USER REFERENCE MANUAL

FOR

MVSS

A FINITE ELEMENT ANALYSIS PROGRAM

for

MASONRY VENEER / STEEL STUD WALL SYSTEMS

Made available by

DRYSDALE ENGINEERING And ASSOCIATES LIMITED

Prepared for

T.W.J. TRESTAIN STRUCTURAL ENGINEERING

as part of a contract with

CANADA MORTGAGE & HOUSING CORPORATION

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NOTE: LE RÉSUMÉ EN FRANÇAIS SUIT IMMÉDIATEMENT LE RÉSUMÉ EN ANGLAIS.

PREFACE

About this manual

This User Reference Manual documents the use of the MVSS finite element program which was developed to assist in the analysis of masonry veneer / steel stud wall systems. This program consists of the six parts listed below:

- Proprietary and disclaimer information
- File and data manager
- Pre-processing
- Analysis of masonry veneer / steel stud walls
- Post-processing
- Case studies

The mathematical basis for this finite element computer program was previously submitted to CMHC under the title *Defining Better Cladding Systems - Theoretical Work.*

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EXECUTIVE SUMMARY

The MVSS finite element computer program was developed to provide an accurate analytical tool for studying the real behaviour of masonry veneer/steel stud wall systems. This User Reference Manual provides detailed description of the program capabilities and limitations, complete instructions on how to use the program and 4 case studies.

The program includes the following capabilities:

- Two way bending of the brick is considered.
- The flexibility of the steel components (ties, tracks and studs) is modelled.
- Maximum tie strengths can be specified.
- The effect of windows and other openings can be included in the analysis.
- Loads from windows or doors can be distributed to the stud frame or the veneer at pre-selected attachment points.
- Various boundary conditions for the brick and the stud (such as corners and intersecting shearwalls) can be specified.
- The cracking behaviour of the masonry can be predicted by program or can be specified by the user.
- The effect of missing brick ties or the introduction of retrofit brick ties can be studied.
- The structural effects of full or partial pressure equalization can be studied.

A number of "user-friendly" features are included:

- The program contains a finite element mesh generator which relieves the user of a lot of tedious input while at the same time retaining the flexibility to handle a wide variety of wall geometries.
- Data banks have been included with experimentally derived stiffnesses for ties, top and bottom tracks (based on the McMaster studies) and stud properties taken from product literature.
- The data banks can be added to or amended as required.
- Extensive use has been made of pop-up screens to facilitate data entry.
- Plotting routines have been added to allow the user to see on-screen the input geometries and boundary conditions and output forces, stresses, deflected shapes and crack patterns.
- The graphical display can be dumped to either a file or a printer
- Detailed input and output data is also sent to an ASCII file for easy access by any standard text editor.

RÉSUMÉ

Le logiciel de modélisation des éléments finis pour placage de maçonnerie sur ossature métallique a été mis au point pour servir d'outil analytique précis dans l'étude du comportement réel de ce genre d'ouvrage mural. Le manuel de l'utilisateur donne une description détaillée des capacités et des limites du logiciel et fournit les instructions complètes sur son utilisation ainsi que quatre études de cas.

Le logiciel possède les capacité suivantes :

- prise en considération de la flexion bidirectionnelle de la brique
- modélisation de la souplesse des composants métalliques (attaches, rails et poteaux)
- possibilité de préciser la résistance maximale des attaches
- possibilité d'inclure dans l'analyse l'effet des fenêtres et d'autres ouvertures
- capacité de répartir les charges des fenêtres ou des portes aux poteaux ou au revêtement intermédiaire selon certains points de fixation présélectionnés
- possibilité d'indiquer diverses conditions aux limites pour la brique et les poteaux (comme les angles et les murs de contreventement servant d'intersection)
- prévision par le logiciel ou indication par l'utilisateur du comportement à la fissuration de la maçonnerie
- étude de l'effet de l'absence d'attaches à brique ou de la pose en rattrapage de nouvelles attaches
- étude des effets structuraux d'un équilibrage partiel ou complet de la pression

Le logiciel offre également des caractéristiques de convivialité :

- le logiciel contient un outil de maillage d'éléments finis qui libère l'utilisateur d'un bon nombre d'opérations fastidieuses tout en conservant la souplesse requise pour traiter un large éventail de géométries murales
- des banques de données intégrées comportent des données de rigidité expérimentales pour les attaches, les rails supérieurs et inférieurs (fondées sur les études de McMaster) et les propriétés des poteaux (tirées de la documentation sur les produits)
- le contenu des banques de données peut être augmenté ou modifié selon les besoins
- on a eu abondamment recours à des écrans instantanés pour faciliter la saisie des données
- des programmes de traçage ont été ajoutés pour permettre à l'utilisateur de visualiser à l'écran les géométries saisies et les conditions aux limites ainsi que les forces résultantes, les contraintes, les manifestations du fléchissement et les types de fissures
- l'affichage peut être sauvegardé sous forme de fichier ou être envoyé à une imprimante
- les paramètres à traiter et le résultat du traitement peuvent être convertis en fichier ASCII pour ensuite être facilement consultés par l'intermédiaire de n'importe quel éditeur de texte standard

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MVSS Overview

Relevant information to assist in the use of the MVSS, finite element computer program, is presented in this manual. The program is written in modular form to facilitate its use and for ease of adding new modules. MVSS includes both pre- and post-processor and an iterative analysis routine to permit cracking of masonry walls and failure of the steel ties. It also includes a data bank that can be modified or augmented. The data bank is used to store the properties and descriptions of the steel studs, steel ties and top and bottom tracks.

A file management system is incorporated in this program so that the user can easily list and choose from the existing files. A special pre-processor is implemented to generate a finite element mesh appropriate for masonry veneer steel stud walls.

A graphical interface has been added to the post-processor module to display the layout of the wall system, the boundary conditions, the deformation of the wall system, the stress contours, the tie forces and the crack pattern. Moreover, the graphical display can be dumped to either a file or a printer. Only PostScript printers and HP-GL plotters are supported.

Analysis of the MVSS Structural System

The rational design of wall systems composed of masonry veneer and steel stud backup walls is hampered by use of analytical methods that, on the one extreme, contain too many simplifying assumptions to provide reasonably accurate information. At the other extreme, use of more sophisticated analytical tools imposes such a large time and cost burden as to be impractical in all but a few special cases. The MVSS program was developed to provide engineers and architects with a sophisticated analytical tool that would permit comprehensive and accurate evaluation of designs without incurring excessive time or financial costs.

A full description of the theoretical background to the MVSS program is available in *Defining Better Cladding Systems - Theoretical Work* available from CMHC. However, the basis for its development will be briefly described here. The masonry veneer is modeled as an elastic - brittle material using a 4-node non-conforming plate bending element, where various edge and support conditions and shapes of openings can be

included. Using previously verified criteria relating flexural cracking strength and crack orientation to the principle stress directions, relative to the orientation of the mortar joints, both the initiation and propagation of cracks are predicted. Although formation of the first crack may be a serviceability concern, it does not constitute a structural failure. Therefore the analysis of the gradually changing structure (changing as cracks developed) can continue until the stress in some other structural elements (i.e. a tie or a steel stud) exceeds its limits.

The attachment of steel stud frame to the structure is formulated in a way that allows the translations and rotations occurring in the track connections (or other connecting devices) to be included in the modeling. End studs can be supported at various points over their length and bridging between studs can be introduced at several elevations. Ties with selected load-deformation properties are used to connect the masonry veneer to the backup wall. Lateral load can be applied to the veneer, the stud wall system, or both and loads from windows and doors in openings can be distributed to the stud frame or the veneer using pre-selected attachment points and load distribution systems. The user should note that openings (doors, windows, etc.) are assumed to be infinitely rigid plates and should be in a separate plane from both the veneer and the backup walls. The plate representing the opening can be attached to either wall using ties between the corresponding opening plate element nodes and wall nodes.

After initiation of the first crack, lateral load is applied incrementally to enable the propagation of that crack and the development of new cracks to be predicted. Alternatively, cracks can be introduced at the time that the initial geometry of the masonry veneer is specified.

The computational method for developing and propagating the cracks within the masonry veneer is based on a fixed smeared crack approach. This approach reduces the stiffness of the element perpendicular to the crack. This usually results in multiple cracks within the finite element depending on the number of integration points used. For further information, the user should refer to CMHC report *Defining Better Cladding Systems - Theoretical Work*. The user can introduce discrete crack in the model by physically separating the elements at the desired locations.

A data bank, compiled from Reference 1 to 3[#] , is included to provide the user with typical information on properties of the structural elements.

[#]1 Drysdale, R.G. and Wilson, M., "A Report on Behaviour of Brick Veneer / Steel Stud Tie Systems", CMHC Publication, March 1989.

The user may select properties from the data bank or input other information as required for the system being analyzed. The use of the program is discussed in greater detail in the following sections.

MVSS Limitations

Version 2.1 of the MVSS finite element program has some limitations that the user should keep in mind. The load transfer between the steel tie and steel stud is assumed to occur at the shear center. This means that the analysis of potential torsional buckling of the steel stud must be done outside the program. Although the Saint Venant torsional constant is required, it is only effective when there is an in-plane load transfer due to the presence of horizontal steel stud framing elements.

To include windows or doors in the model, masonry type elements need to be used with an artificially high stiffness so that it behaves as a rigid member. It can be attached to the masonry veneer or backup wall using steel ties as attachment members.

The lateral pressure can be applied to either the masonry veneer or the steel stud backup wall. The printed deformation and stress correspond to the computed cracking load for the particular stage of cracking. It should also be noted that there is a limitation on the number of elements, nodes, regions, key points, etc., that can be used to generate the model. The user should refer to Table I to check the actual limitations.

System Requirements

The hardware items listed below define the minimum operating environment for use of the MVSS program

- An IBM PC, PS/2 or 100% compatible computer,
- An IBM VGA Adapter and fully compatible display,
- A mathematical co-processor,
- A minimum of 627 K of conventional memory,
- A hard disk,

#2 Drysdale, R.G. and Wilson, M., "Tests of Full Scale Brick Veneer / Steel Stud Walls to Determine Strength and Rain Penetration Characteristics", CMHC Publication, July 1990, 280 pages

#3 Drysdale, R.G., and Breton, N., "Strength and Stiffness Characteristics of Steel Stud Backup Walls Designed to Support Brick Veneer", CMHC Publication, September 1991, 310 pages.

- MS-DOS 5.0 or above,
- A Microsoft-compatible mouse,
- A supported printer.

Table I Maximum values to be used with the program MVSS.

Parameters	Allowable maximum values
Number of regions	100
Number of material set	9
Number of key points	200
Number of boundaries	50
Number of nodes	270
Number of elements	290
Number of degrees of freedom	1300
Number of cracked elements	50
Number of constrained Nodes	50

INSTALLATION

Before installing the program MVSS, the user should:

- Create a backup copy of the distribution diskette and store the original in a safe place
- Check the README.DOC for any messages. This facility is included to provide additional instructions and future information on program upgrades.

Backup

The user should make a backup copy of the original diskette before proceeding with the installation. The user may do this by using the DISKCOPY command available from DOS. This will copy the contents of the original diskette, including those in sub-directories, from a source disk to a destination disk. Once completed, it is advisable that the user works with the backup disk and places the original in a safe place. The steps to be followed are:

1. Place original diskette in drive A
2. Place formatted backup diskette in drive B
3. Type C:\>DISKCOPY A: B:

Installing MVSS

The distribution diskette contains several files and they are:

Files	**Description**
MVSS.EXE	Executable version of the Program MVSS
*.DTA	Data bank for the steel stud, steel ties and the track.
*.LBR	Libraries used by the program MVSS
*.BIN	Printing drivers
BEG.COM, END.COM & DISPLAY.COM	Drivers required to display the graphical interface.

To install the program MVSS, please follow these steps:

1. The user needs to create two directories, the first one will be used to store the program MVSS and the second one will be a working

directory where the computed data will be stored. This can be accomplished by typing:

C:\>MKDIR ***name of directory***

2. Place the distribution diskette in drive B:
3. Type

   C:\>B:
4. Type

   B:\>INSTALL
5. Enter name of the two directories that have been created including device name, i.e., C:***name of directory***
6. If you make a mistake, repeat steps 4 and 5.

Once the installation is complete, the user can go to the working directory and begin the analysis. The user should note that an additional step is required every time a new working directory has been created and the steps are illustrated in the setup of the local path.

Setup of the local path

This step is essential for establishing the link between the menus and the program MVSS. If this link is missing, a menu will pop up as shown below:

MENU

```
*****************************************************
*                                                   *
*  MESSAGE                                          *
*  Path to the program MVSS is defined in FILE      *
*  CONFIG.DAT.  The present working directory       *
*  does not contain this file.                      *
*  Enter the necessary information to create        *
*  CONFIG.DAT.                                      *
*                                                   *
*****************************************************
*                                                   *
* Enter name of directory xxxxxxxxxxxxxxxxxxxxxxxxxxx
```

The user must input the correct path where the program MVSS has been installed. This step is automatically invoked every time a new working directory is created.

FLOW CHART OF MVSS

The analysis procedure employed in this computer program is identical to the first version reported earlier in the CMHC report, *Defining Better Cladding Systems - Theoretical Work.* Improvements in the current version relate to cracking of the masonry and the ability to eliminate the resistance of steel tie when it has reached its specified capacity [user input].

The step by step procedure to be followed to perform an analysis is as follows:

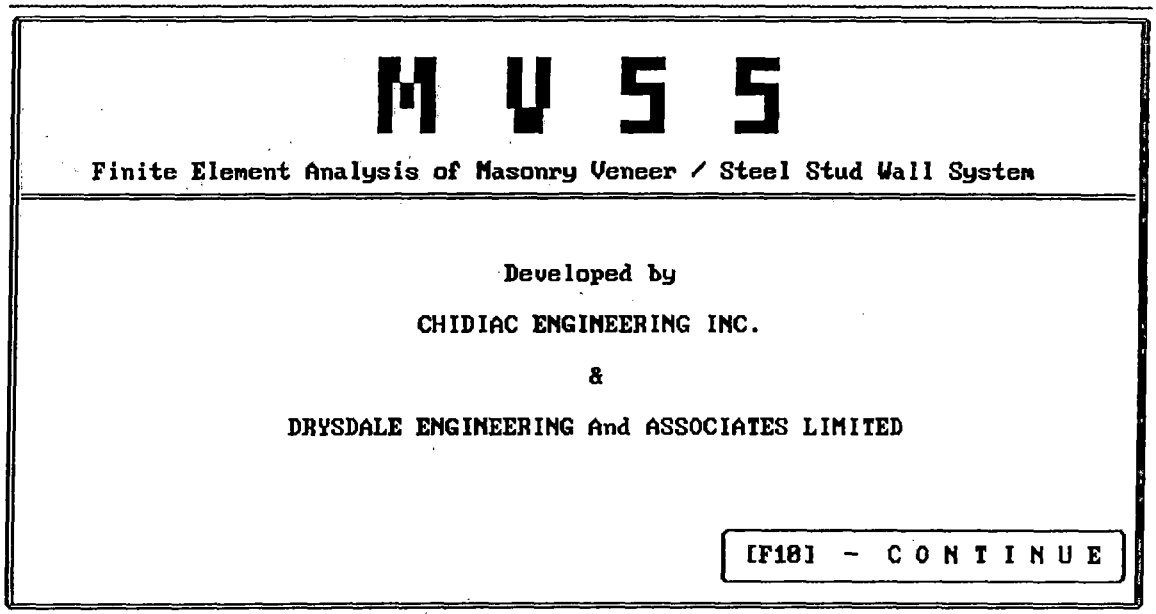
1. Upon entry to MVSS, a proprietary screen is displayed. The user can either use the mouse to click or enter any key to proceed to the next screen.
2. The disclaimer information is presented to inform the user of the conditions attached when using this program. The user can either click or enter *[F10]* to continue or *[ESC]* to exit.
3. By accepting the conditions presented in the disclaimer screen, the user can begin to prepare for the analysis. The first step is to open a file where all the data can be stored. The user can also access the data bank from this menu. To select any of the features, just click on it using the mouse or enter the function key associated with it. You can hit or enter *[F10]* to continue or *[ESC]* to exit MVSS.
4. Before allowing the user to proceed with the analysis, MVSS checks to ensure that the user has opened a new file or retrieved an existing file. Once this is confirmed, the main menu is displayed. This menu directs the user to the pre-processor, the analysis routines and the post-processor.
5. The pre-processor is represented by four menus, namely the geometry, the boundary conditions, the applied load and the member properties.
6. The analysis routine is represented by two menus, namely the data check menu and the analysis menu.
7. The post-processor is accessible using the plot menu.
8. At anytime in the main menu, the user can either hit or enter *[F10]* to save the information before exiting this file. Hit or enter *[ESC]* to exit without saving any of the information entered or computed.

In the following pages, the steps and associated screens have been reproduced using various menus. The appropriate information is presented to help guide the user through the complete process.

PROPRIETARY INFORMATION

This menu is intended to display ownership and copyright for the MVSS program.

MENU

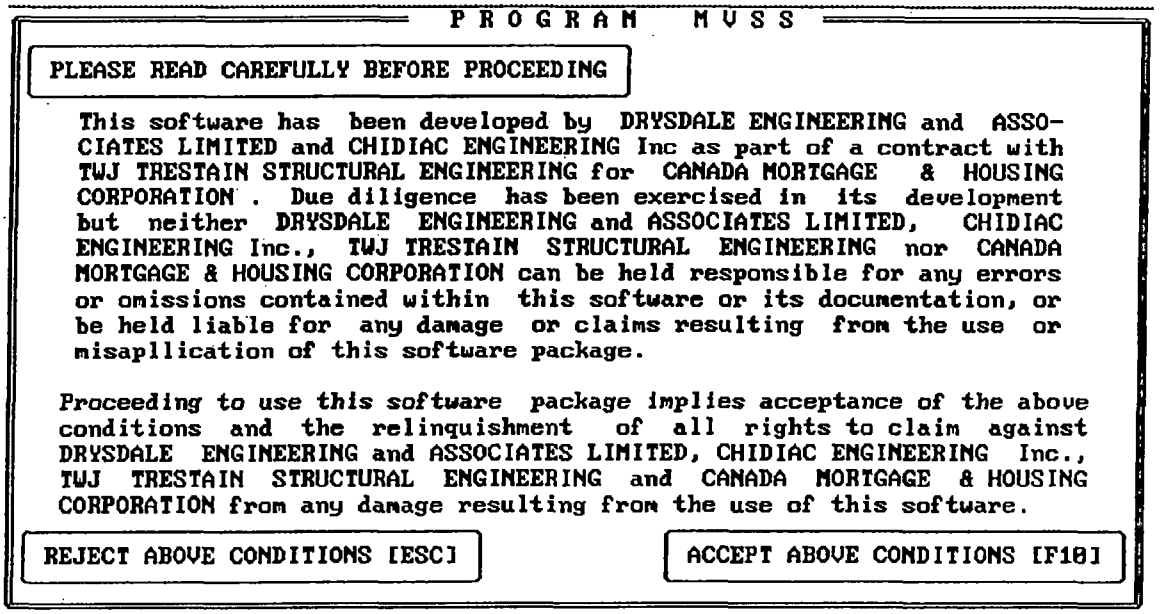


INPUT	DESCRIPTION
[F10]	To proceed to next screen

DISCLAIMER INFORMATION

This menu is displayed to warn users that, even though every effort is made to ensure that this program is error free, by continuing after this menu, the user accepts the conditions noted on this screen.

MENU

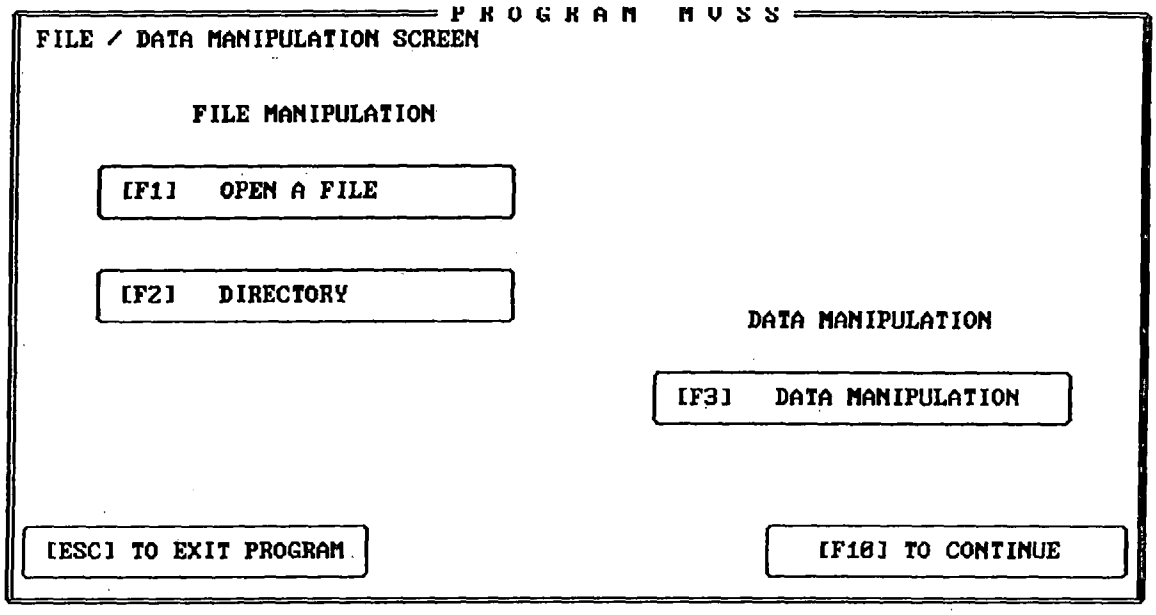


INPUT	DESCRIPTION
[F10]	To accept above conditions and thus proceed with the analysis.
[ESC]	To reject the above conditions and thus exit the program.

