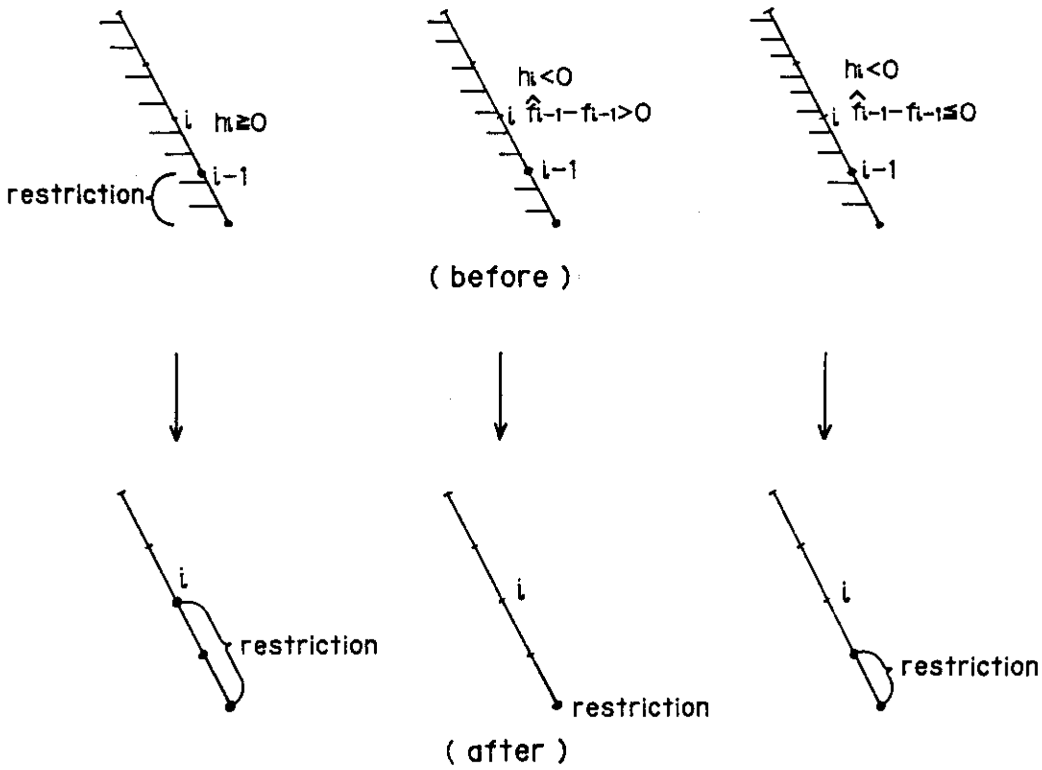
8. Numerical method

Flow chart of this model is shown in Fig. 10. For steady state analysis, eq. (10) becomes following type.

$$[K]\cdot\{h\}=\{f\} \tag{18}$$

As the hydraulic matrix [K] and the load vector {f} are the function of pressure head, eq. (18) is non-linear equation. It is necessary to solve eq. (18) using following iteration method.

1) assume {h}
2) calculation of [K] and {f}
3) calculation of {f} and {h} at the restricted point
4) convergence check (using uniform norm)
5) changing of boundary condition at the seepage point (not converged case only)



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6) let

$$\{h\}_i = \frac{1}{2}\left[\{h\}_i + \{h\}_{i-1}\right] \tag{19}$$

7) let i→i+1 and then 2)

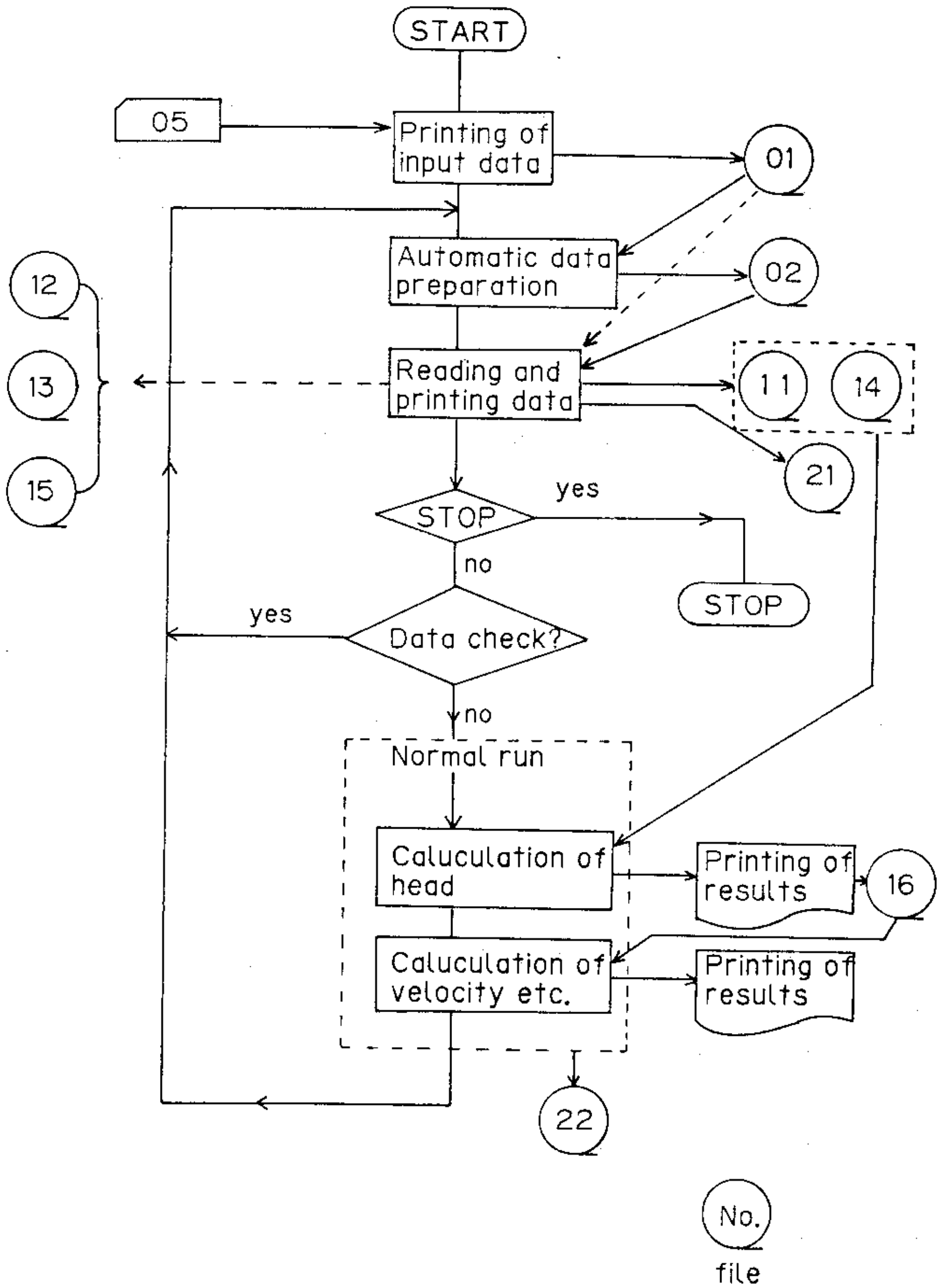

Fig. 10 Flow chart of 3D-SEEP

For transient state analysis, Crank-Nicholson method is adopted for dicretization of time, and the linearlity of eq. (10) is assumed. Calculation is performed by following process.