FILES / DATA MANIPULATION

This menu allows the user to perform various file and data manipulations. The user can open a file, or list the files present in a directory and then choose the required file. Using the Data Manipulation option, the user can add, delete or modify any member information in the data bank. The user can only exit the program from this File Manipulation menu.

MENU

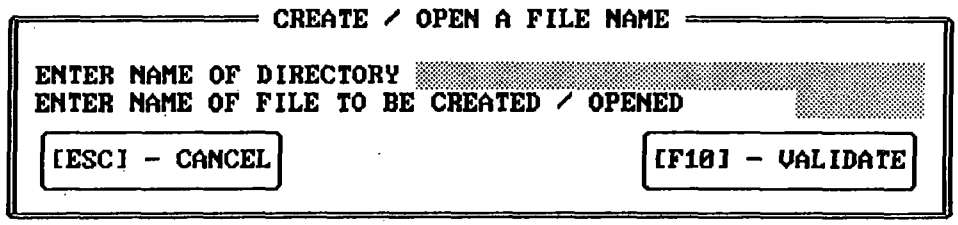


INPUT	DESCRIPTION
[F1]	This selection will open a menu called Open a File.
[F2]	This selection will open a menu called Directory.
[F3]	This selection will lead to the data bank where the user can modify, add or delete any member information.
[F10]	To validate that either a new file has been created or an existing one has been retrieved before proceeding to the main analysis menu. If a file name has not been specified, an error message will appear.
[ESC]	To terminate the analysis and exit the MVSS program.

Open a File

This menu permits the user to open a file in any directory available on the hard disk. If the name of the file has been used before, a warning is given in case a new file is needed.

MENU

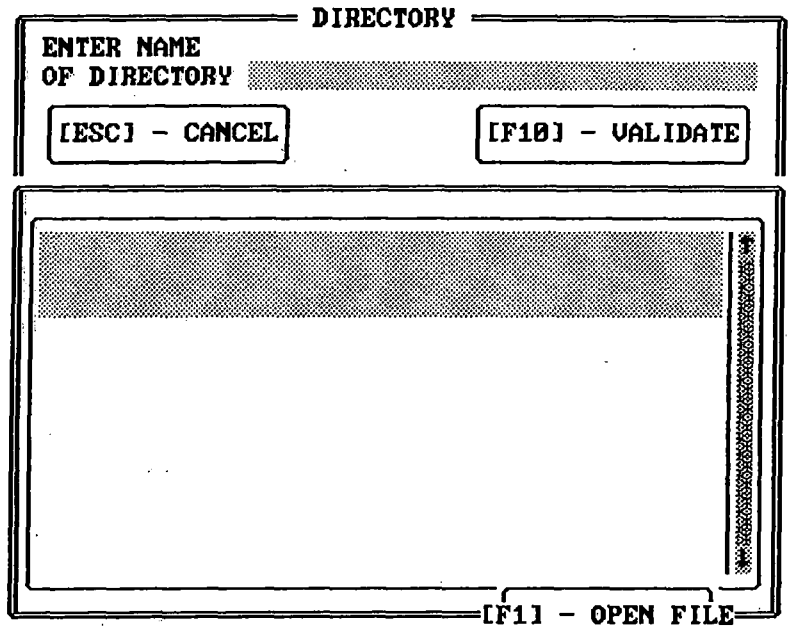


INPUT	DESCRIPTION
ENTER NAME OF DIRECTORY	Enter the name of the directory where the file will reside.
ENTER NAME OF FILE TO BE CREATED / OPENED	Enter the name of a new file to be created or the name of an existing file to be retrieved.
[F10]	To validate the above information. If the file is already present, a warning is given in case a new file name is needed.
[ESC]	To quit and return to the FILES / DATA MANIPULATION menu.

Directory

This menu permits the user to access any directory in order to inspect its content. At the same time a user can select and open an existing file in that directory.

MENU

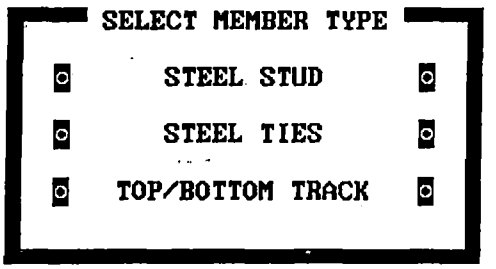


INPUT	DESCRIPTION
Name of Directory	Enter the name of the directory in which a file search will take place.
[F10]	To accept the above information and display the file names present.
[F1]	Once the files are displayed, the user can select the file and use this key to open it.
[ESC]	To quit and return to the FILES / DATA MANIPULATION menu.

Data Bank

This menu permits the user to access the data bank in order to add new information or modify existing data. The data bank allows the user to select either steel stud, steel ties or track as the member to be accessed.

MENU

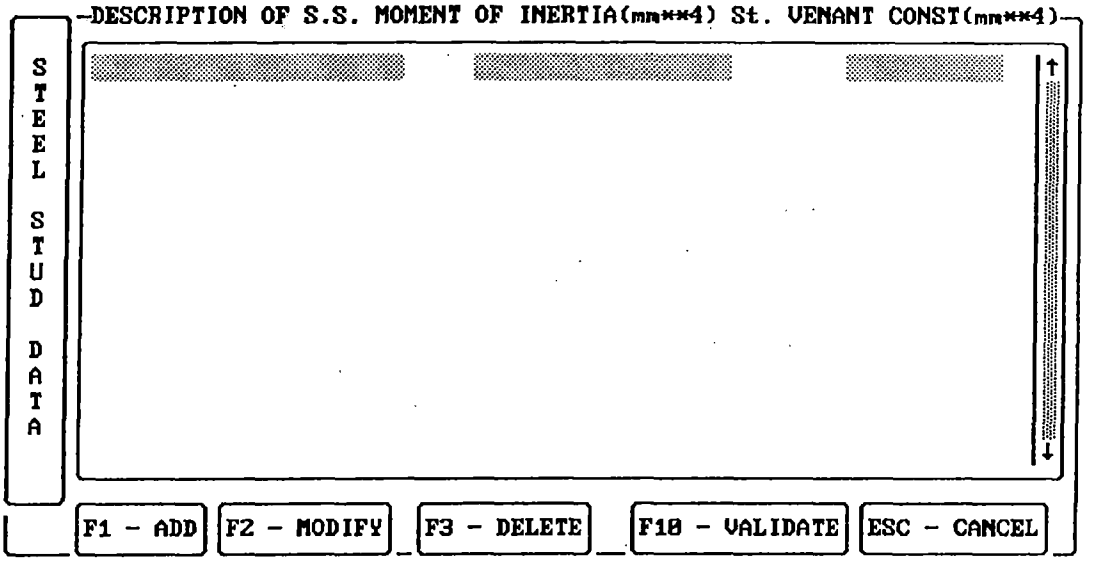


INPUT	DESCRIPTION
Member Type	Click on the member type you want to select and thus access its data bank.

Member Data Bank

This menu permits the user to add new members, modify existing ones or delete an existing one from the data bank. Shown below is the menu for the steel stud.

MENU

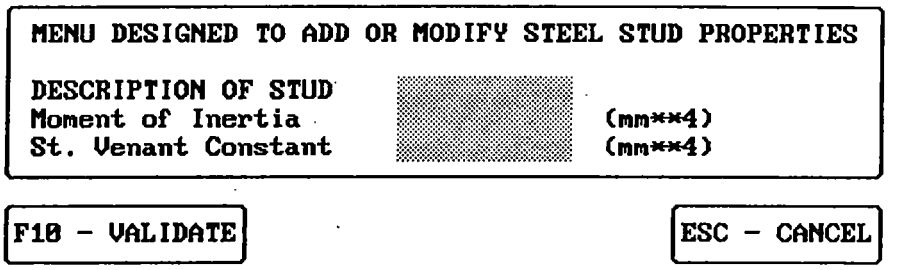


INPUT	DESCRIPTION
[F1]	To add a new member to the data bank.
[F2]	To modify the properties of an existing member.
[F3]	To delete the record of an existing member.
[F10]	To validate input and thus store any new or modified data before returning to the FILES / DATA MANIPULATION menu.
[ESC]	To return to the FILES / DATA MANIPULATION menu without saving any changes.

Add, Modify or Delete Properties in the Steel Stud Menu

This menu permits the user to add to / modify the steel stud data bank.

MENU

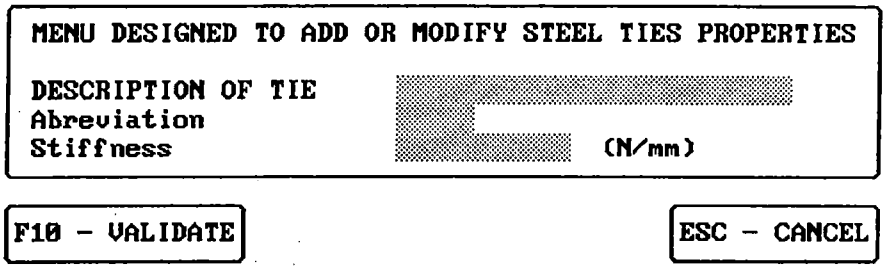


INPUT	DESCRIPTION
Description of Stud	A label used to identify the entry.
Moment of Inertia	The second moment of the area for the section.
St. Venant Constant	This is the resistance of this section to twisting.
[F10]	To validate the input and store it before exiting.
[ESC]	To exit without saving.

Add, Modify or Delete Properties in the Steel Ties Menu

This menu permits the user to add to / modify the steel tie data bank.

MENU

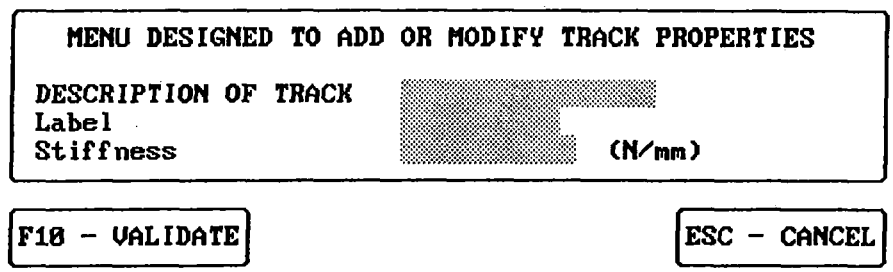


INPUT	DESCRIPTION
Description of Tie	A label used to identify the entry.
Stiffness	The axial stiffness of the tie in N/mm.
[F10]	To validate the input and store it before exiting.
[ESC]	To exit without saving.

Add, Modify or Delete Properties in the Track Menu

This menu permits the user to add to / modify the track data bank.

MENU

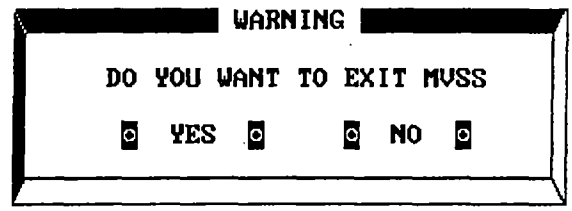


INPUT	DESCRIPTION
Description of Track	A label used to identify the entry.
Stiffness	The shear stiffness of stud to track connection.
[F10]	To validate the input and store it before exiting.
[ESC]	To exit without saving.

EXIT

This entry is required to exit the MVSS program and is only accessible from the FILES / DATA MANIPULATION menu.

MENU

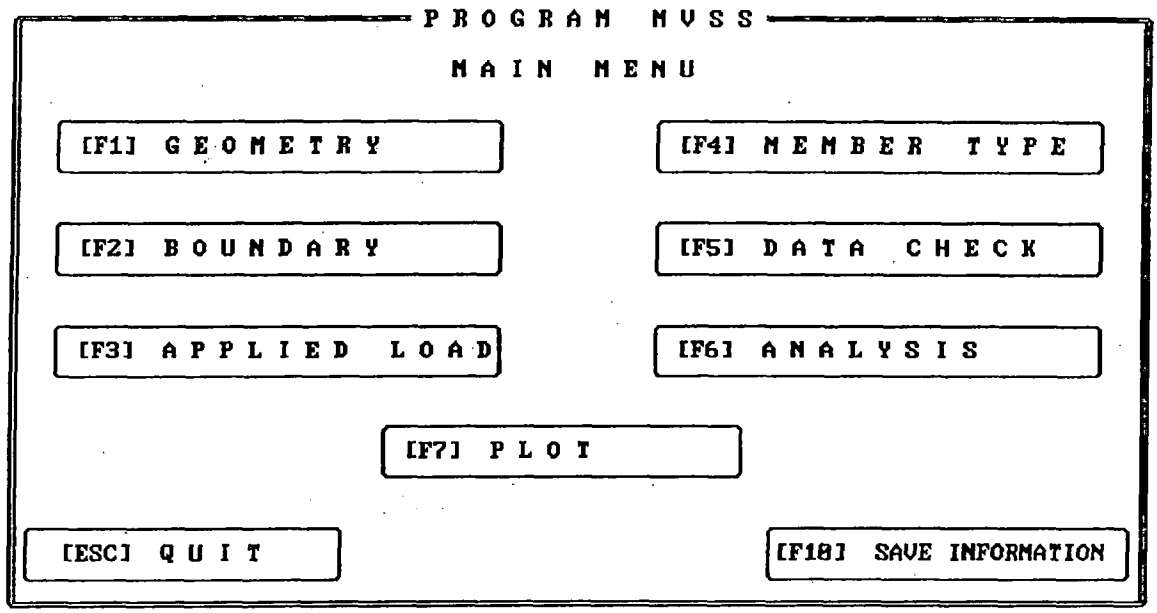


INPUT	DESCRIPTION
[YES]	To exit the program and return to DOS.
[NO]	To ignore entry and return to the FILES / DATA MANIPULATION menu.

PRE-PROCESSOR MENU

This menu allows the user to select the necessary menu in order to enter the preparatory information for the analysis. Both the analysis menus and the graphical output menus are accessible through this menu.

MENU



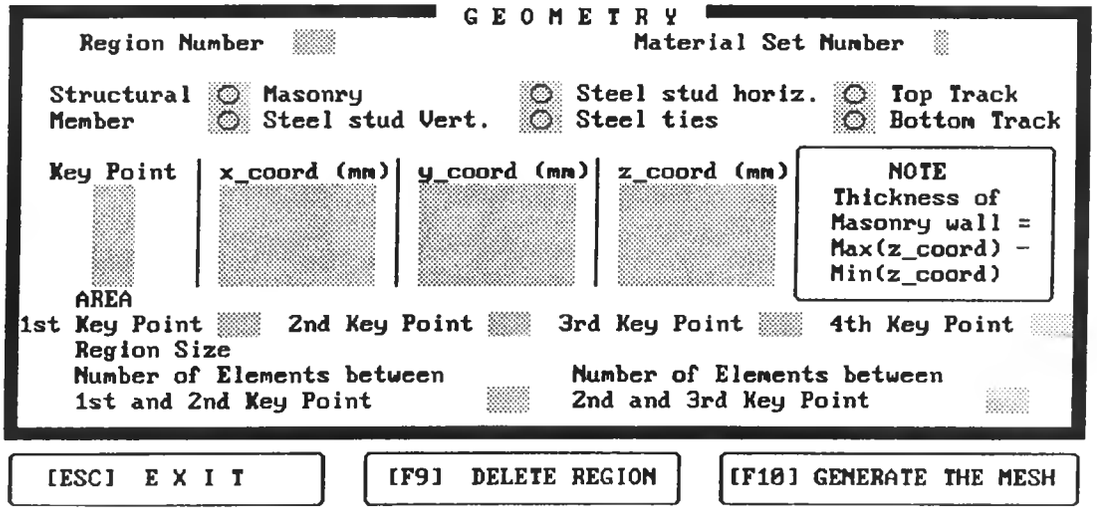
INPUT	DESCRIPTION
[F1]	To open the menu to enter the geometric information.
[F2]	To open the menu to specify the boundary conditions.
[F3]	To open the load menu.
[F4]	To open the member type menu.
[F5]	To open the menu that will allow the program to generate the data in preparation for the analysis.
[F6]	To open the analysis menu to select the type of analysis.
[F7]	To access the plot menu.
[F10]	To save both the input information and computed results before exiting.
[ESC]	To exit the menu without saving any information. A warning is given before accepting the entry.

Input Geometry

This menu permits the user to enter the geometry of the wall to be analyzed. The mesh generator requires all of the information listed in this menu. The wall is always assumed to be positioned in the x-y direction where the x- and y-direction are parallel and normal to the bed joint, respectively. The depth of the wall is in the z-direction. The three-dimensional analysis is performed using layering, where the masonry wall is the first layer and the steel stud backup wall is behind it. The plot menu can be used to check whether the layout of the wall has been entered correctly.

To include windows or doors in the model, the user needs to use the masonry plate element but must modify the properties to reflect a rigid behavior. Furthermore, the element for the windows or doors cannot be lined up with the exterior face of the masonry veneer and must be attached to either the veneer or the backup wall using tie members.

MENU



INPUT	DESCRIPTION
Region Number	A region must be rectangular in shape and is labeled for reference. Once a region number has been defined and saved, the data entry can be revisited by just re-entering the region number.
Material Set Number	Since the model can have up to nine different material sets, a label is used to identify the material set that is appropriate for that geometric region.

Structural Member	Member type. It should be noted that for each material set, the user can define different properties for masonry, steel stud, steel tie, etc.
Key Point	Every region is defined by four key points located at each corner. Key points are labeled for reference. Again, once a key point has been defined, the data entry can be revisited by entering the label number.
Area	The area is defined by the four key points that define the corners of this region.
Region Size	This informs the program of the number of finite elements required to model this region. The first entry defines the number of elements between the 1st and 2nd key point and the second entry between the 2nd and 3rd key point.
[F10]	To save the information.
[ESC]	To exit the menu.

Example

A simple example is used to graphically illustrate the logic behind the mesh generator. Assuming that the region is bounded by (0,0) and (1,1) with a thickness of 0.1, then the corresponding key point entries are:

Key Point	x-coordinate	y-coordinate	z-coordinate
10	0.0	0.0	0.0
15	1.0	0.0	0.0
20	1.0	1.0	0.0
17	0.0	1.0	0.1

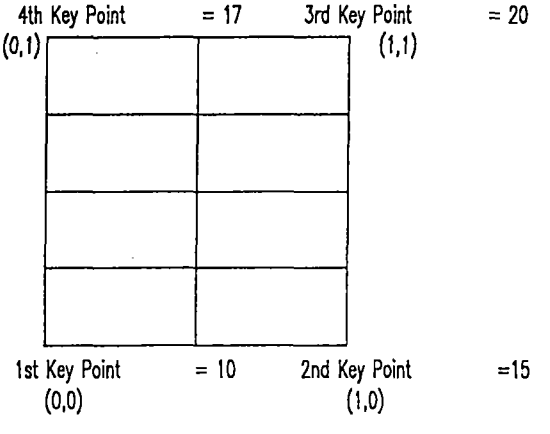
The **AREA** entries are simply the labels used to define the corners of that region, i.e.,

1st Key Point	2nd Key Point	3rd Key Point	4th Key Point
10	15	20	17

The number of finite element required to model this region is specified in the region size where

Number of Elements between 1st and 2nd Key Point	Number of Elements between 2nd and 3rd Key Point
2	4

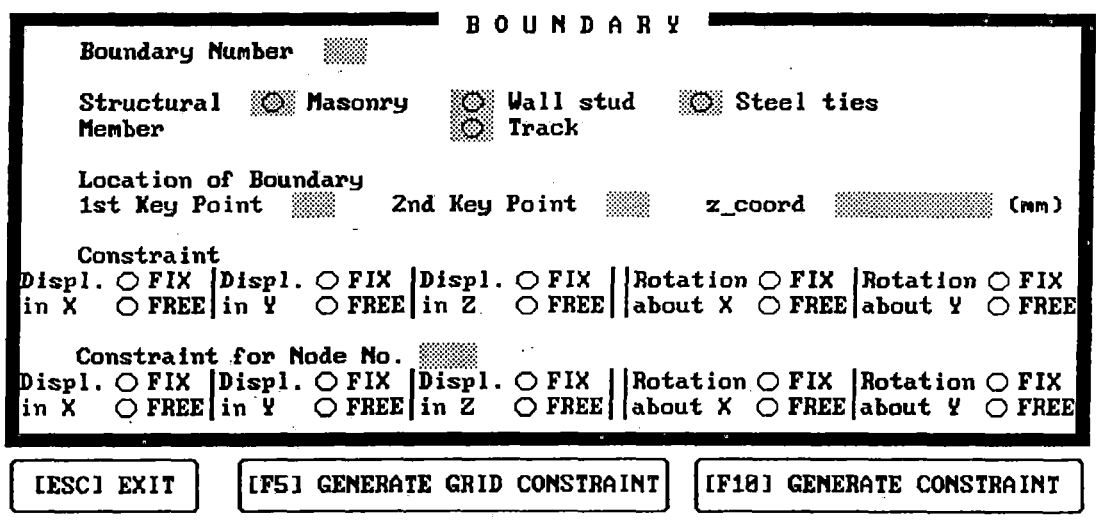
The above entries will generate the mesh shown below.