1) initial setting of {h}
2) setting of boundary condition at the seepage point
3) calculation of [K], [C] and {f}
4) integration of time (Crank-Nicholson method) and calculation of {h}
5) changing of boundary condition at seepage point if necessary then 3)
6) $t \rightarrow t+\Delta t$ then 2)

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Reference

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Appendix 1-A Input data for 3D-SEEP

1. Control data

2. Nodal data

3. Water level data

4. Material data

5. Hydraulic data

6. Element data

7. Time data

8. Fracture data

9. End data

(In input data, # means essential data.)

1.1 Control card (2cards) #

column	entry	contents	format
1~5		Control parameter of caluclation	I5
	0	Normal run	
	1	Data check (cal. of element volume and band-minimize)	
	2	Data check (band-minimize only)	
6~10		Control parameter of permeability matrix calculation	I5
	0	Detailed calculation *	
	1	Simplified calculation **	
11~15		Control parameter of convergence-check	I5
	0	If there is a nodal point error of which is larger than given convergent limit, convergence-check is completed	
	1	Convergence-check for all nodal points	
16~20	>0	Limited number of iteration in a given boundary condition	I5
21~25	>0	Limited number of alternating boundary condition	I5
26~30	>0	Total limited number of iteration	I5
31~35	m	Value of judging the convergence (mantissa)	I5
36~40	n	Value of judging the convergence (exponent)	I5
41~45	m	Value of judging the seepage boundary (mantissa)	I5
46~50	n	Value of judging the seepage boundary (exponent)	I5
51~55	m	Volume ratio of solid element (mantissa)	I5
56~60	n	Volume ratio of solid element (exponent)	I5
61~65	0	Band-minimize	I5
	1	Without band-minimize	

* Linearity of unsaturated reduction coefficient is assumed in the element.

** Unsaturated reduction coefficient is constant in the element.

Second card

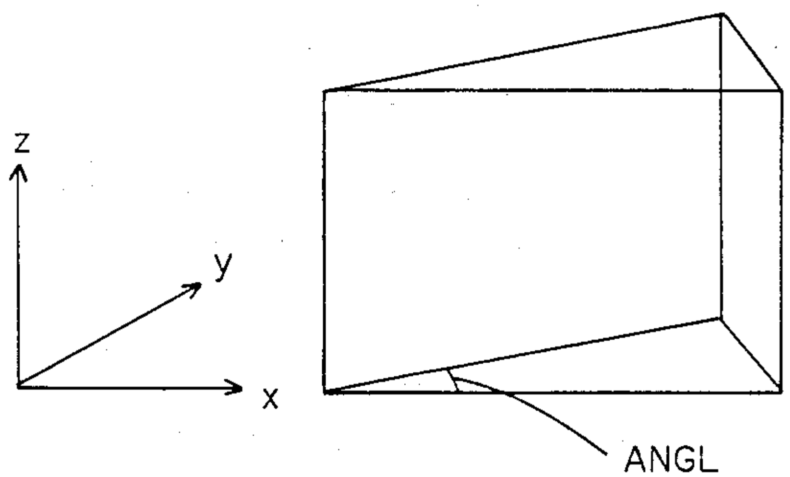
column	entry	contents	format
1~5	0 1	Printing of nodal-point and material data Without printing	I5
6~10	0 1	Printing of element data Without printing	I5
11~15	0 1	Printing of fracture data Without printing	I5
16~20	0 1	Printing of element-volume without printing	I5
21~25	0 1	Printing of band-minimized results Without printing	I5
26~30	0 1	Without printing Printing of iterated calculation	I5
31~35	0 1	Printing of real flow-velocity Without printing	I5
36~40	0 1	Printing of discharge from the nodal points Without printing	I5
41~45	ANGL	Open angle of front-side (X-axis) and back-side (axial symmetry case only, node-data of back-side are automatically prepared)	F5.0
46~50	NDELT	Increasement of nodal number of back-side (axial symmetry case only)	I5

1.2 Title card

column	entry	contents	format
2~72		Name of title (maximum 5 cards)	71A1

1.3 Comment card

column	entry	contents	format
1	'C'	Meaning of comment card	A4
2~72		Comment (anywhere and any time)	



Axial symmetry case

2.1 Header card of node-data #

column	entry	contents	format
1~4	'NODE'	Meaning of node-data	A4
5~72	blank		

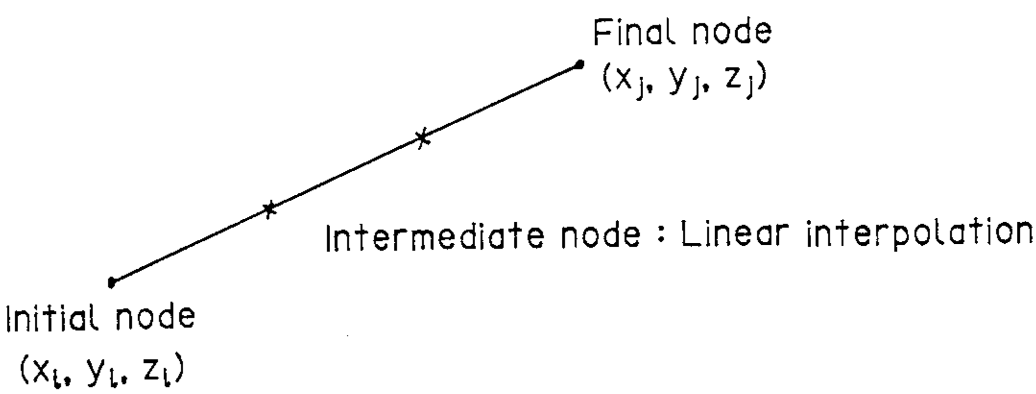
2.2 Node-data (TYPE-1) #

column	entry	contents	format
1~4	'NODE'	Meaning of node-data	A4
7~10	NO	Number of this nodal point	I4
11~20	X	X-coordinate of this nodal point	F10.0
21~30	Y	Y-coordinate of this nodal point	F10.0
31~40	Z	Z-coordinate of this nodal point	F10.0
41~50	HP	Restricted value of hydraulic pressure head (IFX>0) Initial value of hydraulic pressure head (IFX=0)	F10.0
51~60	blank		
61~63	IFX	Sign of restricting hydraulic pressure head (IFX>0)	I3
64~66	IDQ	Sign of specifing boundary-velocity in this nodal point IDQ=0 ; boundary-velocity=0 IDQ>0 ; boundary-velocity is given by user's subroutine	I3

2.3 Node-data (TYPE-2 2cards)

First card

column	entry	contents	format
1~4	'NODE'	Meaning of node-data	A4
7~10	NO	Number of initial nodal point	I4
11~20	X	X-coordinate of initial nodal point	F10.0
21~30	Y	Y-coordinate of initial nodal point	F10.0
31~40	Z	Z-coordinate of initial nodal point	F10.0
41~50	HP	The same as TYPE-1	F10.0
61~63	IFX	The same as TYPE-1	I3
64~66	IDQ	The same as TYPE-1	I3
70~72	'SEQ'	Sign of automatic node-data preparation	A3



Node data (TYPE-2)

Second card

column	entry	contents	format
1~4	'NODE'	Meaning of node-data	A4
7~10	NO	Number of final nodal point	I4
11~20	X	X-coordinate of final nodal point	F10.0
21~30	Y	Y-coordinate of final nodal point	F10.0
31~40	Z	Z-coordinate of final nodal point	F10.0
64~66	Δn	Increment of nodal point number	I3
70~72	'SEQ'	Sign of automatic node-data preparation	A3

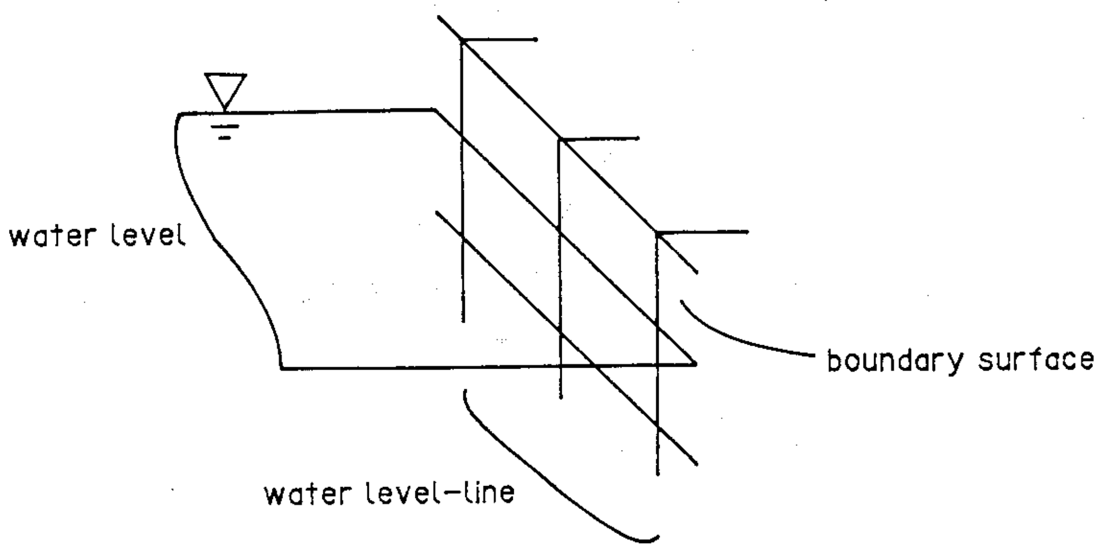
3.1 Water level header card

column	entry	contents	format
1~4	'LINE'	Meaning of water level data (at the seepage boundary)	A4
5~72	blank		

3.2 Water level cards (>1)

First card

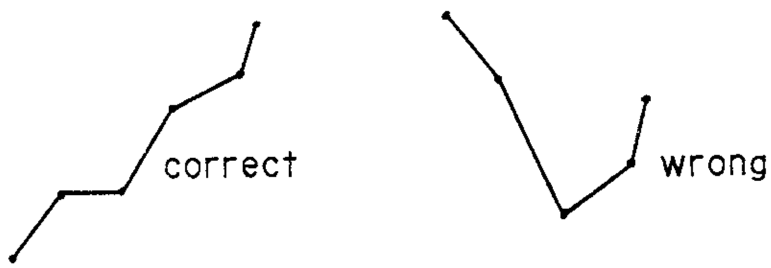
column	entry	contents	format
1~4	'LINE'	Meaning of water level data	A4
7~10	LNO	Line number of water level	I4
11~15	NN	Number of node composing a water level-line	I5
16~25	HIGH	Water level (Z-component)	F10.0
26~30	LTRN	Number of water level condition (transient cal. only) Time-dependent water level can be defined in the user's subroutine HEADTR	I5



Second card (similar cards necessary NN>10)

column	entry	contents	format
1~4	'LINE'	Meaning of water level data	A4
16~20	J1	Node number composing a water level-line *	I5
21~25	J2	The same as above	I5
26~30	J3	The same as above	I5
31~35	J4	The same as above	I5
36~40	J5	The same as above	I5
41~45	J6	The same as above	I5
46~50	J7	The same as above	I5
51~55	J8	The same as above	I5
56~60	J9	The same as above	I5
61~65	J10	The same as above	I5

* Z-coordinate of JN must be larger than or equal to that of JN-1.
J1~JN must be sequential numbers.



water level-line

4.1 Header card of material data

column	entry	contents	format
1~4	'MATE'	Meaning of material data	A4
5~72	blank		

4.2 Material card TYPE-A (for solid part)

column	entry	contents	format
1~4	'MATE'	Meaning of material data	A4
7~10	MNO	Material number	I4
11~15	NF	Function number of hydraulic property	I5
16~22	KXX	Hydraulic conductivity (XX-component)	F7.0
23~29	KYY	Hydraulic conductivity (YY-component)	F7.0
30~36	KZZ	Hydraulic conductivity (ZZ-component)	F7.0
37~43	KXY	Hydraulic conductivity (XY-component)	F7.0
44~50	KXZ	Hydraulic conductivity (XZ-component)	F7.0
51~57	KYZ	Hydraulic conductivity (YZ-component)	F7.0
58~64	RNE	Effective porosity	F7.0
65~71	C	Specific storage	F7.0

4.3 Material card TYPE-B (for fracture part)

column	entry	contents	format
1~4	'MATE'	Meaning of material data	A4
7~10	MNO	Material number	I4
11~15	NF	Function number of hydraulic property in the fracture	I5
16~22	KXX	Hydraulic conductivity (XX-component)	F7.0
23~29	KYY	Hydraulic conductivity (YY-component)	F7.0
30~36	KZZ	Hydraulic conductivity (ZZ-component)	F7.0

5.1 Header card of hydraulic property function #

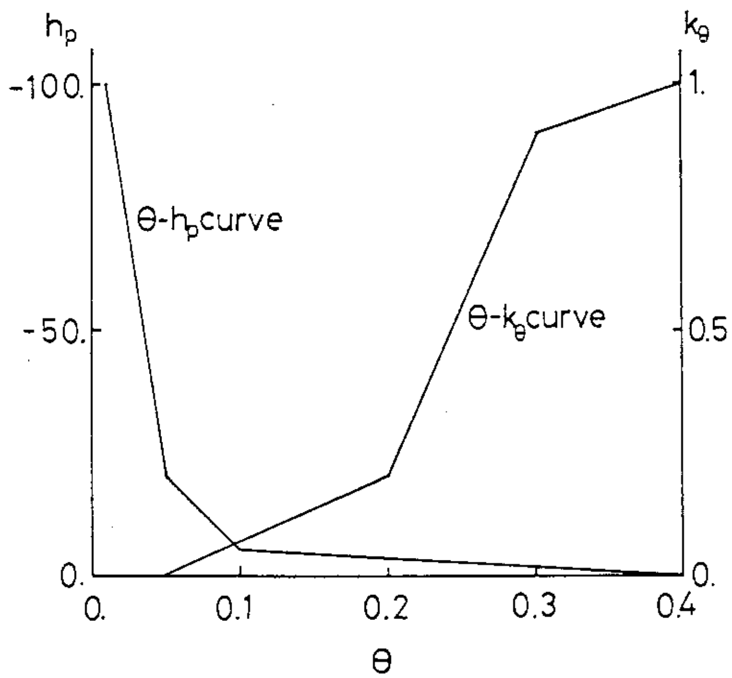
column	entry	contents	format
1~4	'FCON'	Meaning of hydraulic property function data	A4
5~72	blank		