Input Boundary Conditions

This menu permits the user to specify the boundary conditions required for the analysis. This information is very important to accurately model the actual structural system. The boundary conditions are entered using the same general approach as for the geometry. In this case, a line is defined using two key points and the depth is noted using the z-coordinate. The constraints for all the degrees of freedom, i.e. displacement in x-direction, displacement in y-direction, displacement in z-direction, rotation about the x-axis and rotation about the y-axis, must be specified. The label FIX implies no movement is allowed whereas FREE implies free to move. Furthermore, the user has also the option of constraining the movements and rotations of any node generated. To identify the node number to be constrained, the user must review the model using the node number command in the PLOT menu.

MENU



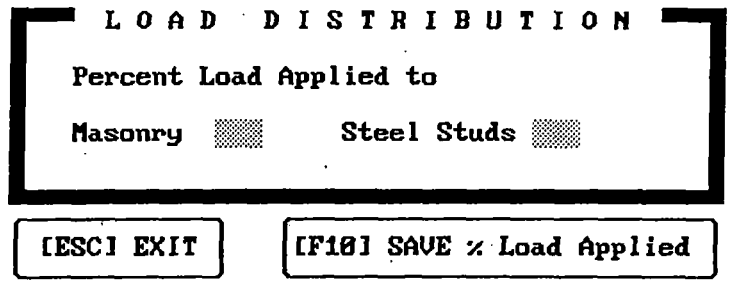
INPUT	DESCRIPTION
Boundary Number	Each boundary is labeled for reference.
Structural Member	Member type.
Key Point	Every boundary is made up of two key points and a z-coordinate. These key points must be defined in the geometry menu.

Constraint	Enter type of constraint for all five degrees of freedom. For the masonry, all five degrees of freedom are activated namely, displacement in x-, y- and z-direction, and rotation about x- and y-axes; for the steel studs, the z-displacement, twisting and bending are activated (twisting and bending are represented by the entry rotation about x- and y- axes, respectively): and for the ties and the track only the z-displacement is activated.
Node	Enter the node number, if not sure of the actual number, use the plot menu to display the node numbers.
[F5]	To save the information for the NODE constraint.
[F10]	To save the information for the boundary constraint.
[ESC]	To exit the menu.

Input Applied Load

The lateral load normal to the wall surface can be applied in any combination between 100% to the surface of the masonry wall to 100 % to the backup wall. The user does not define the applied load, rather, the program calculates the required load to initiate or extend a crack.

MENU

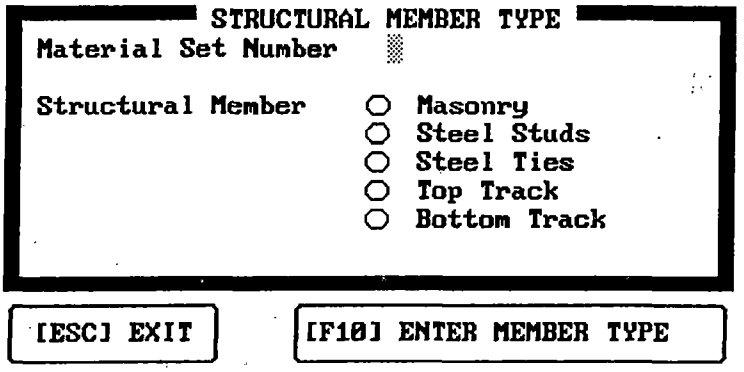


INPUT	DESCRIPTION
Masonry	Enter the percent of the load applied to the masonry wall.
[F10]	To accept the input and display the load applied to the backup steel stud wall.
[ESC]	To exit the menu.

Input Member Type Properties

This menu permits the user to define the member type. For a particular material set number used in the input geometry menu, the user only has to define the properties that will be utilized by the program. The user should note that nine material set numbers are allowed to permit variation in properties of each structural member.

MENU

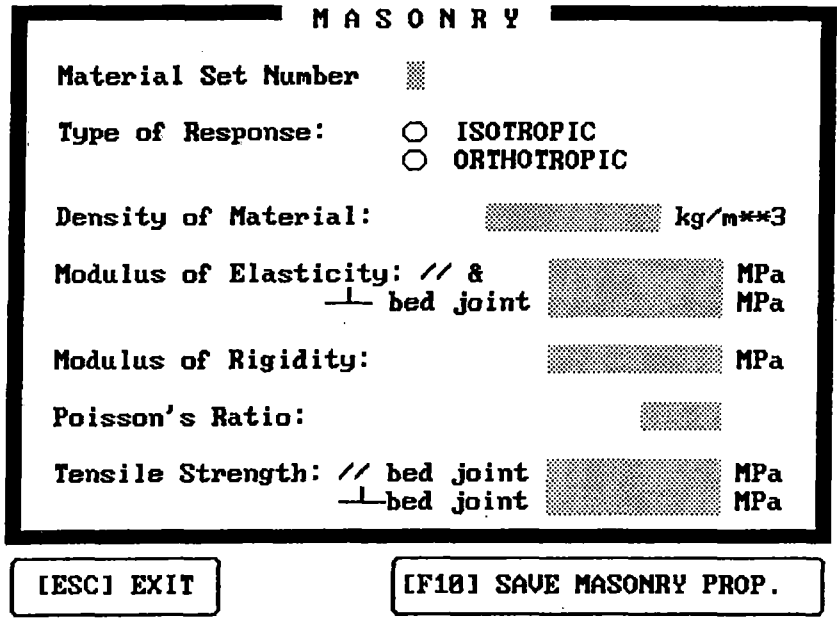


INPUT	DESCRIPTION
Material Set Number	Enter the set number for which the properties need to be defined.
Structural Member	Select the member type whose properties need to be defined for the noted material set number.
[F10]	To accept entry and thus open the selected structural member menu.
[ESC]	To exit the menu.

Masonry

This menu permits the user to enter the properties of masonry. The strengths of the masonry can be defined using either experimental results or specified values such as defined in standards.

MENU



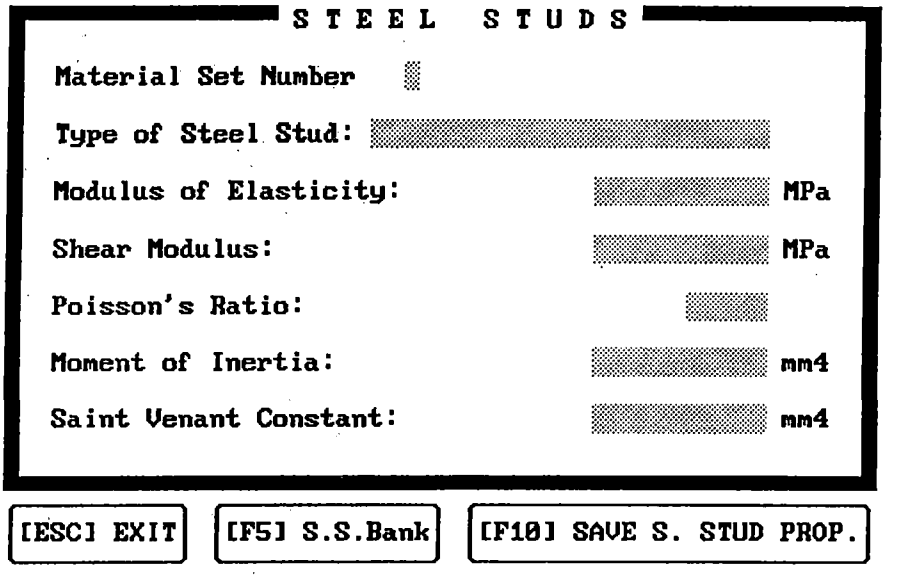
INPUT	DESCRIPTION
Material Set Number	The label is echoed for reference. No entry is required since the set number is defined in the previous menu.
Type of Response	Enter the behavior of the masonry, isotropic or orthotropic. If the behavior is orthotropic, then the user must enter the data for both parallel and perpendicular direction to the bed joint. Bed joint is the horizontal direction (x-direction).
Density of Material	Enter the density of the material if you want the self weight of the masonry to be included in the analysis.
Modulus of Elasticity	Enter the elastic modulus for masonry.
Modulus of Rigidity	Enter the shear modulus for masonry.

Poisson's Ratio	Enter the Poisson's ratio. A value between 0.01 and 0.49 is accepted. If unknown, use a value of 0.2.
Tensile Strength	Enter the value of tensile stress at which the masonry will crack. For orthotropic behavior, tensile strength parallel and perpendicular to the bed joint are required.
[F10]	To save the information and return to the previous menu.
[ESC]	To ignore entry and return to the previous menu.

Steel Stud

This menu permits the user to enter the properties of steel studs. A data bank has been included for the moment of inertia and St. Venant constant. The user is expected to ensure that these values are correct before proceeding. The values can be changed by entering new ones either here or in the data bank. Only the latter will become a permanent record.

MENU



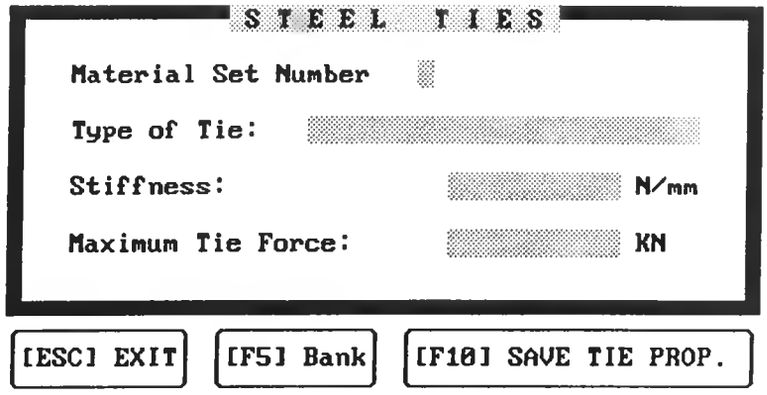
INPUT	DESCRIPTION
Material Set Number	The label is echoed for reference. No entry is required since the set number is defined in the previous menu.
Type of steel stud	Enter the type of steel stud for identification purposes.
Modulus of Elasticity	Enter the elastic modulus for the stud.
Shear Modulus	Enter the shear modulus for the stud.
Poisson's Ratio	Enter the Poisson's ratio for the stud. 0.3 is a typical value.
Moment of Inertia	The value according to TYPE OF STEEL STUD is echoed. The user can modify this value by typing a new one.

St. Venant Constant	The value according to TYPE OF STEEL STUD is echoed. The user can modify this value by typing a new one.
[F5] - S. S. Bank	By invoking this command, the user has access to the stored steel stud data bank, from which the user can select a section using [F10] or ignore the data set by selecting [ESC]. The properties will be echoed onto the menu once a set has been selected. All entries can be changed.
[F10]	To save the information before exiting.
[ESC]	To exit the menu without saving the information.

Steel Tie

This menu permits the user to enter the properties of the steel ties. The maximum tie force can be used to define the maximum value after which the tie will offer zero resistance. Again a data bank is included here based on experimental tests. The user is expected to exercise engineering judgment before adopting any value.

MENU



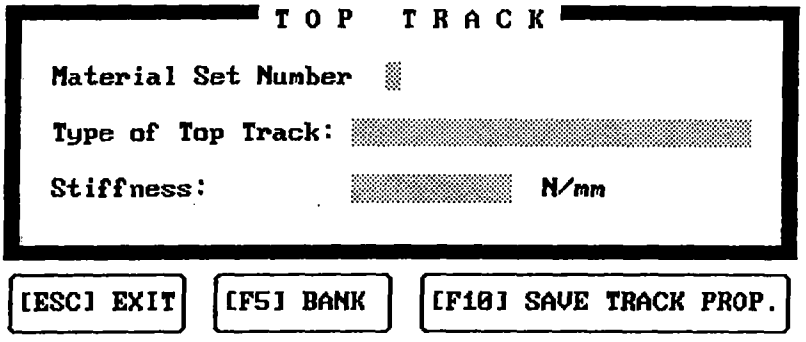
INPUT	DESCRIPTION
Material Set Number	The label is echoed for reference. No entry is required since the set number is defined in the previous menu.
Type of Tie	Enter the type of steel tie for identification purposes.
Stiffness	The value according to TYPE OF TIE is echoed. The user can modify this value by typing a new one.
Maximum Tie Force	Enter a value greater than zero if you want to limit the capacity of the tie. Once this capacity is exceeded, the tie force is reduced to zero.
[F5] - Bank	By invoking this command, the user has access to the stored steel tie data bank, from which the user can select a tie using [F10] or ignore the data set by selecting [ESC]. The properties will be echoed onto the menu once a set has been selected. All entries can be changed.

[F10]	To save the information and return to the previous menu.
[ESC]	To ignore the entry and return to previous menu.

Top Track

This menu permits the user to enter the properties of the top track. The track is assumed to offer lateral resistance and is modeled using an axial spring. The data bank included here is based on experimental tests. The user is expected to exercise engineering judgment before adopting any value.

MENU

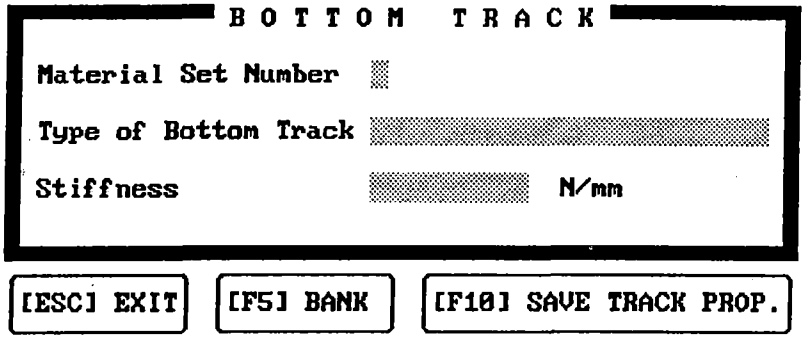


INPUT	DESCRIPTION
Material Set Number	The label is echoed for reference. No entry is required since the set number is defined in the previous menu.
Type of Top Track	Enter the type of top track for identification purposes.
Stiffness	The value according to TYPE OF TOP TRACK is echoed. The user can modify this value by typing a new one.
[F5] - Bank	By invoking this command, the user has access to the stored top track data bank, from which the user can select a section using [F10] or ignore the data set by selecting [ESC]. The properties will be echoed onto the menu once a set has been selected. All entries can be changed.
[F10]	To save the information and return to the previous menu.
[ESC]	To ignore the entry and return to the previous menu.

Bottom Track

This menu permits the user to enter the properties of the bottom track. The track is assumed to offer lateral resistance and is modeled using an axial spring. The data bank included here is based on experimental tests. The user is expected to exercise engineering judgment before adopting any value.

MENU

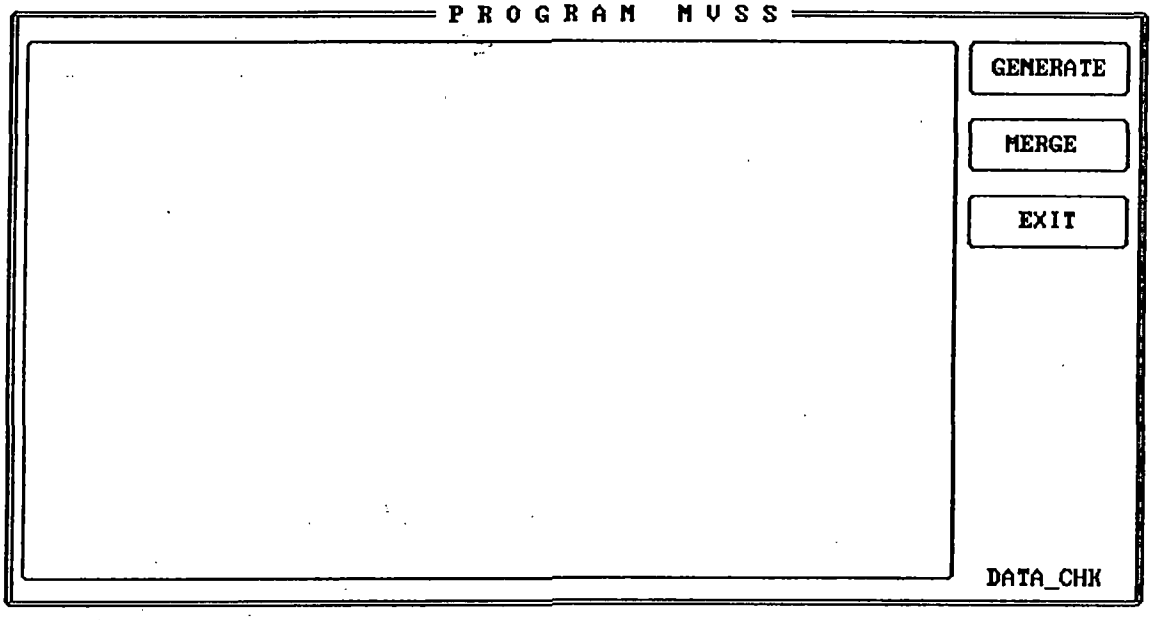


INPUT	DESCRIPTION
Material Set Number	The label is echoed for reference. No entry is required since the set number is defined in the previous menu.
Type of Bottom Track	Enter the type of bottom track for identification purposes.
Stiffness	The value according to TYPE OF BOTTOM TRACK is echoed. The user can modify this value by typing a new one.
[F5] - Bank	By invoking this command, the user has access to the stored bottom track data bank, from which the user can select a section using [F10] or ignore the data set by selecting [ESC]. The properties will be echoed onto the menu once a set has been selected. All entries can be changed.
[F10]	To save the information and return to the previous menu.
[ESC]	To ignore the entry and return to the previous menu.

DATA CHECK MENU

This menu is used to generate the mesh, the boundary conditions and the load for the finite element analysis. Every time the program MVSS is used, the user **must** run the data check, i.e. generate the mesh and then merge the finite element model. Moreover, this menu **must** be used after any modification if it is to be included in the analysis.

MENU



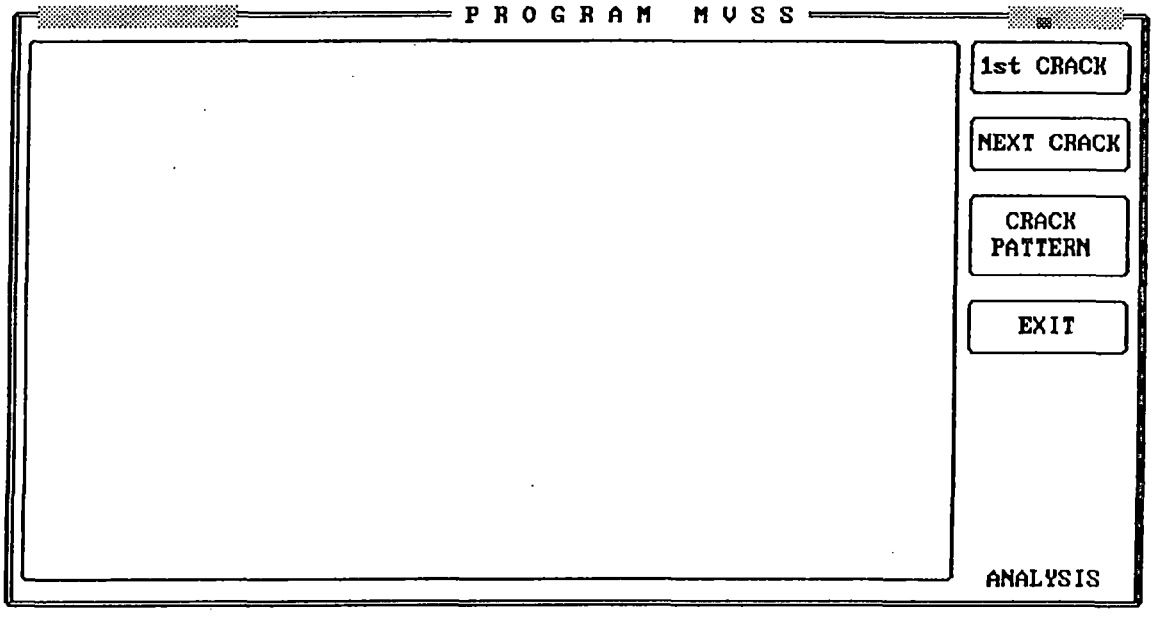
INPUT	DESCRIPTION
GENERATE	To generate the mesh, boundary conditions, load, and material properties.
MERGE	To merge the data so that all the regions form the model to be analyzed.
EXIT	To exit the menu.

ANALYSIS MENU

Perform Analysis of Wall

This menu is used to call the analysis routine. The various levels of analysis available are; compute the load to initiate the first crack, propagate a crack and define a crack pattern. It is preferred that the 1st CRACK command be used first before using the CRACK PATTERN one.

MENU

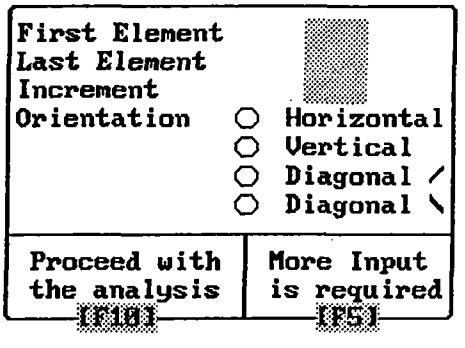


INPUT	DESCRIPTION
1st CRACK	To compute the load that will cause initiation of the first crack in the masonry wall. This entry opens a menu that displays the computation process.
NEXT CRACK	To compute the load that will either cause the crack to propagate or initiate a new crack. This entry opens a menu that displays the computation process.
CRACK PATTERN	This feature allows the user to define a crack pattern in order to expedite the analysis. The entry is as shown in the Crack Pattern in Wall menu.
EXIT	To exit this menu.

Crack Pattern in Wall

This menu permits the user to specify a crack pattern in order to expedite the analysis. Before using this feature, two steps are required; the user must identify the elements that will be cracked and the orientation of the crack. The user must then establish a crack pattern in order to minimize the required entries. This is best illustrated using an example: If elements 3,6,9,10 and 15 are to be cracked, then one can note that there are two series, the first between elements 3,6, and 9 which increase by an increment of 3. Their entry is 3 for the first element, 9 for the last element and 3 for the increment along with the orientation of the crack. The second series is between elements 10 and 15 which increase by an increment of 5. Their entry is 10, 15 and 5 along with the orientation of the crack.

MENU

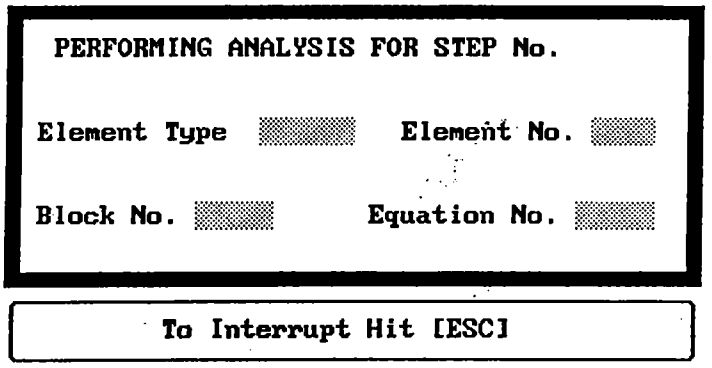


INPUT	DESCRIPTION
First Element	Enter the first element of the series of element to be cracked.
Last Element	Enter the last element of the series of element to be cracked.
Increment	Enter the increment between two successive elements in the series of elements.
Orientation	Enter the orientation of the crack.
[F5] More Input is required	To save the current entry and wait for more entries before proceeding with the analysis.
[F10] Proceed with the analysis	To save the current entry and then proceed with the analysis.

Computation Display Menu

This menu permits the user to monitor the progress of the analysis with the option to interrupt it and if needed stop it. This screen disappears when the analysis is complete.

MENU

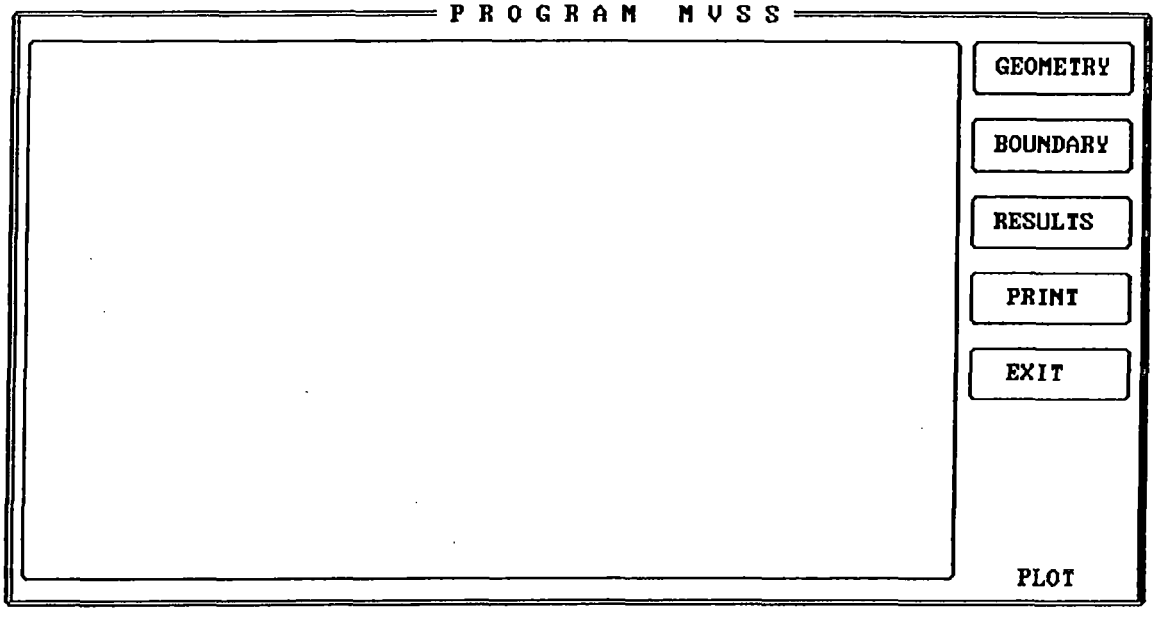


INPUT	DESCRIPTION
[ESC]	To interrupt the analysis. A warning message is given before accepting entry.

PLOT MENU

This menu controls the post-processing features of the MVSS program. It permits the user to plot the geometry, the boundary conditions and the results. Also, it allows the user to look at the model from outside in or inside out.

MENU

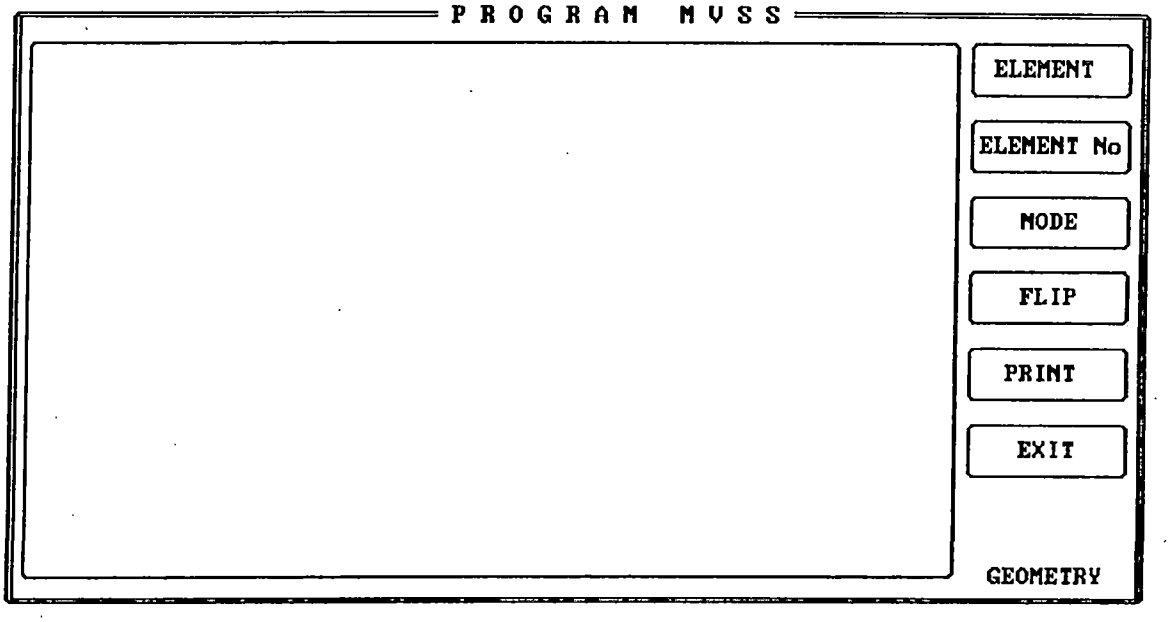


INPUT	DESCRIPTION
GEOMETRY	To open the Display Geometry MENU.
BOUNDARY	To display on the screen the boundary conditions.
RESULTS	To open the Results MENU.
PRINT	This print command will first open the PRINT MENU and then will only print the boundary conditions if selected next.
EXIT	To exit the plot menu.

Display Geometry

This menu permits the user to display and or print the geometry of the wall.

MENU

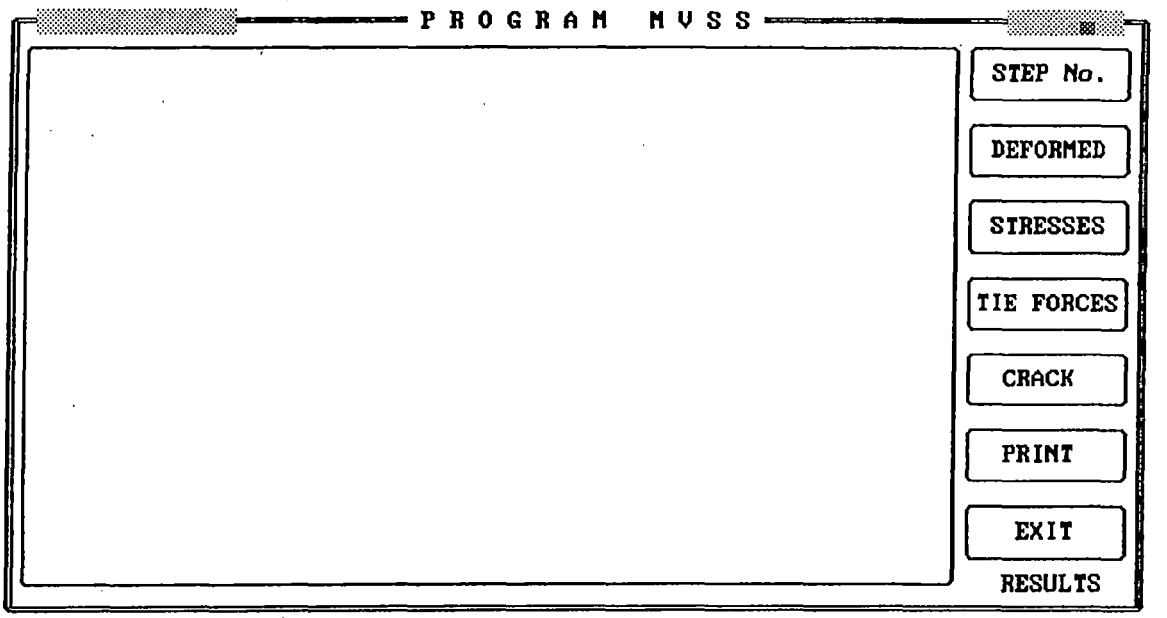


INPUT	DESCRIPTION
ELEMENT	To display the finite element mesh.
ELEMENT No.	To display the element number.
NODE	To display the node number.
FLIP	To examine the model from inside out. This allows the user to see the mesh from both sides. This command also allows the user to plot the stresses at the exterior and interior faces of the masonry veneer wall.
PRINT	This command, once activated, can be used to print the finite element mesh, element number, or node number by selecting them after accepting entries in the PRINT menu.
EXIT	To exit the Geometry Display menu

Results

This menu permits the user to plot the deformation, the stress contours, the crack pattern and the tie forces for every analysis step number. A step number refers to the analysis step number and is employed to allow the user to plot the results for intermediate stages of crack development.

MENU



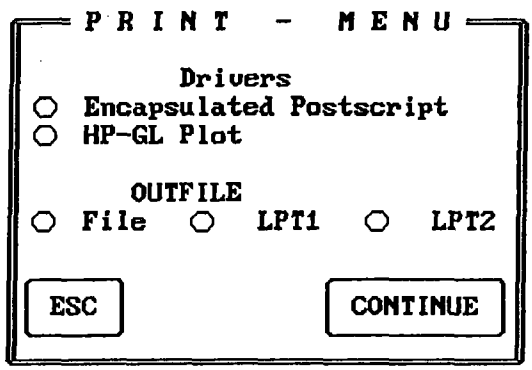
INPUT	DESCRIPTION
STEP NUMBER	Enter the step number to be plotted. The step refers to the analysis step number. The total number of steps is displayed for reference.
DEFORMED	To display the deformation of the wall. Two options are available; the deformed mesh or both the deformed and undeformed mesh.
STRESSES	To plot the stress contours for the masonry veneer wall only. Stresses in the x- or y-direction or the shear stress can be plotted. It should be noted that x-direction is parallel to the bed joint and the y-direction is normal to the bed joint. The FLIP command in the display geometry menu can be used to plot the stresses at the exterior and interior faces of the masonry wall.
TIE FORCES	To plot the tie forces.

CRACK	To plot the crack pattern and orientation along with the load that will cause the next crack.
PRINT	This command will first activate the PRINT menu. The information to be printed is selected thereafter.
EXIT	To exit the Results menu.

PRINT MENU

This menu, once chosen, permits the user to print the display onto a file or a printer. After activation of this command, the next input will not be displayed on the screen but rather is either copied to a file or send to a printer. This menu is activated every time the user selects the PRINT command.

MENU



INPUT	DESCRIPTION
Drivers	Select the type of printer. At present only two devices are available, PostScript printers and HPGL plotters.
Outfile	Select the route of the outfile, Options are LPT1, LPT2, or a file.
CONTINUE	Enter to accept entry.
[ESC]	Enter to exit the print menu and return to the previous menu.

Two case studies are provided in this User Reference Manual to demonstrate the use and capabilities of the MVSS program.

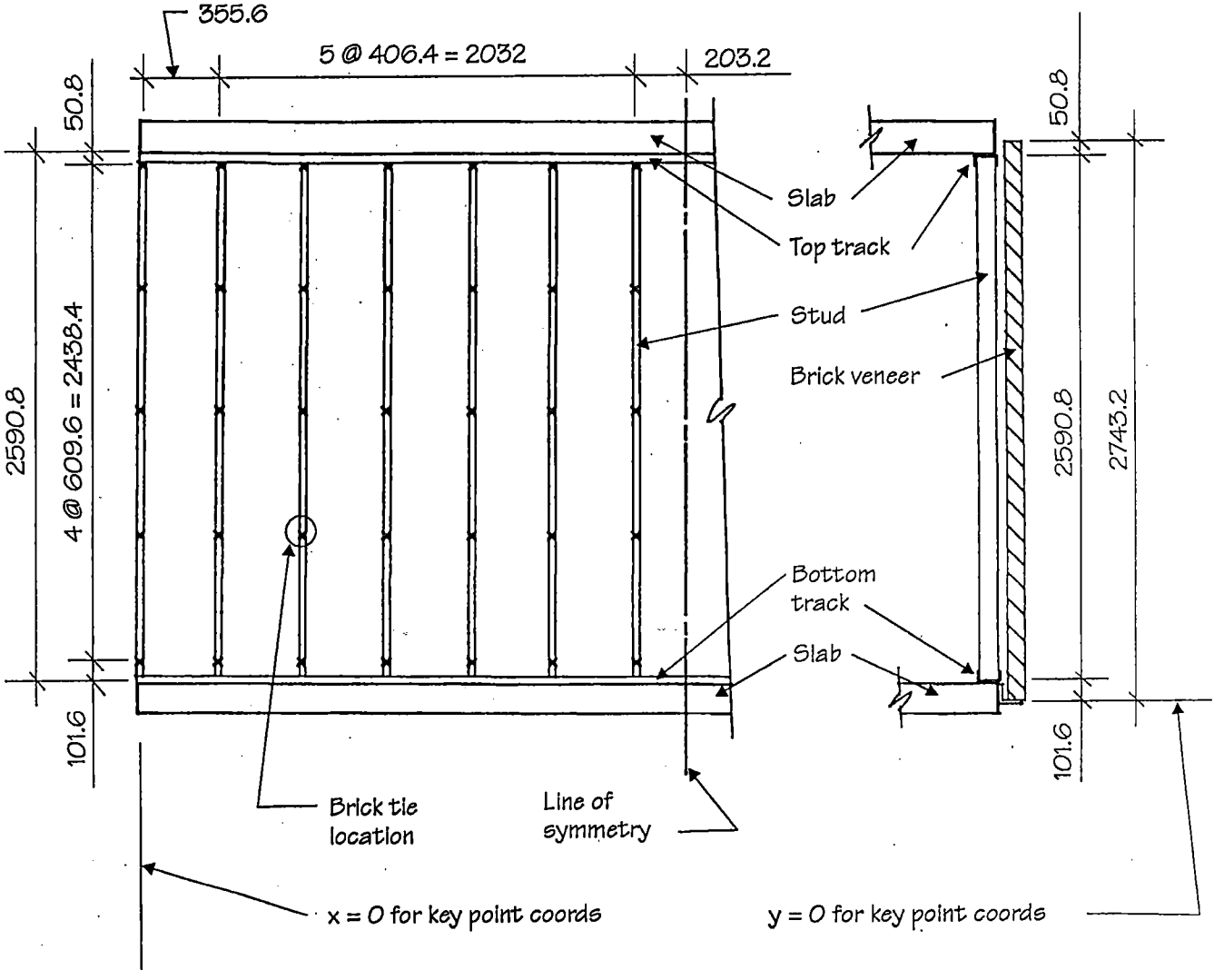
Case 1-A
Problem Description
The MVSS wall shown in Fig. C1-1, corresponds to a wall tested at McMaster University which was 5.2 m long constructed with 2.6 m high studs and 2.8 m high veneer. For test conditions, the actual vertical span of the veneer was 2743 mm and the actual horizontal span was 5181.6 mm. The veneer thickness is 90 mm and 92 mm studs are used. Since the wall is assumed to be symmetric, only half of the geometry is needed for the analysis. The properties used for the analysis are given in Table II.

Table II: Geometrical and mechanical properties for case study 1.

Masonry Veneer	Modulus of Elasticity, Ep	28 000 MPa
	Modulus of Elasticity, En	20315 MPa
	Poisson's Ratio	0.2
	Modulus of Rigidity, Gxy	9663 MPa
	Tensile strength normal to bed joints	0.73 MPa
	Tensile strength parallel to bed joint	4.37 MPa
Steel Stud Backup Wall	Modulus of Elasticity, E	200 000 MPa
	Shear Modulus, G	80 000 MPa
	Poisson's Ratio	0.3
	Moment of Inertia, I	310092.4 mm^4/stud
	St. Venant Constant, J	290 mm^4/stud
Steel Tie	Axial stiffness	300 N/mm
Bottom Track	Shear stiffness of bottom stud to track connection	1070 N/mm
Top Track	Shear stiffness of top stud to track connection	489 N/mm

The procedure to generate the finite element model and perform the analysis is outlined below:

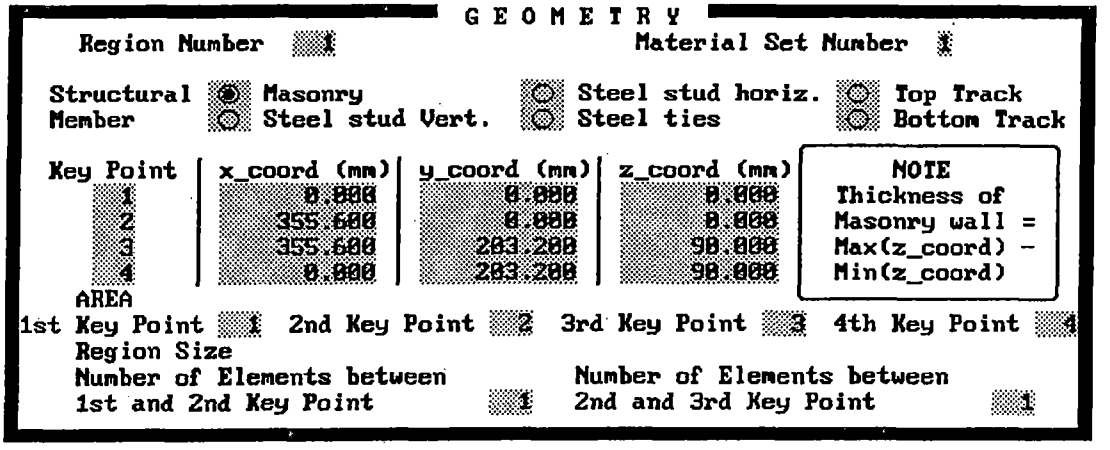
Figure C1-1 This sketch illustrates the as-built conditions of the MVSS wall used for first case study.