5.2 Data of hydraulic property function (first card) #

column	entry	contents	format
1~5	'TH-HP'	Meaning of hydraulic property-relation (θ-h_p)	A4,1X
11~15	IFN	Funcion number of hydraulic property	I5
16~20	ND1	Number of dividing hydraulic property-curve (θ-h_p)	I5
21~25	TH1	Moisture content (ND1 pieces necessary)	F5.0
26~30	TH2	Moisture content	F5.0
31~35	TH3	Moisture content	F5.0
36~40	TH4	Moisture content	F5.0
41~45	TH5	Moisture content	F5.0
46~50	TH6	Moisture content	F5.0
51~55	TH7	Moisture content	F5.0
56~60	TH8	Moisture content	F5.0
61~65	TH9	Moisture content	F5.0
66~70	TH10	Moisture content	F5.0

Second card

column	entry	contents	format
21~25	H1	Corresponding pressure head to moisture content TH1	F5.0
26~30	H2	Corresponding pressure head to moisture content TH2	F5.0
31~35	H3	Corresponding pressure head to moisture content TH3	F5.0
36~40	H4	Corresponding pressure head to moisture content TH4	F5.0
41~45	H5	Corresponding pressure head to moisture content TH5	F5.0
46~50	H6	Corresponding pressure head to moisture content TH6	F5.0
51~55	H7	Corresponding pressure head to moisture content TH7	F5.0
56~60	H8	Corresponding pressure head to moisture content TH8	F5.0
61~65	H9	Corresponding pressure head to moisture content TH9	F5.0
66~70	H10	Corresponding pressure head to moisture content TH10	F5.0



Third card

column	entry	contents	format
1~5	'TH-K'	Meaning of hydraulic property-relation (θ-k)	5X
16~20	ND2	Number of dividing hydraulic property-curve (θ-k)	I5
21~25	TS1	Moisture content (ND2 pieces necessary)	F5.0
26~30	TS2	Moisture content	F5.0
31~35	TS3	Moisture content	F5.0
36~40	TS4	Moisture content	F5.0
41~45	TS5	Moisture content	F5.0
46~50	TS6	Moisture content	F5.0
51~55	TS7	Moisture content	F5.0
56~60	TS8	Moisture content	F5.0
61~65	TS9	Moisture content	F5.0
66~70	TS10	Moisture content	F5.0

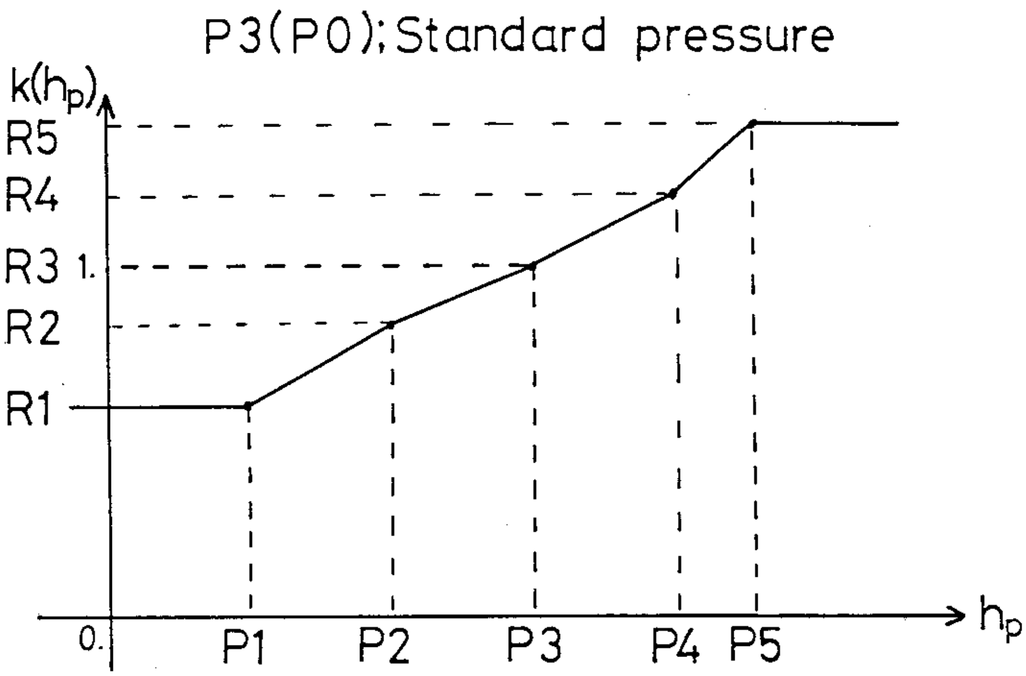
Fourth card

column	entry	contents	format
21~25	K1	Corresponding coefficient of unsaturated hydraulic conductivity to moisture content TS1	F5.0
26~30	K2	Corresponding coefficient of unsaturated hydraulic conductivity to moisture content TS2	F5.0
31~35	K3	Corresponding coefficient of unsaturated hydraulic conductivity to moisture content TS3	F5.0
36~40	K4	Corresponding coefficient of unsaturated hydraulic conductivity to moisture content TS4	F5.0
41~45	K5	Corresponding coefficient of unsaturated hydraulic conductivity to moisture content TS5	F5.0
46~50	K6	Corresponding coefficient of unsaturated hydraulic conductivity to moisture content TS6	F5.0
51~55	K7	Corresponding coefficient of unsaturated hydraulic conductivity to moisture content TS7	F5.0
56~60	K8	Corresponding coefficient of unsaturated hydraulic conductivity to moisture content TS8	F5.0
61~65	K9	Corresponding coefficient of unsaturated hydraulic conductivity to moisture content TS9	F5.0
66~70	K10	Corresponding coefficient of unsaturated hydraulic conductivity to moisture content TS10	F5.0

5.3 Header card of fracture hydraulic property data #

Hydraulic conductivity of fracture media can be expressed as the function of hydraulic pressure head.

column	entry	contents	format
1~4	'FFCN'	Meaning of fracture hydraulic property	A4
5~72	blank		



5.4 Fracture hydraulic property data #

First card

column	entry	contents	format
1~4	'TH-K'	Meaning of hydraulic property-relation (h_p-k)	A4
11~15	K2	Function number of fracture hydraulic property	I5
16~20	K3	Number of dividing fracture hydraulic property-curve	I5
21~25	R1	Coefficent of hydraulic conductivity (K3 pieces necessary)	F5.0
26~30	R2	Coefficent of hydraulic conductivity	F5.0
31~35	R3	Coefficent of hydraulic conductivity	F5.0
36~40	R4	Coefficent of hydraulic conductivity	F5.0
41~45	R5	Coefficent of hydraulic conductivity	F5.0
46~50	R6	Coefficent of hydraulic conductivity	F5.0
51~55	R7	Coefficent of hydraulic conductivity	F5.0
56~60	R8	Coefficent of hydraulic conductivity	F5.0
61~65	R9	Coefficent of hydraulic conductivity	F5.0
66~70	R10	Coefficent of hydraulic conductivity	F5.0

Second card

column	entry	contents	format
16~20	P0	Standard pressure head (correspond to k =1.0)	I5
21~25	P1	Corresponding pressure head to R1	I5
26~30	P2	Corresponding pressure head to R2	I5
31~35	P3	Corresponding pressure head to R3	I5
36~40	P4	Corresponding pressure head to R4	I5
41~45	P5	Corresponding pressure head to R5	I5
46~50	P6	Corresponding pressure head to R6	I5
51~55	P7	Corresponding pressure head to R7	I5
56~60	P8	Corresponding pressure head to R8	I5
61~65	P9	Corresponding pressure head to R9	I5
66~70	P10	Corresponding pressure head to R10	I5

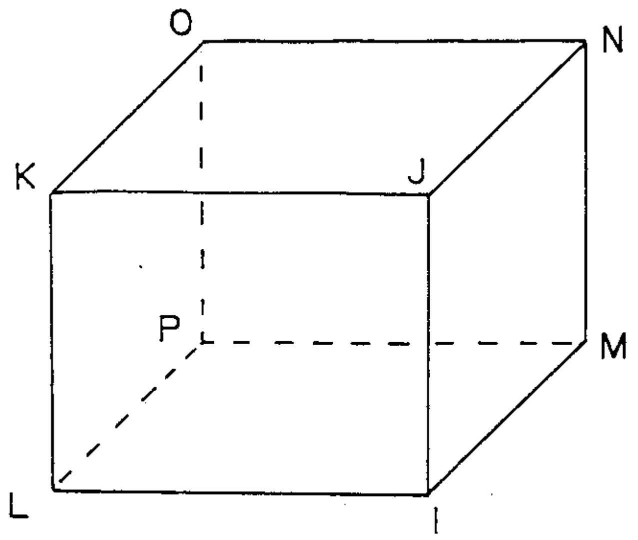
6.1 Header card of element data #

column	entry	contents	format
1~4	'ELEM'	Meaning of element data	A4
5~72	blank		

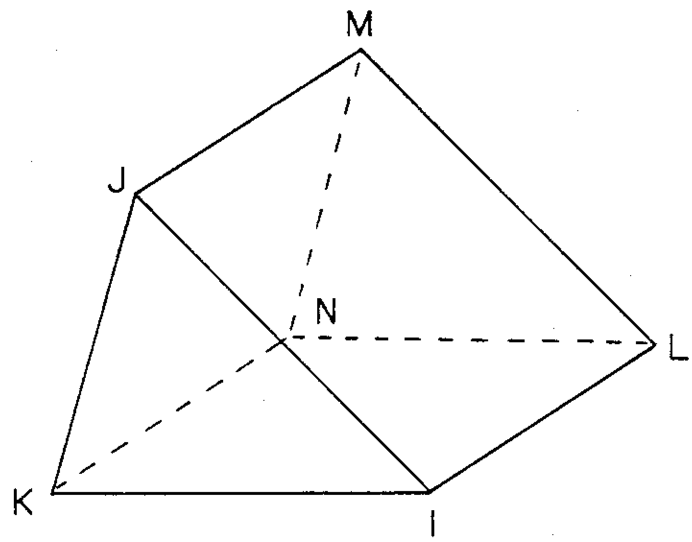
6.2 Element data (TYPE-1 tetrahedron, pentahedron and hexahedron)

column	entry	contents	format
1~5	'SOLID'	Meaning of element data	A4,1X
7~10	N3	Element number	I4
11~15	I	1-st nodal number constructing this element	I5
16~20	J	2-nd nodal number constructing this element	I5
21~25	K	3-rd nodal number constructing this element	I5
26~30	L	4-th nodal number constructing this element	I5
31~35	M	5-th nodal number constructing this element *	I5
36~40	N	6-th nodal number constructing this element	I5
41~45	O	7-th nodal number constructing this element	I5
46~50	P	8-th nodal number constructing this element	I5
51~55	IS	Material number	I5
56~60	IHGS	Index of discharge rate from this element (discharge rate is defined in the user's subroutine BLMCHQ)	I5

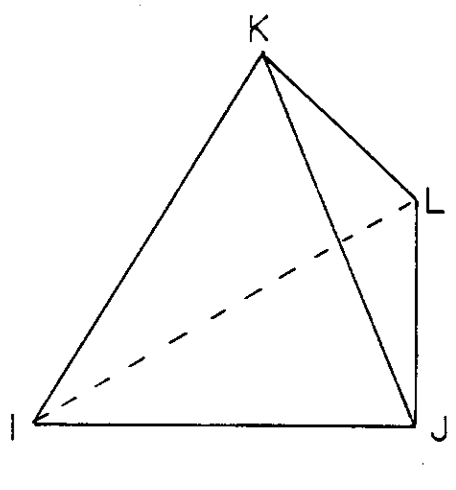
* 5~8-th and 7~8th data are unnecessary for tetrahedron and pentahedron respectively.