Define Geometry
Before proceeding with any entry, the user is encouraged to sketch the geometry of the wall system to ensure compatibility of node locations between the brick veneer and the backup wall.

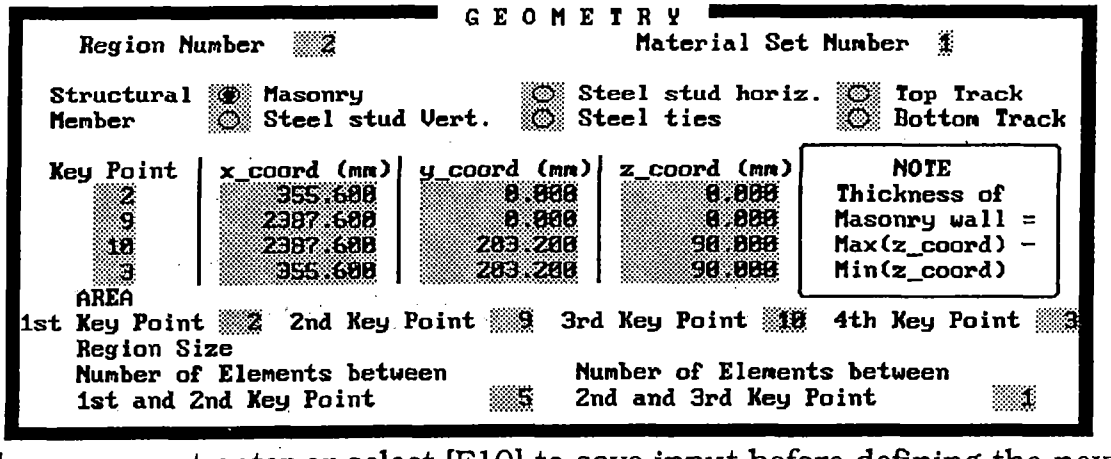
Generate the masonry veneer wall
To ensure compatibility of nodes between the two layers, the wall geometry is sub-divided into nine regions. The number of regions is based on the changes in either the geometry of the masonry veneer or the backup wall. This is best described by following the logic explained here. The input for each region is shown in the next nine screens.

Screen-1

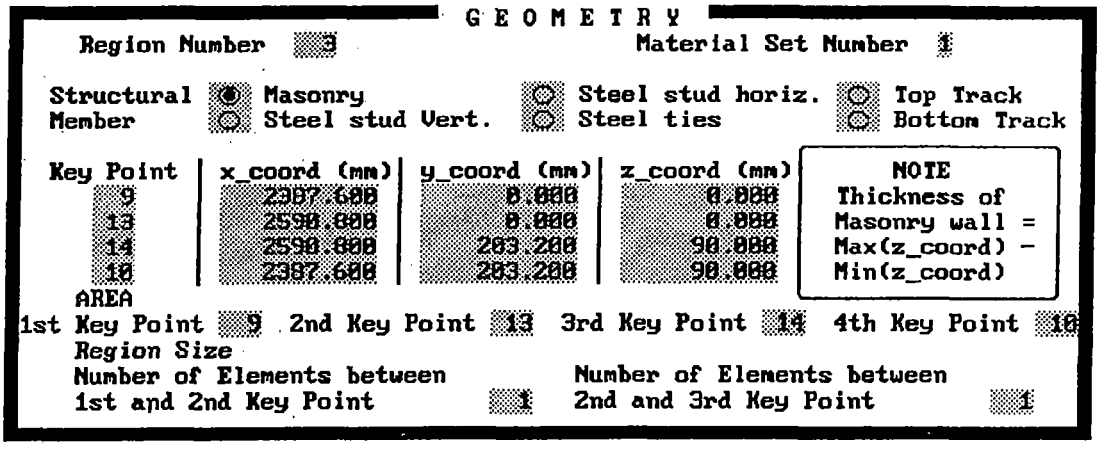


The user must enter or select [F10] to save input before defining the next region.

Screen-2

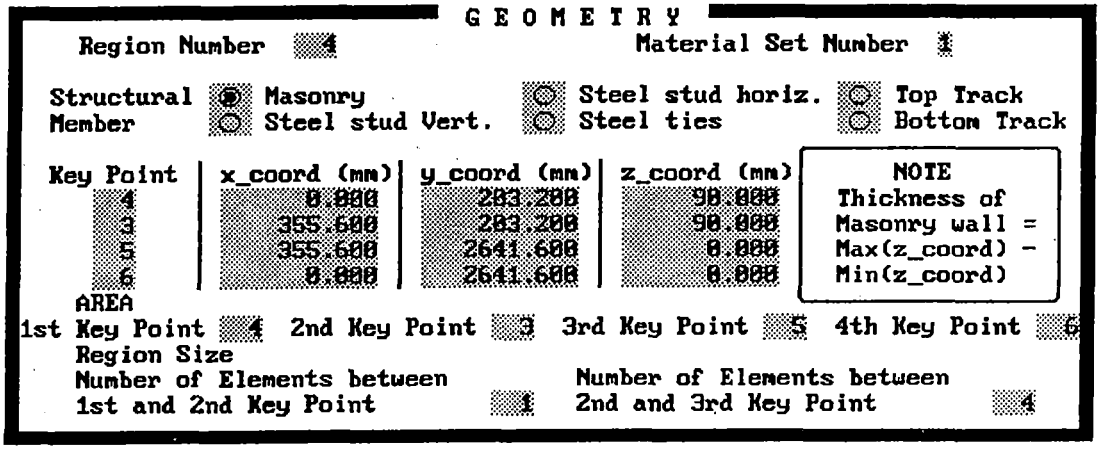


The user must enter or select [F10] to save input before defining the next region.
Screen-3



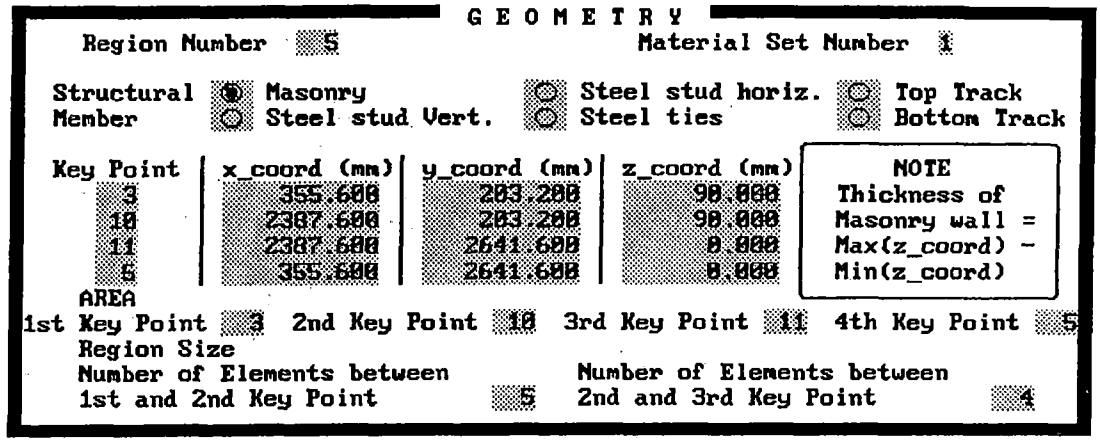
The user must enter or select [F10] to save input before defining the next region. If the user wishes to check the generated mesh, go to DATA CHECK menu to generate the actual finite elements then go to the PLOT menu to display the geometry.

Screen-4



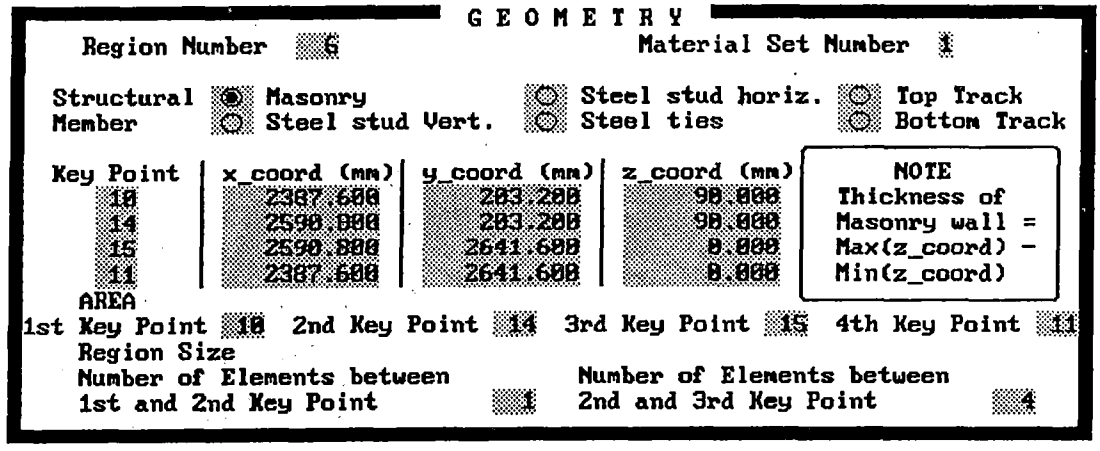
The user must enter or select [F10] to save input before defining the next region.

Screen-5



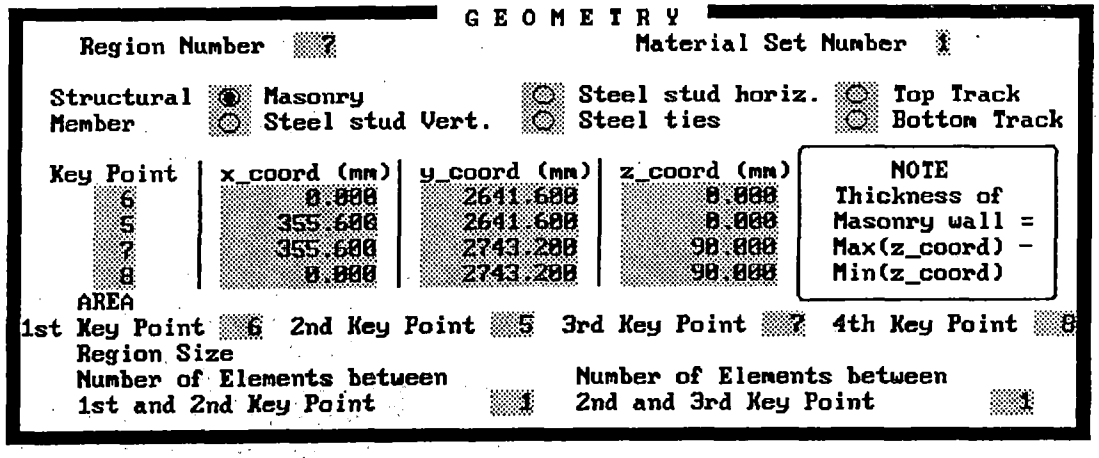
The user must enter or select [F10] to save input before defining the next region.

Screen-6



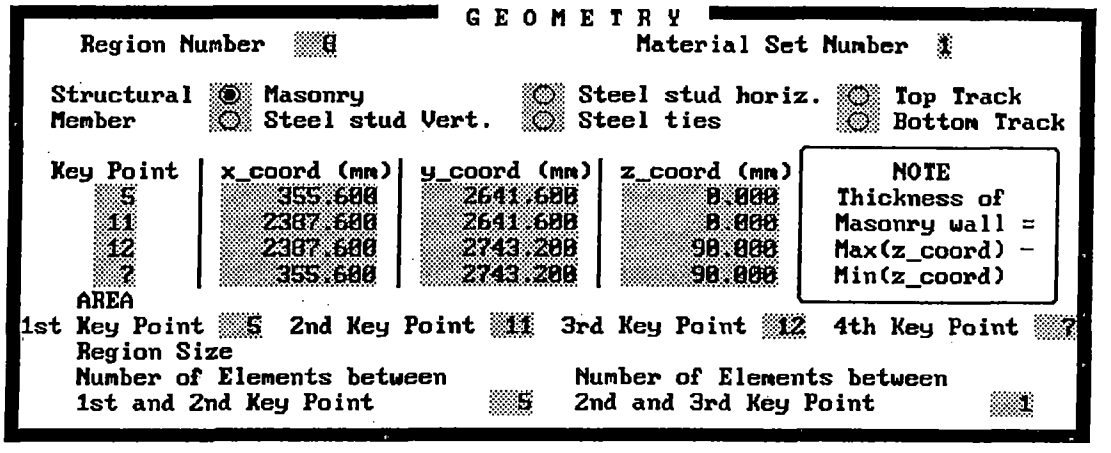
The user must enter or select [F10] to save input before defining the next region.

Screen-7



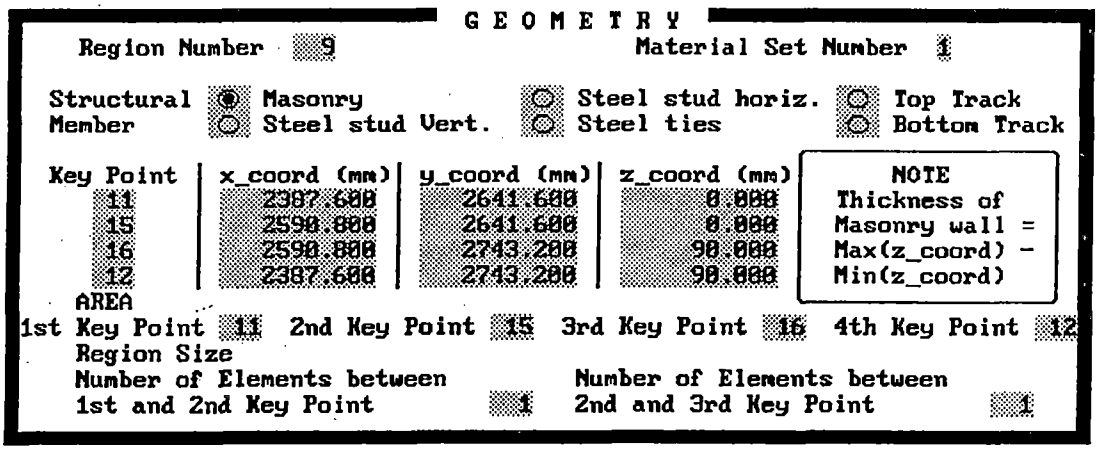
The user must enter or select [F10] to save input before defining the next region.

Screen-8



The user must enter or select [F10] to save input before defining the next region.

Screen-9

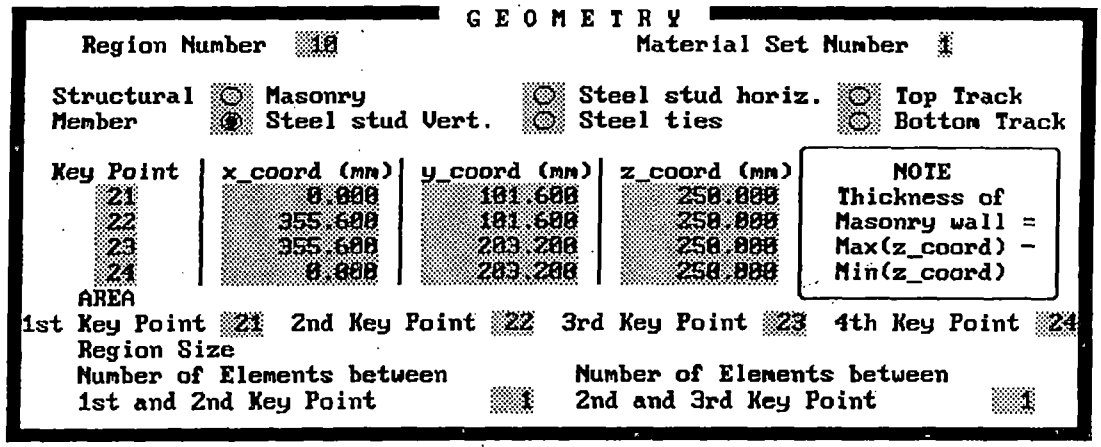


The user must enter or select [F10] to save input before defining the next region. The masonry veneer geometry has now been generated and can be checked using the DATA CHECK menu to generate the mesh and then using the PLOT menu to display it.

Generate the steel stud backup wall

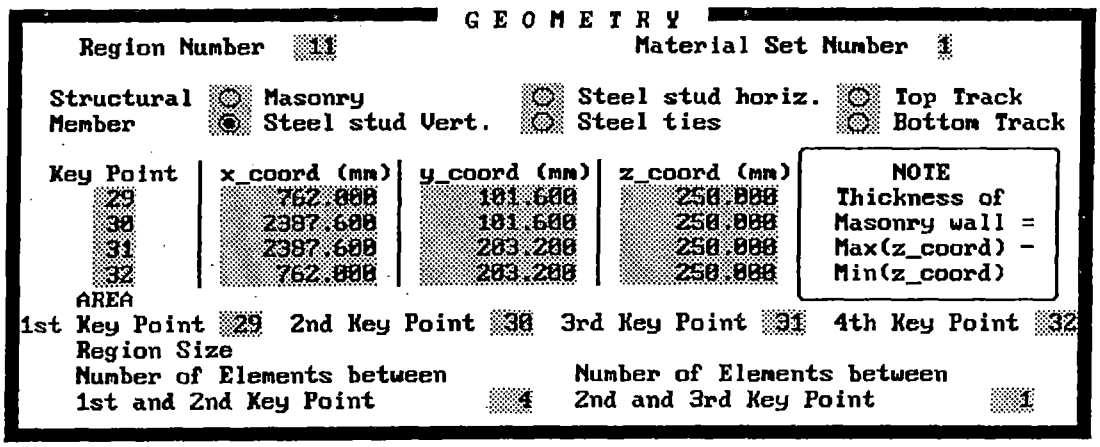
Because the steel stud backup wall has a different geometry, it needs to be entered accordingly. Six regions are needed here to represent the overall geometry of the backup wall. The input is as follows:

Screen-10



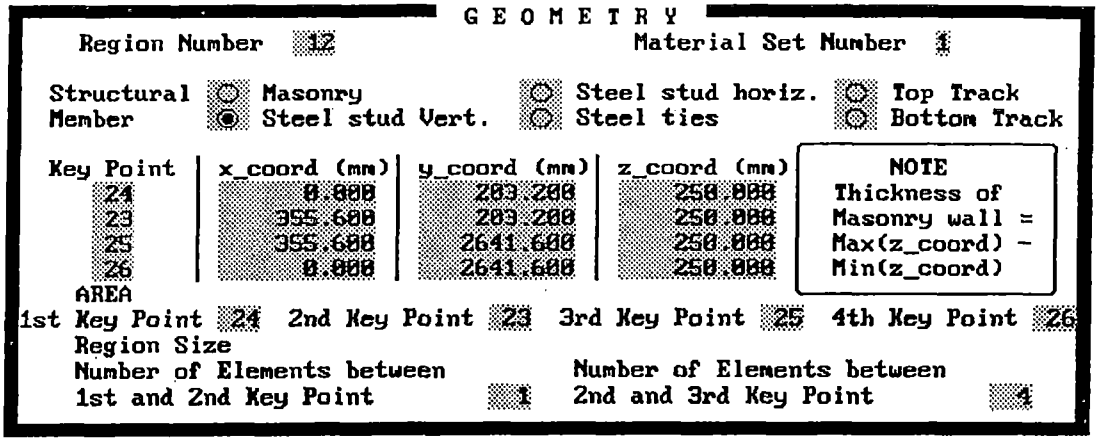
The user must enter or select [F10] to save input before defining the next region. The z-coordinate represents the centerline of the steel stud. For improved graphical display, it is recommended to artificially increase the spacing between the two layers.

Screen-11



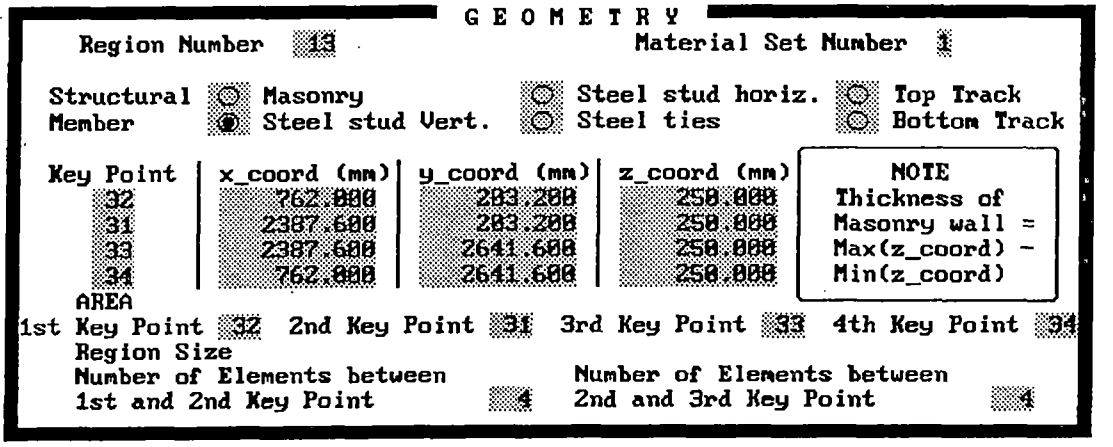
The user must enter or select [F10] to save input before defining the next region.