hexahedron



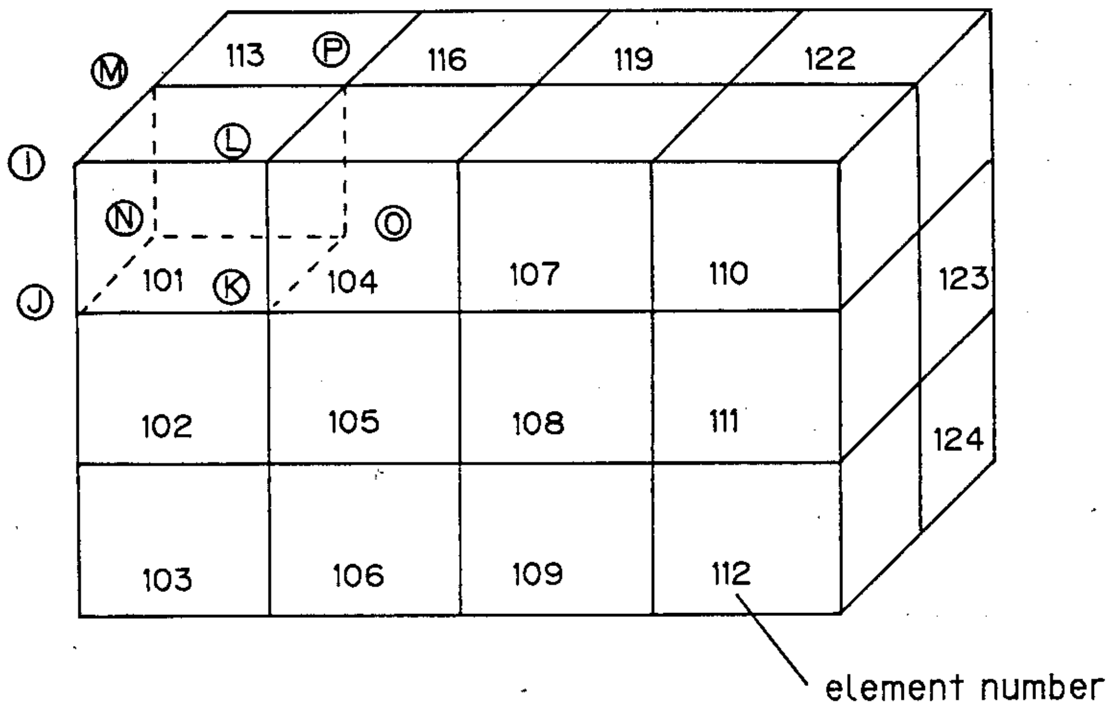
pentahedron



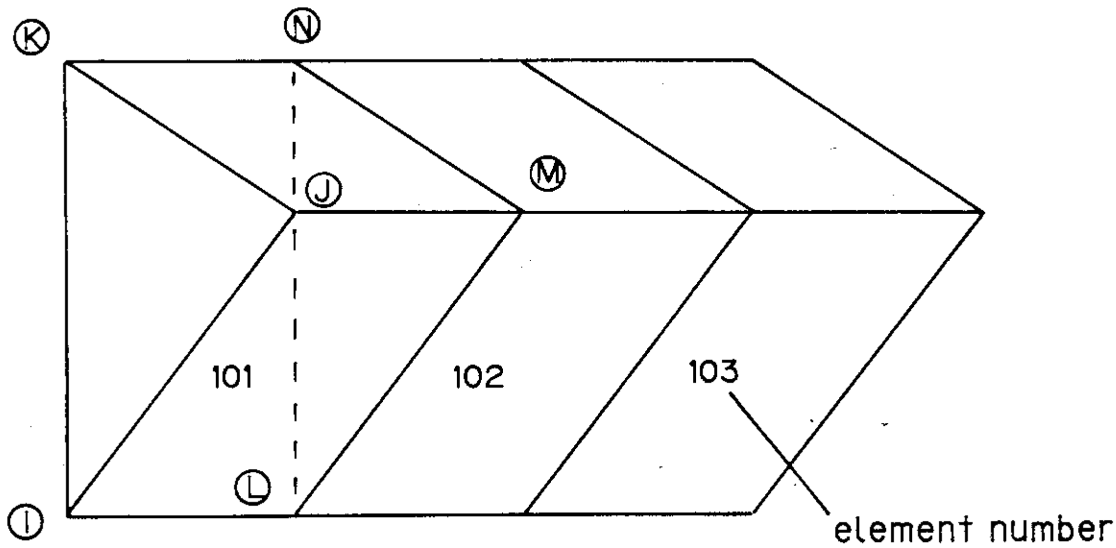
tetrahedron

6.3 Element data (TYPE-2 (hexahedron) automatic element data preparation)

column	entry	contents	format
1~5	'SOLID'	Meaning of element data	A4,1X
7~10	N3	Initial element number	I4
11~15	I	Initial 1-st nodal number constructing this element	I5
16~20	J	Initial 2-nd nodal number constructing this element	I5
21~25	K	Initial 3-rd nodal number constructing this element	I5
26~30	L	Initial 4-th nodal number constructing this element	I5
31~35	M	Initial 5-th nodal number constructing this element	I5
36~40	N	Initial 6-th nodal number constructing this element	I5
41~45	O	Initial 7-th nodal number constructing this element	I5
46~50	P	Initial 8-th nodal number constructing this element	I5
51~55	IS	Material number	I5
56~60	IHGS	The same as TYPE-1	I5
64~65	N1	Number of automatic prepared element (I-J direction)	I5
66~67	N2	Number of automatic prepared element (I-L direction)	I5
68~69	N3	Number of automatic prepared element (I-M direction)	I5
70~72	'BLK'	Sign of automatic data preparation (TYPE-2)	A3



Hexahedral element



Trigonal prism element

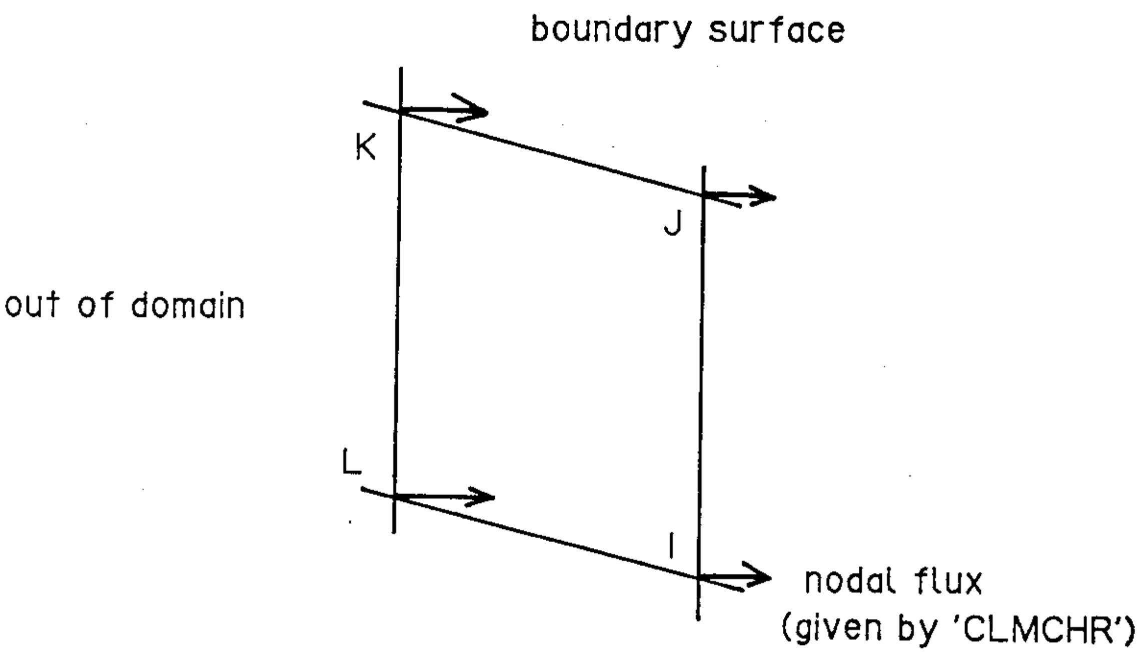
6.4 Element data (TYPE-3 (trigonal prism) automatic element data preparation)

column	entry	contents	format
1~5	'SOLID'	Meaning of element data	A4,1X
7~10	N3	Initial element number	I4
11~15	I	Initial 1-st nodal number constructing this element	I5
16~20	J	Initial 2-nd nodal number constructing this element	I5
21~25	K	Initial 3-rd nodal number constructing this element	I5
26~30	L	Initial 4-th nodal number constructing this element	I5
31~35	M	Initial 5-th nodal number constructing this element	I5
36~40	N	Initial 6-th nodal number constructing this element	I5
51~55	IS	Material number	I5
56~60	IHGS	The same as TYPE-1	I5
68~69	N1	Number of automatic prepared element (I-L direction)	I5
70~72	'TRI'	Sign of automatic data preparation (TYPE-3)	A3

6.5 Boundary element data (TYPE-1)

This data define boundary surface.

column	entry	contents	format
1~5	'BOUND'	Meaning of boundary element data	A4,1X
7~10	NB	Element number	I4
11~15	I	1-st nodal number of boundary surface	I5
16~20	J	2-nd nodal number of boundary surface	I5
21~25	K	3-rd nodal number of boundary surface	I5
26~30	L	4-th nodal number of boundary surface	I5
56~60	IHGB	Index of rainfall recharge from this surface (recharge rate can be difined in the user's subroutine CLMCHR)	I5



6.6 Boundary element data (TYPE-2 automatic data preparation)

column	entry	contents	format
1~5	'BOUND'	Meaning of boundary element data	A4,1X
7~10	NB	Element number	I4
11~15	I	1-st nodal number of boundary surface	I5
16~20	J	2-nd nodal number of boundary surface	I5
21~25	K	3-rd nodal number of boundary surface	I5
26~30	L	4-th nodal number of boundary surface	I5
56~60	IHGB	The same as TYPE-1	I5
64~65	N1	Number of automatic prepared element to define boundary surface (I-J direction)	I5
66~67	N2	Number of automatic prepared element to define boundary surface (I-L direction)	I5
70~72	'BLK'	Sign of automatic data preparation (TYPE-2)	A3