Screen-12



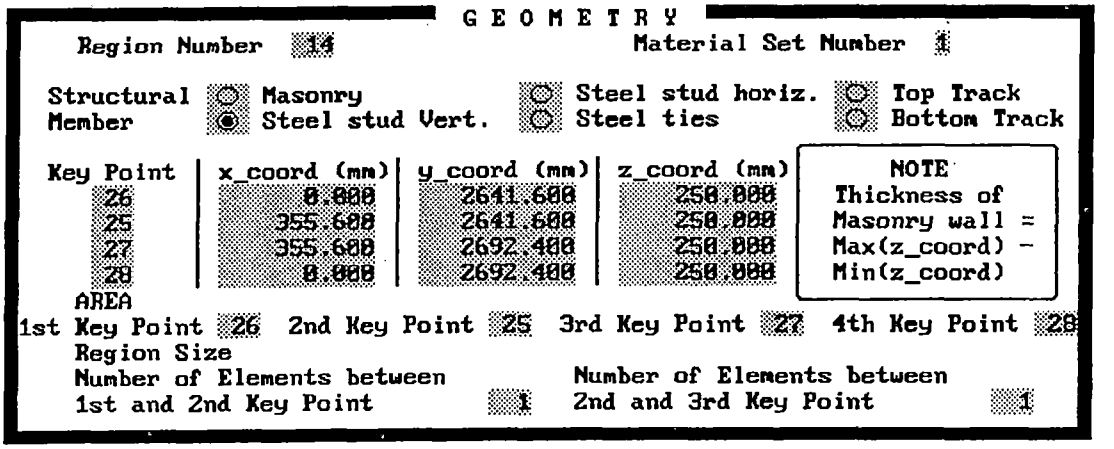
The user must enter or select [F10] to save input before defining the next region.

Screen-13



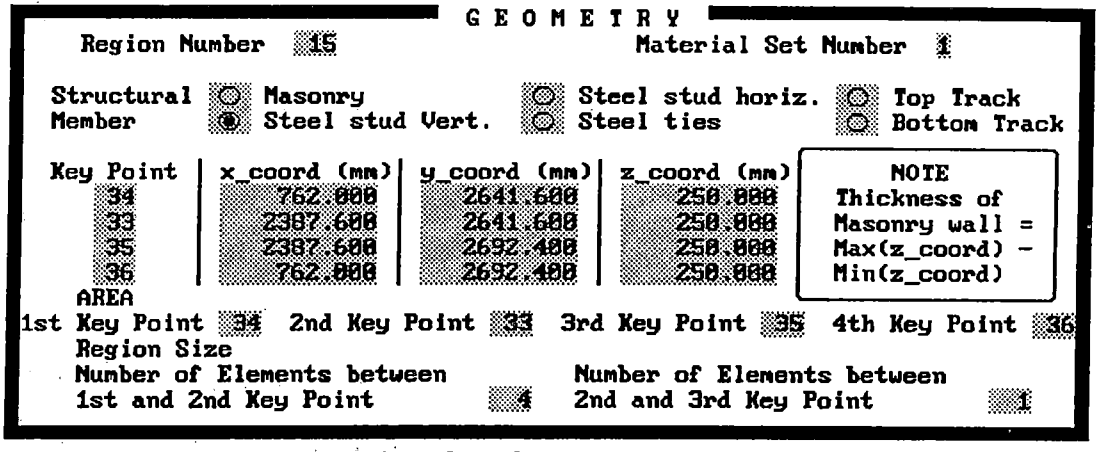
The user must enter or select [F10] to save input before defining the next region.

Screen-14



The user must enter or select [F10] to save input before defining the next region.

Screen-15

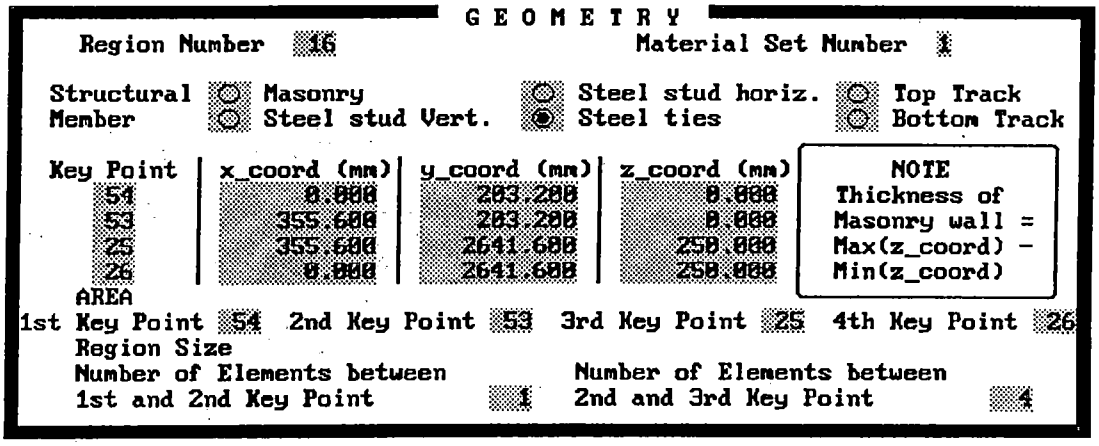


The user must enter or select [F10] to save input before defining the next region. At this point, the geometry of both the veneer and the backup wall have been generated. The user can select the Data Check menu to generate the mesh and then the PLOT menu to display it.

Generate the steel ties between the veneer and the backup wall

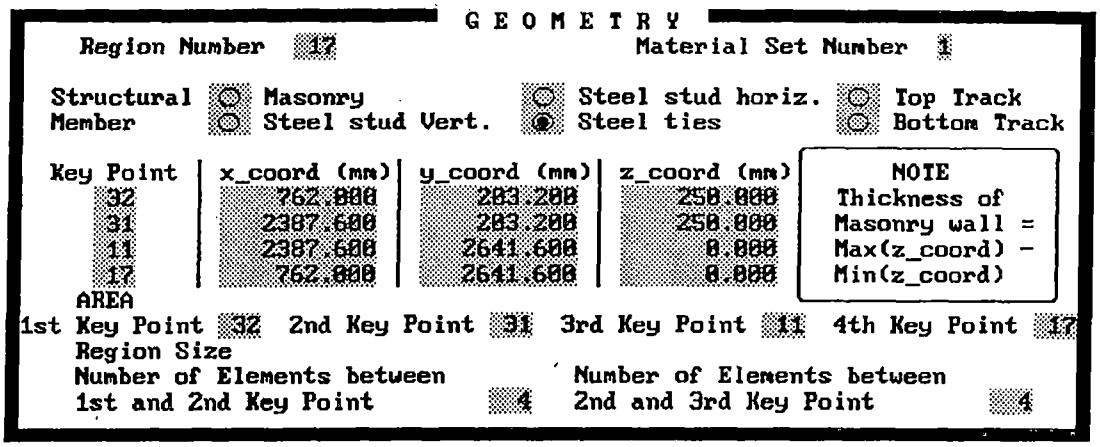
The steel ties must be generated to coincide with nodes previously generated for the masonry veneer and the backup wall. For display purpose, ties are connected from the exterior face of the masonry veneer to the steel stud centerlines. For this example, two regions are needed and are shown next.

Screen-16



The user must enter or select [F10] to save input before defining the next region. Key Points previously defined can be re-used but not redefined since this will alter the previously defined geometry.

Screen-17

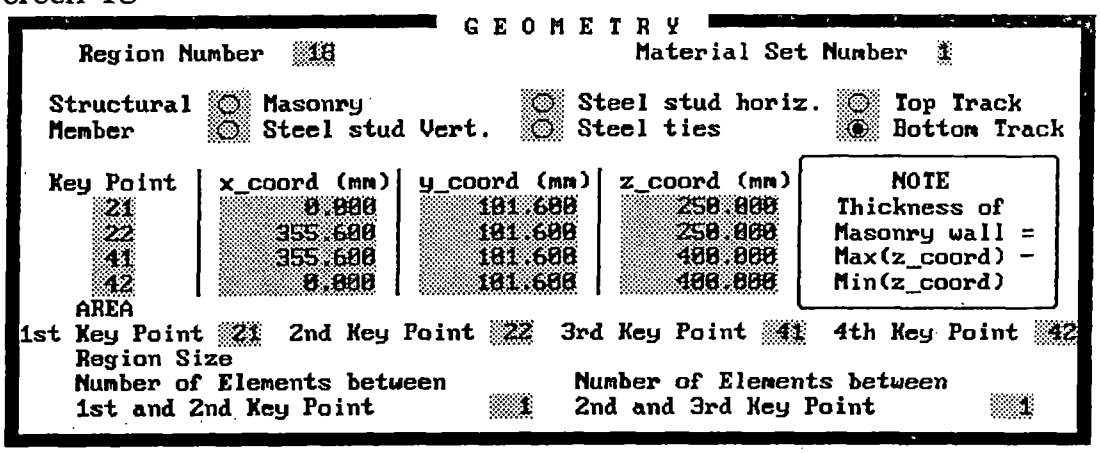


The user must enter or select [F10] to save input before defining the next region. At this point, the geometry of the veneer, the backup wall and the steel ties have been generated. The user can select the Data Check menu to generate the mesh and then the PLOT menu to display it.

Generate the bottom track connection to steel stud backup wall

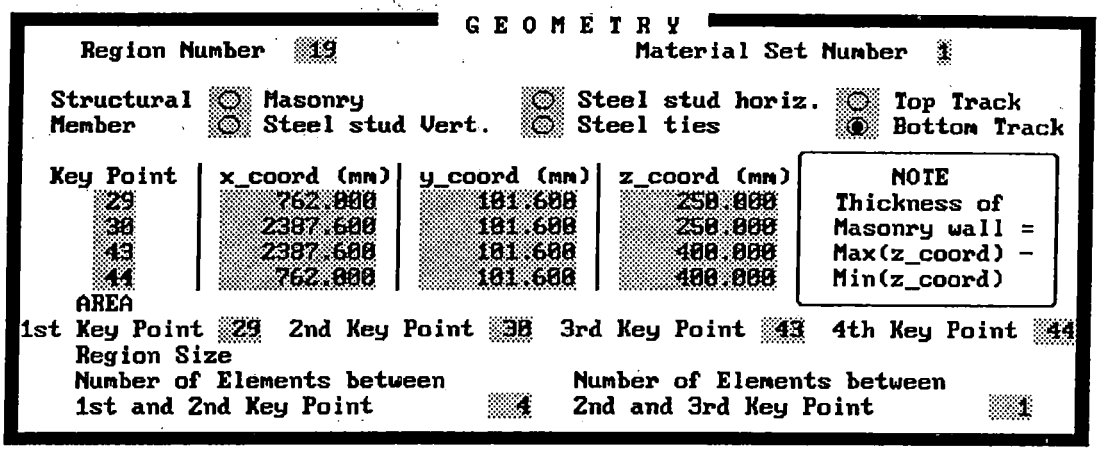
The bottom track is represented by a spring at each stud and the step required to generate their geometry is shown next. For the purpose of display, the springs are given an arbitrary dimension.

Screen-18



The user must enter or select [F10] to save input before defining the next region. The z-coordinate value of 400 mm, is the arbitrary dimension added for plotting purposes.

Screen-19

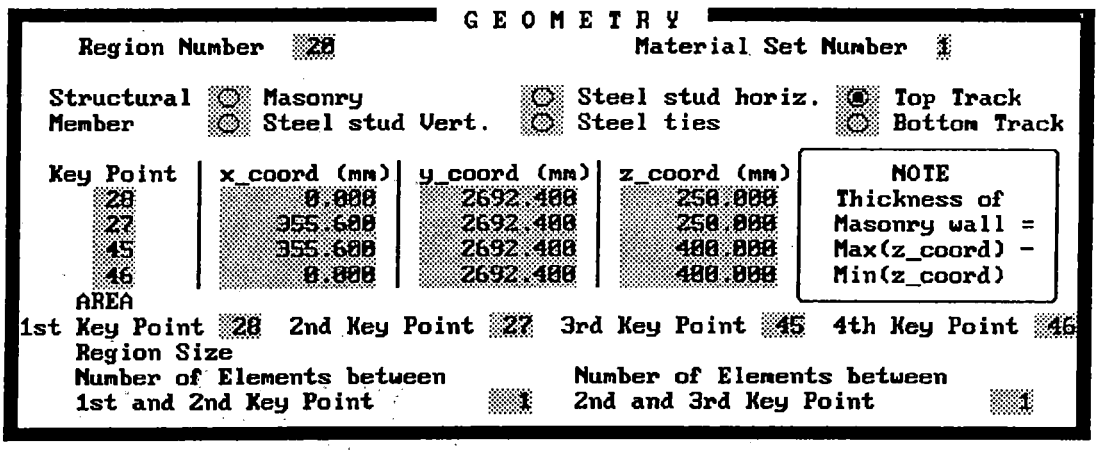


The user must enter or select [F10] to save input before defining the next region. At this point, the geometry of the veneer, the backup wall, the steel ties and the bottom track have been generated. The user can select the Data Check menu to generate the mesh and then the PLOT menu to display it.

Generate the top track connection to steel stud backup wall

The top track is represented by a spring at each stud and the step required to generate their geometry is shown next. For the purpose of display, the springs are given an arbitrary dimension produced by using a z-coordinate value of 400 mm..

Screen-20



The user must enter or select [F10] to save input before defining the next region.

Screen-21

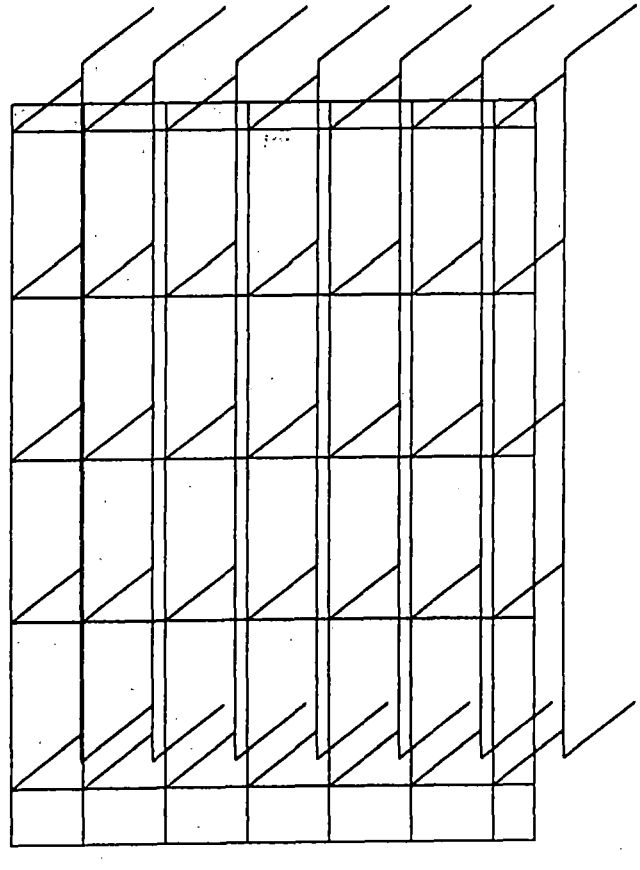
```
                              G E O M E T R Y
   Region Number  21                          Material Set Number  1

Structural  ( ) Masonry          ( ) Steel stud horiz.   (*) Top Track
Member      ( ) Steel stud Vert. ( ) Steel ties          ( ) Bottom Track

Key Point | x_coord (mm) | y_coord (mm) | z_coord (mm)
    36    |     762.000  |    2692.400  |    250.000      NOTE
    35    |    2387.600  |    2692.400  |    250.000      Thickness of
    47    |    2387.600  |    2692.400  |    400.000      Masonry wall =
    48    |     762.000  |    2692.400  |    400.000      Max(z_coord) -
                                                         Min(z_coord)
   AREA
1st Key Point  36  2nd Key Point  35  3rd Key Point  47  4th Key Point  48
   Region Size
   Number of Elements between
   1st and 2nd Key Point  4          Number of Elements between
                                     2nd and 3rd Key Point  1
```

The user must enter or select [F10] to save input before defining the next region. At this point, the geometry of the veneer, the backup wall, the steel ties, the bottom track and the top track have been generated. The user can select the Data Check menu to generate the mesh and then the PLOT menu to display it. Figure C1-2 displays the complete finite element mesh.

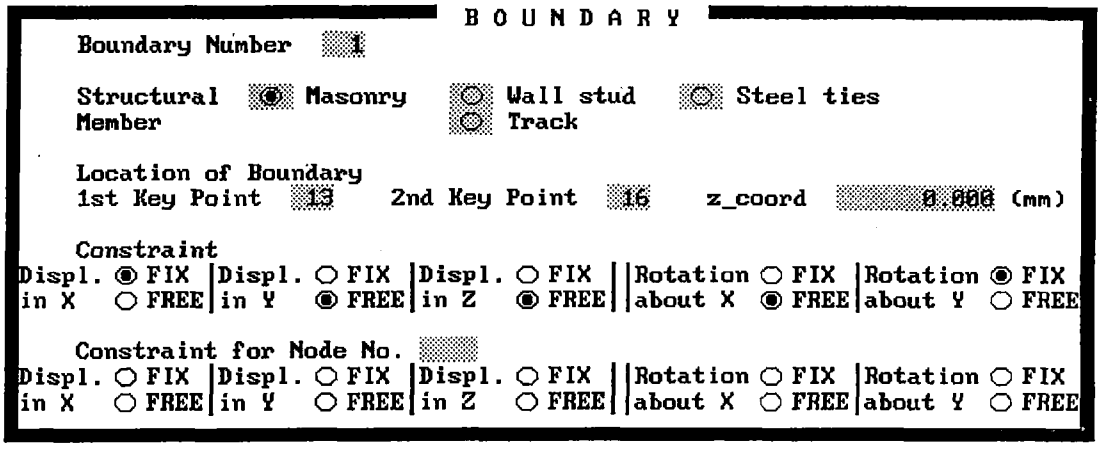
Figure C1-2 Finite element mesh of masonry veneer and steel stud backup walls.



Define Boundary Conditions

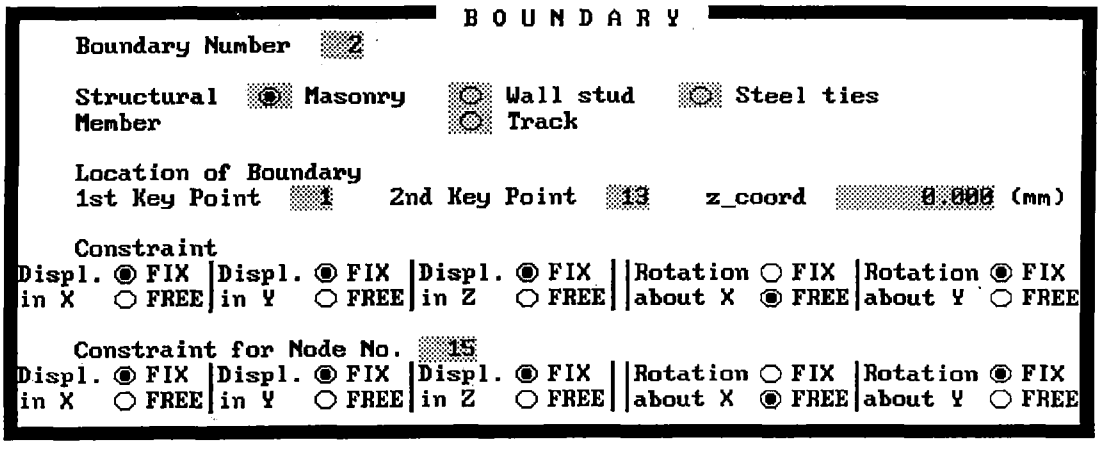
The veneer will have two boundary conditions, one at the bottom using the simply supported conditions and one for the right side due to the symmetric boundary conditions. Because the tracks are modeled as springs, two boundary conditions (considered to be fixed) are needed to constrain the free end of the spring. The input for all the boundary conditions is shown below:

Screen-22



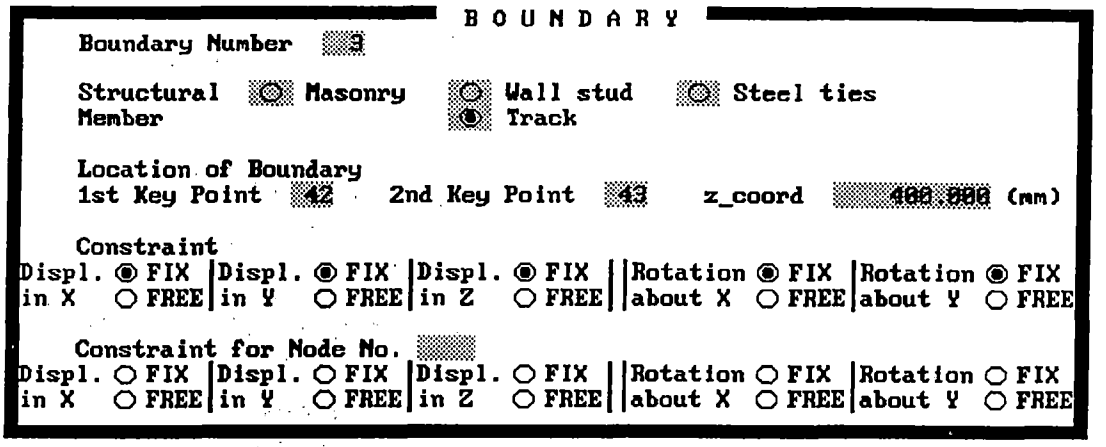
The user must enter or select [F10] to save input before defining the next boundary number. This boundary is along the line of symmetry of the masonry wall.