7.1 Header card of transient calculation (transient only)

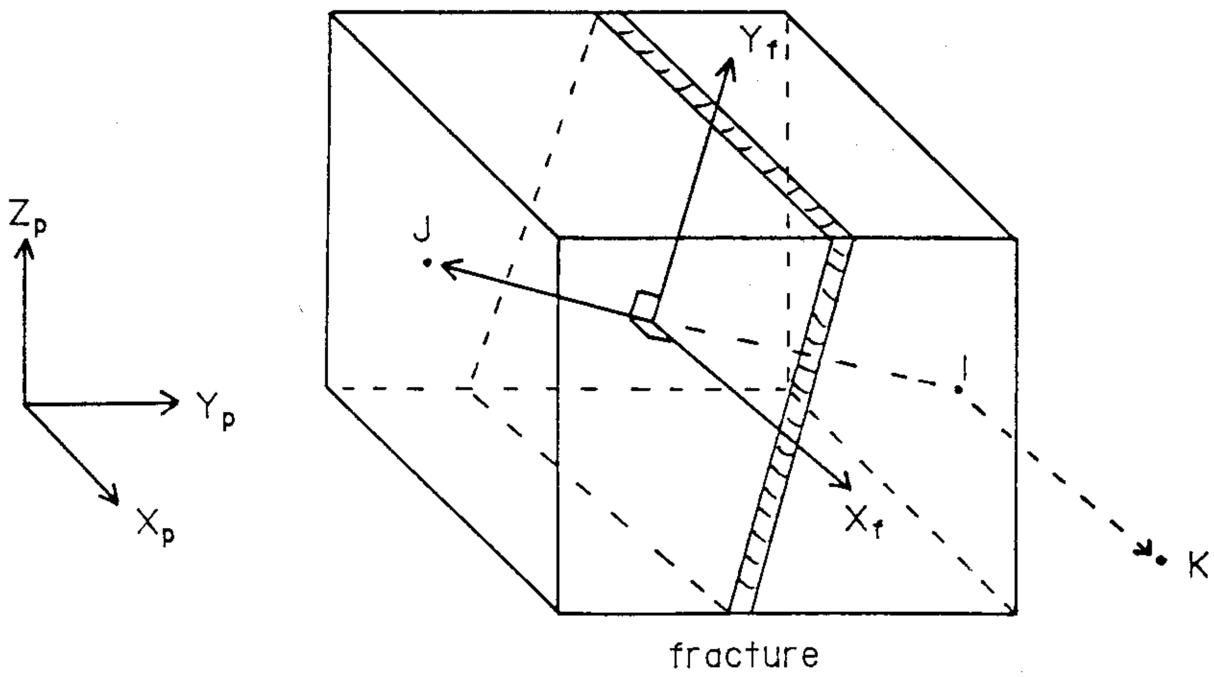
column	entry	contents	format
1~4	'TIME'	Meaning of time data	A4
7~10	NPRN	Interval of printing calculated results 1 ; printing every time step	I4

7.2 Time data of transient calculation (transient only, any card)

column	entry	contents	format
1~4	'TIME'	Meaning of time data	A4
7~10	NSTEP	Number of time step	I4
11~18	DT	Increment of time	F8.0

8.1 Header card of fracture data (for Smearing model)

column	entry	contents	format
1~4	'FRC1'	Meaning of fracture data	A4
5~72	blank		



8.2 Fracture data (TYPE-1)

Fracture is located in the element

column	entry	contents	format
1~4	'FRC1'	Meaning of fracture data	A4
6~10	K2	Fracture number	I5
11~15	K3	Element number includes fracture	I5
16~20	K4	Nodal number of I	I5
21~25	K5	Nodal number of J (Normal direction of fracture is given as the direction from I to J node.)	I5
26~30	K6	Nodal number of K 0 or blank ; hydraulic conductivity tensor is isotropy >0 ; X-direction of fracture is I-K direction	I5
31~35	K7	Material number of fracture	I5
41~50	R1	Volume ratio of fracture ($0.0<R1<1.0$)	F10.0
51~60	R2	Thickness of fracture	F10.0
64~66	L1	Number of element (automatic fracture data preparation)	I3
67~69	L2	Increment of element number (automatic data preparation)	I3
70~72	'SEQ'	Sign of automatic data preparation *	A3

8.3 Fracture data (TYPE-2)

Fracture is located between elements (a and b)

column	entry	contents	format
1~4	'FRC1'	Meaning of fracture data	A4
6~10	K2	Fracture number	I5
11~15	K3	Element number includes fracture (a)	I5
16~20	K4	The same as TYPE-1	I5
21~25	K5	The same as TYPE-1	I5
26~30	K6	The same as TYPE-1	I5
31~35	K7	The same as TYPE-1	I5
36~40	K8	Element number includes fracture (b)	I5
41~50	R1	Volume ratio of fracture (0.0<R1<1.0)	F10.0
51~60	R2	Thickness of fracture	F10.0
64~66	L1	Number of element (automatic fracture data preparation)	I3
67~69	L2	Increment of element number (automatic data preparation)	I3
70~72	'SEQ'	Sign of automatic data preparation *	A3

* 'SEQ', L1 and L2 are unnecessary in the case without automatic data preparation

9.1 End card #

column	entry	contents	format
1~4	'END'	Meaning of data end	A4
5~72	blank		

Appendix 1-B Files for 3D-SEEP

File No.	contents
1	File for input data
2	File for input data
5	Input data file
11	File for elements
12	File for elements
13	Work file for out-core solving
14	File for nodal point
15	File for nodal point
16	Output file
17	Work file for out-core solving
18	Work file for out-core solving
19	Work file for out-core solving
21	Structural data file for plotter program PLOTSEEP
22	Output data file for plotter program PLOTSEEP

Appendix 1-C Extension of program-size

1) Extension of nodal data-size

- Maximum number of nodal point ; MNJT
- Maximum input nodal number ; MUPNO
- Maximum number of nodal points connecting one nodal point ; MNRE
- One-dimensional array size ; NSPACE
- One-dimensional array ; IW (*****)

  Replace new one and put NSPACE into ***** in the subroutine MAIN and MSTEMP.

  NSPACE = Max (L1,L2)

  L1 = MUPNO - (8 - MNRE)*MNJT + 9*IFRC1

  L2 = (8 + (2 + NBW) + 2)*MNJT + 974

  where NBW ; Maximum size of half band-width

  IFRC1 ; Number of fracture data

2) Extension of water level data-size

- Maximum number of water level-line ; MAXL
- 2-dimensional arrays ; ILIN (3,***), RLIN (3,***)

  Replace new one in the subroutine CKLINE and put MAXL into *** in the subroutine MSTEMP, INPGNR, INDMKU, PRNTMP, STEADY, CKLINE and HDCHEK.

3) Extension of material data-size

- 2-dimensional arrays ; IMAT (2,****), RMAT (2,****)

  Put new maximum number of material data into **** in the subroutine MSTEMP, INPGNR, CKMAT1, TBOUKF, HFLUXC, HFLUX and ALMCHA.

4) Extension of number of hydraulic property function

- Maximum number of hydraulic property function ; MFNC
- 2-dimensional array ; IFNC (3,**)
- 3-dimensional arrays ; FNC1 (2,10,**), FNC2 (2,10,**)

  Replace new one in the subroutine CKMAT2 and put MFNC into ** in the subroutine MSTEMP, INPGNR, ALMCHA and CKMAT2.

Appendix 2-A   Input data for PLOTSEEP

(PLOTSEEP is the plotter program for 3D-SEEP.)

1. Control data

2. Region data

3. Plotting data

4. Magnification data

5. End data

(In input data, # means essential data.)

1.1 Title card

column	entry	content	format
1~4	'TITL'	Meaning of title card	A4
5~80		Name of title	18A4

1.2 Comment card

column	entry	content	format
1~4	'C***'	Meaning of comment card	A4
5~80		Comment (any place)	

1.3 Control card #

column	entry	content	format
1~4	'CONT'	Meaning of control card	A4
12	0 1	Size of plotting (295 mm x 210 mm is given) Specify the size of plotting by following value R	I1
21~30	R	Length of Y-direction (if necessary)	F10.0

2. Region card (card1)

These cards specify the size of region for plotting calculated results

column	entry	content	format
1~4	'BOUN'	Meaning of region card	A4
11	1 2 3	Specification by coordinate (use card2) Specification by element (write all element, use card3) Specification by element (write initial and final element and increment of element number, use card4)	I1

Card2

column	entry	content	format
11~20	R1	Minimum value of X-coordinate	F10.0
21~30	R2	Minimum value of Y-coordinate	F10.0
31~40	R3	Minimum value of Z-coordinate	F10.0
41~50	R4	Maximum value of X-coordinate	F10.0
51~60	R5	Maximum value of Y-coordinate	F10.0
61~70	R6	Maximum value of Z-coordinate	F10.0

Card3 (plural cards if necessary)

column	entry	contents	format
11~15	K1	Element number for plotting	I5
⋮	⋮	⋮	⋮
76~80	K14	Element number for plotting	I5

Card4

column	entry	contents	format
11~15	L1	Initial element number for plotting	I5
16~20	L2	Final element number for plotting	I5
21~25	L3	Increment of element number (default = 1)	I5

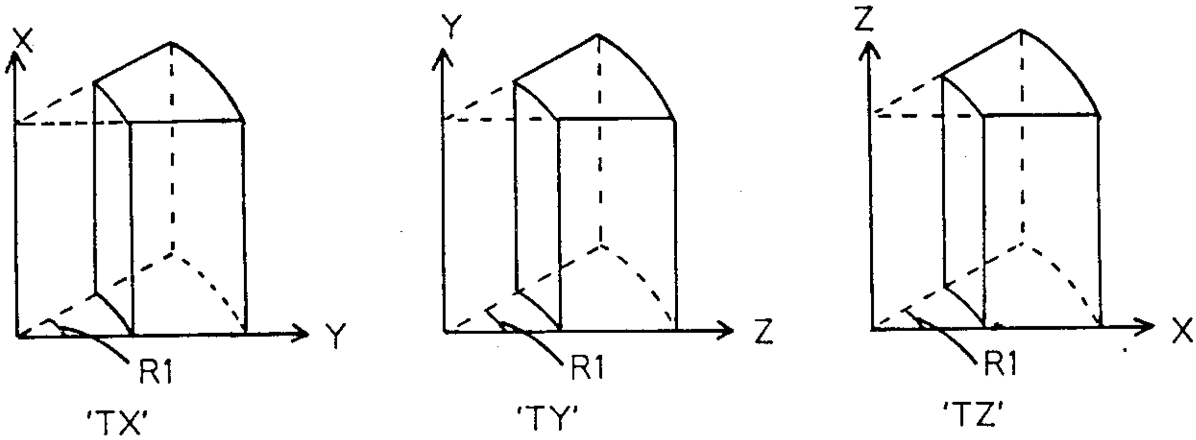
3.1 Mesh card

Plotting the finite element grids

column	entry	contents	format
1~4	'MESH'	Meaning of mesh card	A4
11	0 1	Without printing node number Printing node number	I1
12	0 1	Without printing element number Printing element number	I1
14~15	blank ' X' ' Y' ' Z' 'TX' 'TY' 'TZ'	3-dimensional perspective view Cutting plane perpendicular to X-axis Cutting plane perpendicular to Y-axis Cutting plane perpendicular to Z-axis Rotated cutting plane around X-axis Rotated cutting plane around Y-axis Rotated cutting plane around Z-axis	A2
21~30	R1	Value of coordinate for cutting (' X' ~ ' Z') Right-handed rotation angle ('TX' ; from Y-axis, 'TY' ; from Z-axis, 'TZ' ; from X-axis)	F10.0
41~45	R2	Angle of viewpoint to X-axis (default = 0 degree)	F5.0
46~50	R3	Angle of viewpoint to Y-axis (default = 45 degree)	F5.0
51~55	R4	Angle of viewpoint to Z-axis (default = 90 degree)	F5.0

3.2 Contour card

column	entry	contents	format
1~4	'CNTR'	Meaning of contour card	A4
7~10	'PRES' 'TOTA'	Plotting contour line of pressure head Plotting contour line of total head	A4
14~15	' X' ' Y' ' Z' 'TX' 'TY' 'TZ'	Cutting plane perpendicular to X-axis Cutting plane perpendicular to Y-axis Cutting plane perpendicular to Z-axis Rotated cutting plane around X-axis Rotated cutting plane around Y-axis Rotated cutting plane around Z-axis	A2
21~30	R1	Value of coordinate for cutting (' X' ~ ' Z') Right-handed rotation angle ('TX' ; from Y-axis, 'TY' ; from Z-axis, 'TZ' ; from X-axis)	F10.0
31~40	R2	Increment of contour line (default = 1.0)	F10.0



3.3 Velocity card

column	entry	contents	format
1~4	'VELO'	Meaning of velocity card	A4
7~10	'SOLI' 'FRC1'	Plotting vector of primary pore velocity Plotting vector of fracture velocity	A4
14~15	' X' ' Y' ' Z' 'TX' 'TY' 'TZ'	Cutting plane perpendicular to X-axis Cutting plane perpendicular to Y-axis Cutting plane perpendicular to Z-axis Rotated cutting plane around X-axis Rotated cutting plane around Y-axis Rotated cutting plane around Z-axis	A2
21~30	R1	Value of coordinate for cutting (' X' ~ ' Z') Right-handed rotation angle ('TX' ; from Y-axis, 'TY' ; from Z-axis, 'TZ' ; from X-axis)	F10.0
31~40	R2	Maximum size of velocity vector (default = 20 mm)	F10.0

4. Magnification card #

column	entry	contents	format
1~4	'MAGN'	Meaning of magnification card	A4
9~10	'X' 'Y' 'Z'	Magnifying X-component Magnifying Y-component Magnifying Z-component	A2
11~20	SCL	Scale of magnification	F10.0

5. End card #

column	entry	contents	format
1~4	'END'	Meaning of end card	A4
5~80	blank		

Appendix 2-B Files for PLOTSEEP

File No.	contents
5	Input data file
13	Work file
14	Work file
21	Structural data file (given by 3D-SEEP)
22	File of head and velocity (given by 3D-SEEP)