Screen-23



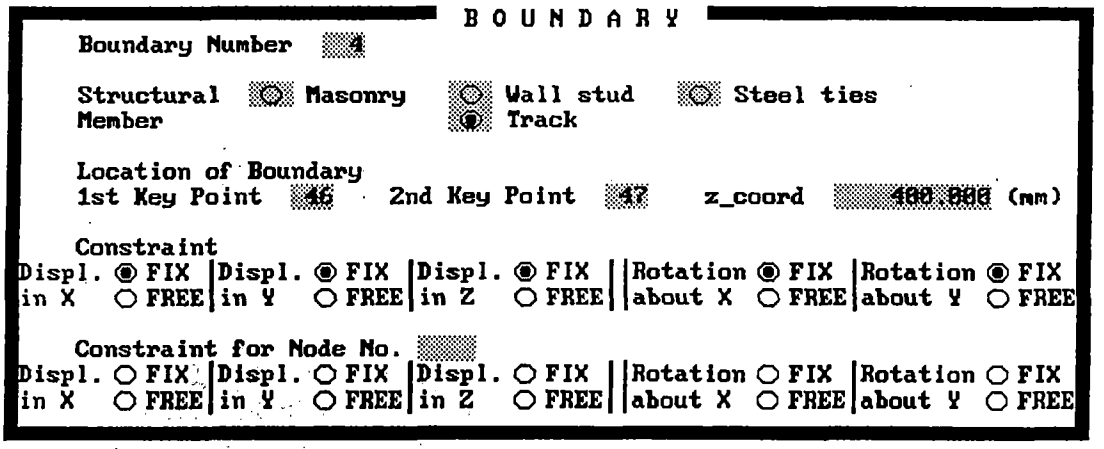
The user must enter or select [F10] to save input before defining the next boundary number. This boundary simulates the simply support base of the masonry wall. At the intersection of boundaries (including line of symmetry), the constraint for Node No. entry can be used to ensure accurate boundary condition. This entry is shown in Screen-23 and the user must enter or select [F5] to save the Node No. input.

Screen-24



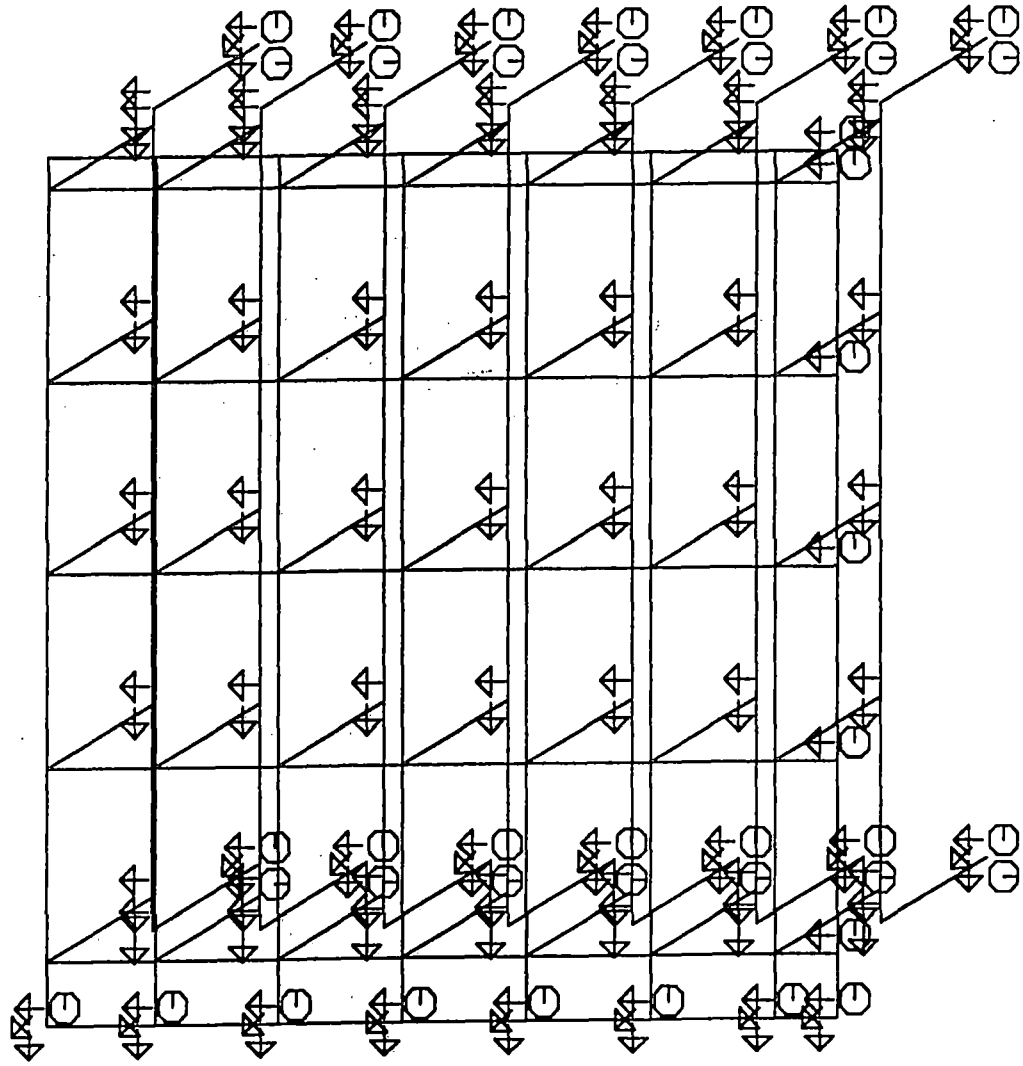
The user must enter or select [F10] to save input before defining the next boundary number. This boundary is mainly to constrain the free end of the spring used to model the track resistance.

Screen-25



The user must enter or select [F10] to save input before defining the next boundary number. At this point, the entry of the boundary conditions is complete. The user can select the Data Check menu to generate the mesh and then select the PLOT menu to display it. The boundary can be plotted by selecting the Boundary key from the PLOT menu. Figure C1-3 displays of the boundary conditions generated.

Figure C1-3 Plot of the Finite element mesh and boundary conditions.

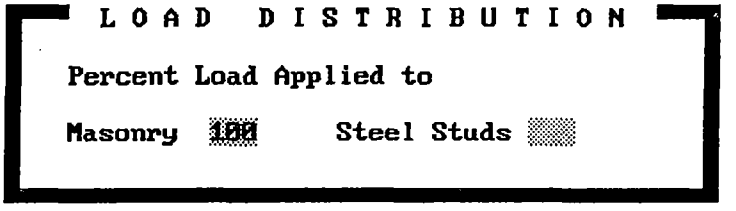


Note
The circles and arrows represent rotational and translation degrees of freedom, respectively. The horizontal and vertical line inside the circle represents the rotation about the x- and y-axis, respectively. Only the constrained degrees of freedom are shown.

Define the Applied load

There are two options available in applying loads to the model. The load can be applied fully to the surface of the veneer wall, fully to the backup wall, or in any combination. In this example, the load is applied only to the veneer. The input is straight forward as displayed below.

Screen-26

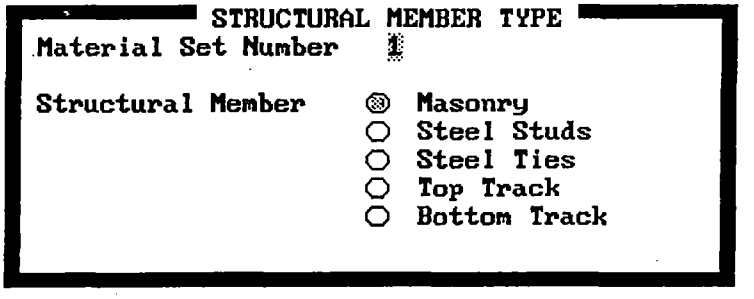


The user must enter or select [F10] to save input.

Define the Material Properties

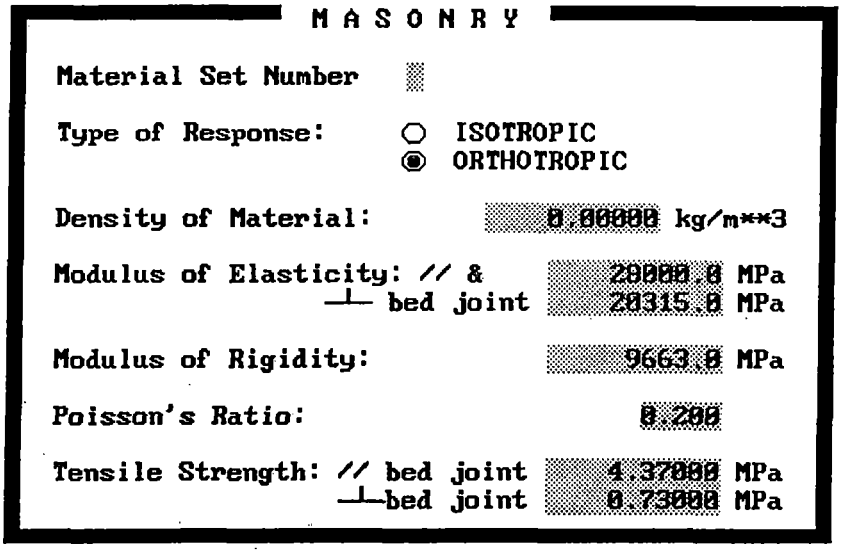
The properties have been defined at the beginning of this example and they must be entered accordingly. The user must first define the material set number and then define the properties of the structural members that have used the set number during the generation of the model. The input for the masonry is shown next.

Screen-27



The user must enter or select [F10] to open the masonry menu.

Masonry
Screen-28



To save the information, the user must enter or select [F10]. The same process needs to be repeated for the steel stud, steel ties, and the bottom and top tracks.

Data Preparation
Before performing the analysis, the regions specified must be generated by invoking the command GENERATE in DATA CHECK MENU. Once this is done, the user must integrate all the regions together using the MERGE command located in the same menu. Exit using [F10] key.

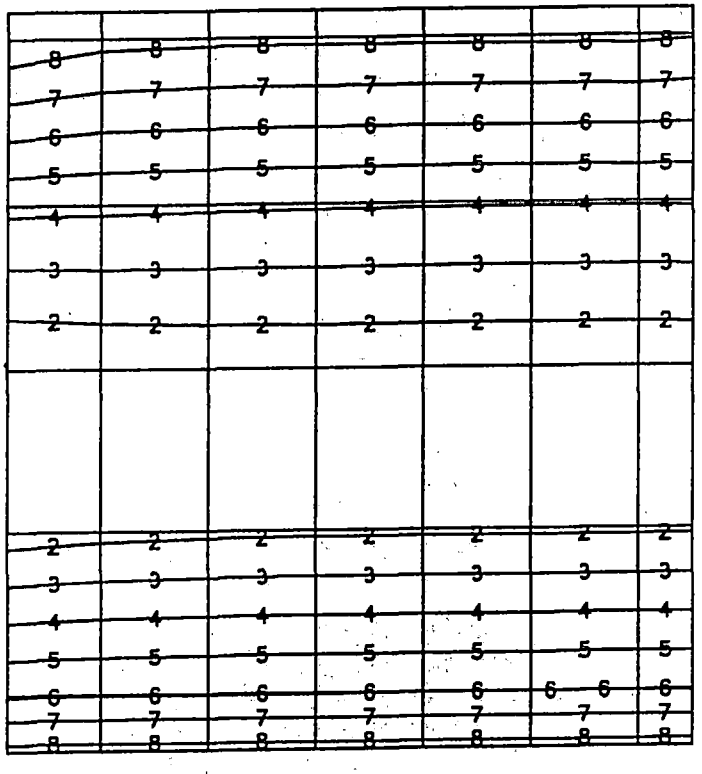
Perform the Analysis
Select ANALYSIS MENU in order to perform the number crunching. It is recommended that the 1st CRACK key be used first.

Results & Discussion
Once the analysis is complete, the results can be seen using the PLOT MENU. For the load that initiates the first crack, the results in the form of stresses, tie forces, crack pattern and cracking load are displayed in Figures C1-4 to C1-6. It should be noted that these results correspond to the state of stress prior to the initiation of the crack. Table III gives the maximum stud forces and deflections, and the maximum tie force before and after full propagation of the first crack. Figure C1-7 displays the location of the second crack along with the magnitude of the applied load that can cause its initiation.

Table III Summary of the maximum stud and tie forces at the initiation of the first crack and second crack.

	At the initiation of the first crack (1.44 kPa)	At the initiation of the second crack (8.04 kPa)
Maximum Stud Bending (kN m)	0.15	2.59
Maximum Stud Shear Force (kN)	0.76	4.19
Maximum Tie Force (kN)	0.58	2.39
Tie Number	119	116

Figure C1-4 Stresses normal to bed joint, MPa (at 1.44 kPa load just prior to cracking).



SIG-YY MPa

1 -.720E+00

2 -.628E+00

3 -.537E+00

4 -.445E+00

5 -.353E+00

6 -.262E+00

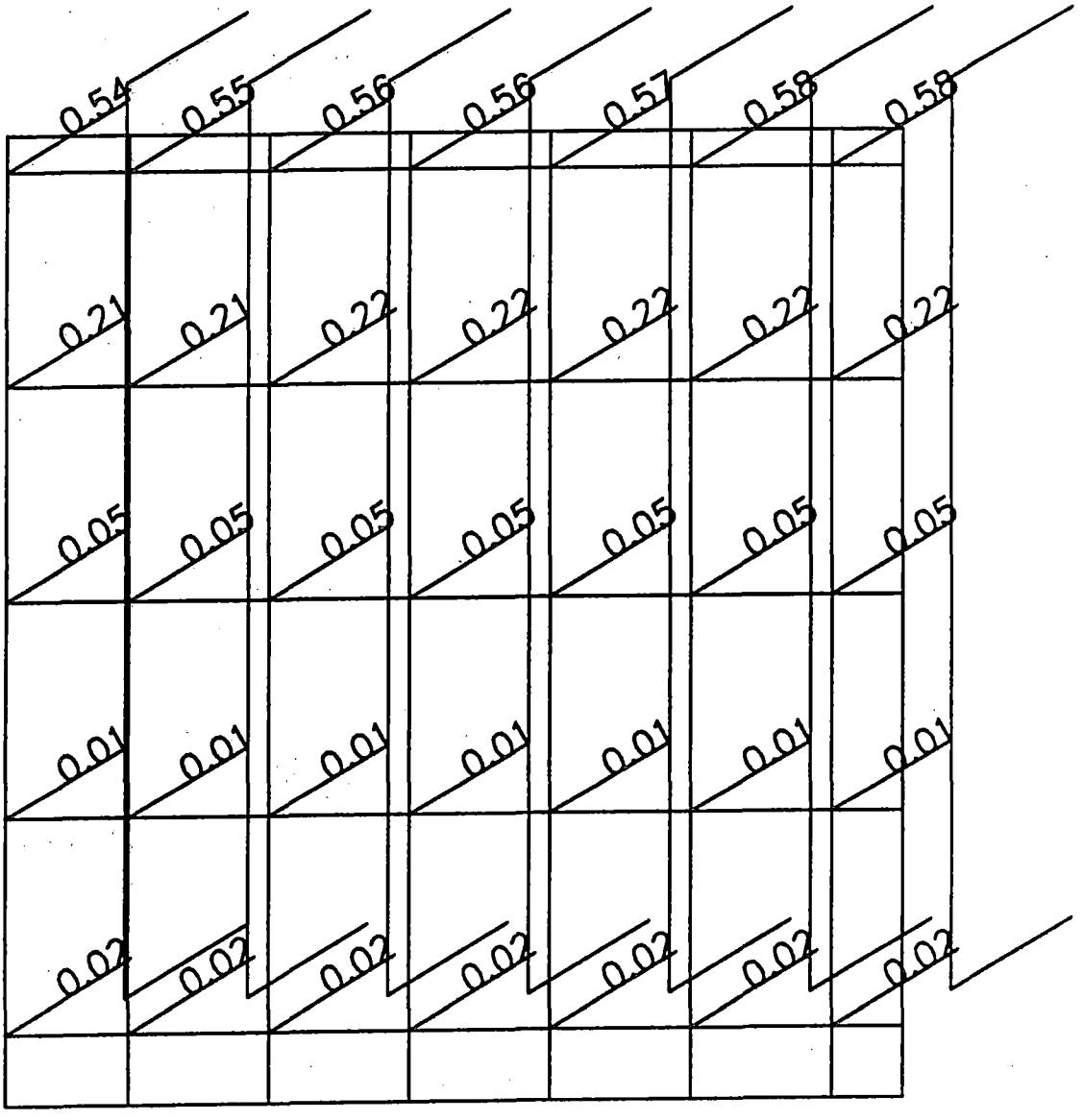
7 -.170E+00

8 -.785E-01

9 0.131E-01

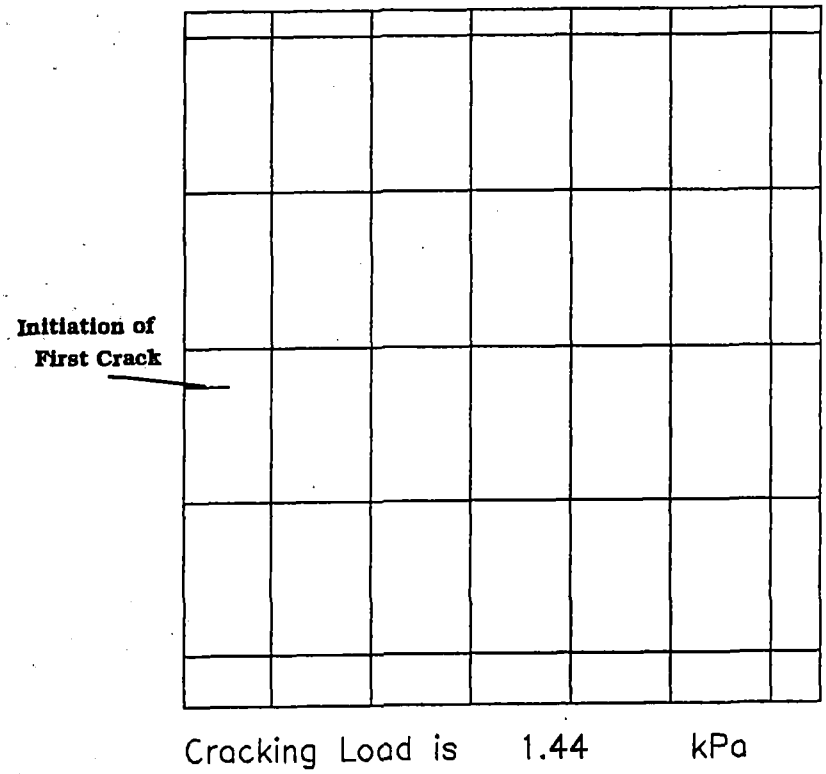
It should be noted that (+) is compressive stress and (-) is tensile stress.

Figure C1-5 Tie Forces, kN (at 1.44 kPa load just prior to cracking).



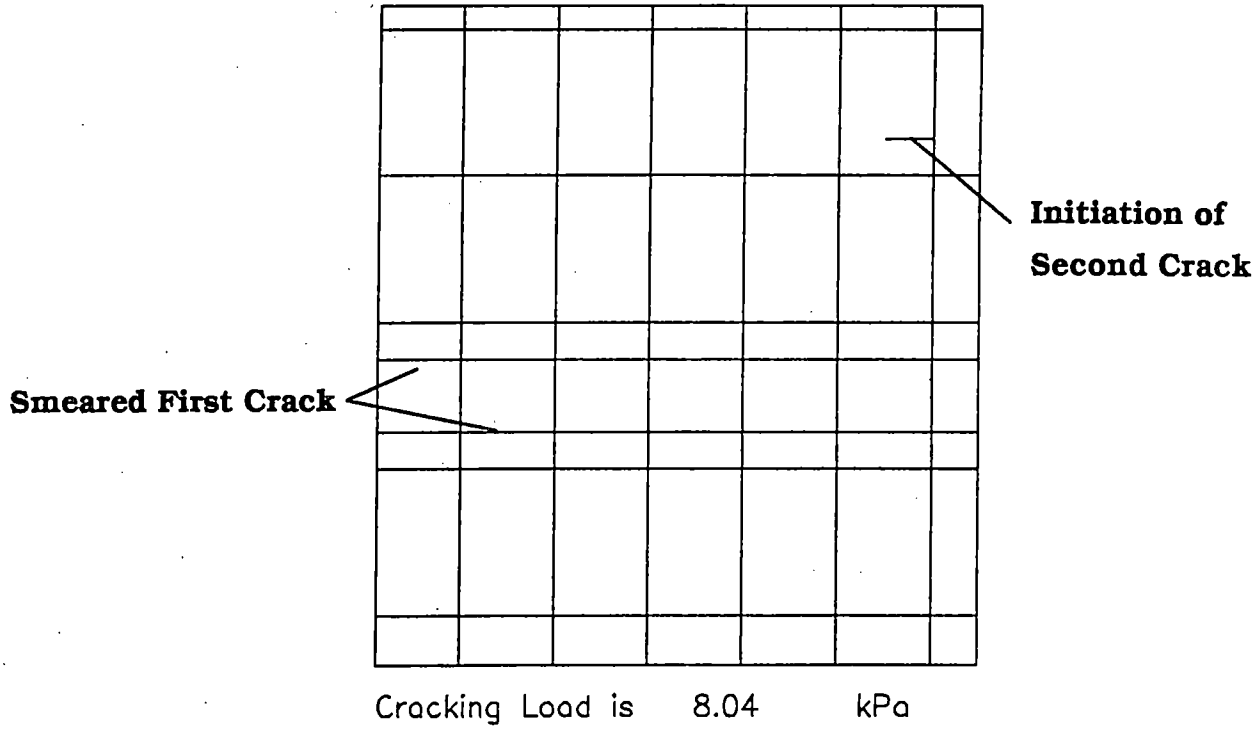
It should be noted that (+) is compressive force and (-) is tensile force.

Figure C1-6 Location and load for initiation of first crack.



Both the crack location and orientation are plotted. The user should remember that the output deformations, tie forces and stresses are responses to the cracking load of 1.44 kPa.

Figure C1-7 Location of fully developed first crack and location and load for initiation of second crack



Output file

An ASCII output file with the extension '.OUT' is also generated during the analysis. The user can edit the file using any text editor such as EDIT that is included in DOS. A sample copy is printed next.

```
**************************************************************************
*                                                                        *
*            F I N I T E  E L E M E N T  A N A L Y S I S                 *
*                              O F                                       *
*     M A S O N R Y  V E N E E R / S T E E L  S T U D  S Y S T E M       *
*                                                                        *
*                              by                                        *
*     CHIDIAC ENGINEERING Inc.    &   Drysdale Engineering & Asso. Ltd.  *
*                                                                        *
**************************************************************************
*      M.V.S.S.  ver. 2.1            Last Update : December,1993         *
**************************************************************************


**************************************************************************
  G E N E R A L  I N F O R M A T I O N
**************************************************************************
     TOTAL NO. OF ELEMENTS          NEL    =  133
     NO. OF NODES                   NNOD   =  251


**************************************************************************
  M A T E R I A L  P R O P E R T I E S  O F  M A S O N R Y  W A L L
**************************************************************************
     MATERIAL SET NUMBER                              =          1
     TYPE OF RESPONSE                                 = ORTHOTROPIC
     MOD. OF ELASTICITY PARALLEL TO BED JOINT = 0.2800E+05 MPa
     MOD. OF ELASTICITY NORMAL TO BED JOINT   = 0.2031E+05 MPa
     MODULUS OF RIGIDITY                              = 0.9663E+04 MPa
     POISSON RATIO                                    =      0.200


**************************************************************************
 P R O P E R T I E S  F O R  T H E  F A I L U R E  C R I T E R I O N
**************************************************************************
     TENSILE STRENGTH PARALLEL TO BED JOINT =     4.370000 MPa
     TENSILE STRENGTH NORMAL TO BED JOINT   =     0.730000 MPa


**************************************************************************
  M A T E R I A L  P R O P E R T I E S  O F  S T E E L  S T U D S
**************************************************************************
     MATERIAL SET NUMBER       =          1
     MODULUS OF ELASTICITY     = 0.2000E+06
     POISSON RATIO             =      0.300
     MODULUS OF RIGIDITY       = 0.8000E+05


**************************************************************************
   B A N D W I D T H  M I N I M I Z A T I O N  P E R F O R M E D
**************************************************************************
```

ELEMENT BAND WIDTH WAS CHANGED FROM 57 TO 25

****

N O D A L C O N F I G U R A T I O N

****

NODE	X-CORD (mm)	Y-CORD (mm)	degree of freedom in X	Y	Z	RY	RX
1	0.000000E+00	0.000000E+00	0	0	0	0	1
2	0.000000E+00	0.203200E+03	1	1	1	1	1
3	0.355600E+03	0.000000E+00	0	0	0	0	1
4	0.355600E+03	0.203200E+03	1	1	1	1	1
5	0.762000E+03	0.000000E+00	0	0	0	0	1
6	0.762000E+03	0.203200E+03	1	1	1	1	1
7	0.116840E+04	0.000000E+00	0	0	0	0	1
8	0.116840E+04	0.203200E+03	1	1	1	1	1
9	0.157480E+04	0.000000E+00	0	0	0	0	1
10	0.157480E+04	0.203200E+03	1	1	1	1	1
11	0.198120E+04	0.000000E+00	0	0	0	0	1
12	0.198120E+04	0.203200E+03	1	1	1	1	1
13	0.238760E+04	0.000000E+00	0	0	0	0	1
14	0.238760E+04	0.203200E+03	1	1	1	1	1
15	0.259080E+04	0.000000E+00	0	0	0	0	1
16	0.259080E+04	0.203200E+03	0	1	1	0	1
17	0.000000E+00	0.812800E+03	1	1	1	1	1
18	0.000000E+00	0.142240E+04	1	1	1	1	1
19	0.000000E+00	0.203200E+04	1	1	1	1	1
20	0.000000E+00	0.264160E+04	1	1	1	1	1
21	0.355600E+03	0.812800E+03	1	1	1	1	1
22	0.355600E+03	0.142240E+04	1	1	1	1	1
23	0.355600E+03	0.203200E+04	1	1	1	1	1
24	0.355600E+03	0.264160E+04	1	1	1	1	1
25	0.762000E+03	0.812800E+03	1	1	1	1	1
26	0.762000E+03	0.142240E+04	1	1	1	1	1
27	0.762000E+03	0.203200E+04	1	1	1	1	1
28	0.762000E+03	0.264160E+04	1	1	1	1	1
29	0.116840E+04	0.812800E+03	1	1	1	1	1
30	0.116840E+04	0.142240E+04	1	1	1	1	1
31	0.116840E+04	0.203200E+04	1	1	1	1	1
32	0.116840E+04	0.264160E+04	1	1	1	1	1
33	0.157480E+04	0.812800E+03	1	1	1	1	1
34	0.157480E+04	0.142240E+04	1	1	1	1	1
35	0.157480E+04	0.203200E+04	1	1	1	1	1
36	0.157480E+04	0.264160E+04	1	1	1	1	1
37	0.198120E+04	0.812800E+03	1	1	1	1	1
38	0.198120E+04	0.142240E+04	1	1	1	1	1
39	0.198120E+04	0.203200E+04	1	1	1	1	1
40	0.198120E+04	0.264160E+04	1	1	1	1	1
41	0.238760E+04	0.812800E+03	1	1	1	1	1
42	0.238760E+04	0.142240E+04	1	1	1	1	1
43	0.238760E+04	0.203200E+04	1	1	1	1	1
44	0.238760E+04	0.264160E+04	1	1	1	1	1
45	0.259080E+04	0.812800E+03	0	1	1	0	1
46	0.259080E+04	0.142240E+04	0	1	1	0	1
47	0.259080E+04	0.203200E+04	0	1	1	0	1
48	0.259080E+04	0.264160E+04	0	1	1	0	1
49	0.000000E+00	0.274320E+04	1	1	1	1	1
50	0.355600E+03	0.274320E+04	1	1	1	1	1
51	0.762000E+03	0.274320E+04	1	1	1	1	1
52	0.116840E+04	0.274320E+04	1	1	1	1	1
53	0.157480E+04	0.274320E+04	1	1	1	1	1
54	0.198120E+04	0.274320E+04	1	1	1	1	1
55	0.238760E+04	0.274320E+04	1	1	1	1	1
56	0.259080E+04	0.274320E+04	0	1	1	0	1

57	0.000000E+00	0.101600E+03	0	0	1	1	1
58	0.000000E+00	0.203200E+03	0	0	1	1	1
59	0.355600E+03	0.101600E+03	0	0	1	1	1
60	0.355600E+03	0.203200E+03	0	0	1	1	1
61	0.762000E+03	0.101600E+03	0	0	1	1	1
62	0.762000E+03	0.203200E+03	0	0	1	1	1
63	0.116840E+04	0.101600E+03	0	0	1	1	1
64	0.116840E+04	0.203200E+03	0	0	1	1	1
65	0.157480E+04	0.101600E+03	0	0	1	1	1
66	0.157480E+04	0.203200E+03	0	0	1	1	1
67	0.198120E+04	0.101600E+03	0	0	1	1	1
68	0.198120E+04	0.203200E+03	0	0	1	1	1
69	0.238760E+04	0.101600E+03	0	0	1	1	1
70	0.238760E+04	0.203200E+03	0	0	1	1	1
71	0.000000E+00	0.812800E+03	0	0	1	1	1
72	0.000000E+00	0.142240E+04	0	0	1	1	1
73	0.000000E+00	0.203200E+04	0	0	1	1	1
74	0.000000E+00	0.264160E+04	0	0	1	1	1
75	0.355600E+03	0.812800E+03	0	0	1	1	1
76	0.355600E+03	0.142240E+04	0	0	1	1	1
77	0.355600E+03	0.203200E+04	0	0	1	1	1
78	0.355600E+03	0.264160E+04	0	0	1	1	1
79	0.762000E+03	0.812800E+03	0	0	1	1	1
80	0.762000E+03	0.142240E+04	0	0	1	1	1
81	0.762000E+03	0.203200E+04	0	0	1	1	1
82	0.762000E+03	0.264160E+04	0	0	1	1	1
83	0.116840E+04	0.812800E+03	0	0	1	1	1
84	0.116840E+04	0.142240E+04	0	0	1	1	1
85	0.116840E+04	0.203200E+04	0	0	1	1	1
86	0.116840E+04	0.264160E+04	0	0	1	1	1
87	0.157480E+04	0.812800E+03	0	0	1	1	1
88	0.157480E+04	0.142240E+04	0	0	1	1	1
89	0.157480E+04	0.203200E+04	0	0	1	1	1
90	0.157480E+04	0.264160E+04	0	0	1	1	1
91	0.198120E+04	0.812800E+03	0	0	1	1	1
92	0.198120E+04	0.142240E+04	0	0	1	1	1
93	0.198120E+04	0.203200E+04	0	0	1	1	1
94	0.198120E+04	0.264160E+04	0	0	1	1	1
95	0.238760E+04	0.812800E+03	0	0	1	1	1
96	0.238760E+04	0.142240E+04	0	0	1	1	1
97	0.238760E+04	0.203200E+04	0	0	1	1	1
98	0.238760E+04	0.264160E+04	0	0	1	1	1
99	0.000000E+00	0.269240E+04	0	0	1	1	1
100	0.355600E+03	0.269240E+04	0	0	1	1	1
101	0.762000E+03	0.269240E+04	0	0	1	1	1
102	0.116840E+04	0.269240E+04	0	0	1	1	1
103	0.157480E+04	0.269240E+04	0	0	1	1	1
104	0.198120E+04	0.269240E+04	0	0	1	1	1
105	0.238760E+04	0.269240E+04	0	0	1	1	1
106	0.000000E+00	0.101600E+03	0	0	0	0	0
107	0.355600E+03	0.101600E+03	0	0	0	0	0
108	0.762000E+03	0.101600E+03	0	0	0	0	0
109	0.116840E+04	0.101600E+03	0	0	0	0	0
110	0.157480E+04	0.101600E+03	0	0	0	0	0
111	0.198120E+04	0.101600E+03	0	0	0	0	0
112	0.238760E+04	0.101600E+03	0	0	0	0	0
113	0.000000E+00	0.269240E+04	0	0	0	0	0
114	0.355600E+03	0.269240E+04	0	0	0	0	0
115	0.762000E+03	0.269240E+04	0	0	0	0	0
116	0.116840E+04	0.269240E+04	0	0	0	0	0
117	0.157480E+04	0.269240E+04	0	0	0	0	0
118	0.198120E+04	0.269240E+04	0	0	0	0	0
119	0.238760E+04	0.269240E+04	0	0	0	0	0

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E L E M E N T C O N F I G U R A T I O N

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ELEMENT	NODE NUMBERS				THICK (mm)	INERTIA (mm**4)	J (mm**4)	SPRING (N/mm)
1	1	3	4	2	90.000			
2	3	5	6	4	90.000			
3	5	7	8	6	90.000			
4	7	9	10	8	90.000			
5	9	11	12	10	90.000			
6	11	13	14	12	90.000			
7	13	15	16	14	90.000			
8	2	4	21	17	90.000			
9	17	21	22	18	90.000			
10	18	22	23	19	90.000			
11	19	23	24	20	90.000			
12	4	6	25	21	90.000			
13	21	25	26	22	90.000			
14	22	26	27	23	90.000			
15	23	27	28	24	90.000			
16	6	8	29	25	90.000			
17	25	29	30	26	90.000			
18	26	30	31	27	90.000			
19	27	31	32	28	90.000			
20	8	10	33	29	90.000			
21	29	33	34	30	90.000			
22	30	34	35	31	90.000			
23	31	35	36	32	90.000			
24	10	12	37	33	90.000			
25	33	37	38	34	90.000			
26	34	38	39	35	90.000			
27	35	39	40	36	90.000			
28	12	14	41	37	90.000			
29	37	41	42	38	90.000			
30	38	42	43	39	90.000			
31	39	43	44	40	90.000			
32	14	16	45	41	90.000			
33	41	45	46	42	90.000			
34	42	46	47	43	90.000			
35	43	47	48	44	90.000			
36	20	24	50	49	90.000			
37	24	28	51	50	90.000			
38	28	32	52	51	90.000			
39	32	36	53	52	90.000			
40	36	40	54	53	90.000			
41	40	44	55	54	90.000			
42	44	48	56	55	90.000			
43	57	58				0.310E+06	0.290E+03	
44	59	60				0.310E+06	0.290E+03	
45	61	62				0.310E+06	0.290E+03	
46	63	64				0.310E+06	0.290E+03	
47	65	66				0.310E+06	0.290E+03	
48	67	68				0.310E+06	0.290E+03	
49	69	70				0.310E+06	0.290E+03	
50	58	71				0.310E+06	0.290E+03	
51	71	72				0.310E+06	0.290E+03	
52	72	73				0.310E+06	0.290E+03	
53	73	74				0.310E+06	0.290E+03	
54	60	75				0.310E+06	0.290E+03	
55	75	76				0.310E+06	0.290E+03	
56	76	77				0.310E+06	0.290E+03	
57	77	78				0.310E+06	0.290E+03	
58	62	79				0.310E+06	0.290E+03	
59	79	80				0.310E+06	0.290E+03	
60	80	81				0.310E+06	0.290E+03	
61	81	82				0.310E+06	0.290E+03	
62	64	83				0.310E+06	0.290E+03	

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 63   83   84                0.310E+06 0.290E+03
 64   84   85                0.310E+06 0.290E+03
 65   85   86                0.310E+06 0.290E+03
 66   66   87                0.310E+06 0.290E+03
 67   87   88                0.310E+06 0.290E+03
 68   88   89                0.310E+06 0.290E+03
 69   89   90                0.310E+06 0.290E+03
 70   68   91                0.310E+06 0.290E+03
 71   91   92                0.310E+06 0.290E+03
 72   92   93                0.310E+06 0.290E+03
 73   93   94                0.310E+06 0.290E+03
 74   70   95                0.310E+06 0.290E+03
 75   95   96                0.310E+06 0.290E+03
 76   96   97                0.310E+06 0.290E+03
 77   97   98                0.310E+06 0.290E+03
 78   74   99                0.310E+06 0.290E+03
 79   78  100                0.310E+06 0.290E+03
 80   82  101                0.310E+06 0.290E+03
 81   86  102                0.310E+06 0.290E+03
 82   90  103                0.310E+06 0.290E+03
 83   94  104                0.310E+06 0.290E+03
 84   98  105                0.310E+06 0.290E+03
 85    2   58                                    0.300E+03 0.000E+00
 86   17   71                                    0.300E+03 0.000E+00
 87   18   72                                    0.300E+03 0.000E+00
 88   19   73                                    0.300E+03 0.000E+00
 89   20   74                                    0.300E+03 0.000E+00
 90    4   60                                    0.300E+03 0.000E+00
 91   21   75                                    0.300E+03 0.000E+00
 92   22   76                                    0.300E+03 0.000E+00
 93   23   77                                    0.300E+03 0.000E+00
 94   24   78                                    0.300E+03 0.000E+00
 95    6   62                                    0.300E+03 0.000E+00
 96   25   79                                    0.300E+03 0.000E+00
 97   26   80                                    0.300E+03 0.000E+00
 98   27   81                                    0.300E+03 0.000E+00
 99   28   82                                    0.300E+03 0.000E+00
100    8   64                                    0.300E+03 0.000E+00
101   29   83                                    0.300E+03 0.000E+00
102   30   84                                    0.300E+03 0.000E+00
103   31   85                                    0.300E+03 0.000E+00
104   32   86                                    0.300E+03 0.000E+00
105   10   66                                    0.300E+03 0.000E+00
106   33   87                                    0.300E+03 0.000E+00
107   34   88                                    0.300E+03 0.000E+00
108   35   89                                    0.300E+03 0.000E+00
109   36   90                                    0.300E+03 0.000E+00
110   12   68                                    0.300E+03 0.000E+00
111   37   91                                    0.300E+03 0.000E+00
112   38   92                                    0.300E+03 0.000E+00
113   39   93                                    0.300E+03 0.000E+00
114   40   94                                    0.300E+03 0.000E+00
115   14   70                                    0.300E+03 0.000E+00
116   41   95                                    0.300E+03 0.000E+00
117   42   96                                    0.300E+03 0.000E+00
118   43   97                                    0.300E+03 0.000E+00
119   44   98                                    0.300E+03 0.000E+00
120   57  106                                    0.107E+04
121   59  107                                    0.107E+04
122   61  108                                    0.107E+04
123   63  109                                    0.107E+04
124   65  110                                    0.107E+04
125   67  111                                    0.107E+04
126   69  112                                    0.107E+04
127   99  113                                    0.489E+03
128  100  114                                    0.489E+03
129  101  115                                    0.489E+03
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130 102 116                                          0.489E+03
131 103 117                                          0.489E+03
132 104 118                                          0.489E+03
133 105 119                                          0.489E+03

     No. of degrees of freedom  =        580
     Size of bandwidth          =        125
     Size of Stiffness          =      31135
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S O L U T I O N F O R S T E P N o. 1

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L O A D A P P L I E D

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ELEMENT	FX (N)	FY (N)	FZ (N)	MX (N.mm)	MY (N.mm)
1	0.00000E+00	0.00000E+00	0.18064E+05	0.10706E+07	0.61178E+06
	0.00000E+00	0.00000E+00	0.18064E+05	-0.10706E+07	0.61178E+06
	0.00000E+00	0.00000E+00	0.18064E+05	-0.10706E+07	-0.61178E+06
	0.00000E+00	0.00000E+00	0.18064E+05	0.10706E+07	-0.61178E+06
2	0.00000E+00	0.00000E+00	0.20645E+05	0.13984E+07	0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	-0.13984E+07	0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	-0.13984E+07	-0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	0.13984E+07	-0.69918E+06
3	0.00000E+00	0.00000E+00	0.20645E+05	0.13984E+07	0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	-0.13984E+07	0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	-0.13984E+07	-0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	0.13984E+07	-0.69918E+06
4	0.00000E+00	0.00000E+00	0.20645E+05	0.13984E+07	0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	-0.13984E+07	0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	-0.13984E+07	-0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	0.13984E+07	-0.69918E+06
5	0.00000E+00	0.00000E+00	0.20645E+05	0.13984E+07	0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	-0.13984E+07	0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	-0.13984E+07	-0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	0.13984E+07	-0.69918E+06
6	0.00000E+00	0.00000E+00	0.20645E+05	0.13984E+07	0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	-0.13984E+07	0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	-0.13984E+07	-0.69918E+06
	0.00000E+00	0.00000E+00	0.20645E+05	0.13984E+07	-0.69918E+06
7	0.00000E+00	0.00000E+00	0.10323E+05	0.34959E+06	0.34959E+06
	0.00000E+00	0.00000E+00	0.10323E+05	-0.34959E+06	0.34959E+06
	0.00000E+00	0.00000E+00	0.10323E+05	-0.34959E+06	-0.34959E+06
	0.00000E+00	0.00000E+00	0.10323E+05	0.34959E+06	-0.34959E+06
8	0.00000E+00	0.00000E+00	0.54193E+05	0.32119E+07	0.55061E+07
	0.00000E+00	0.00000E+00	0.54193E+05	-0.32119E+07	0.55061E+07
	0.00000E+00	0.00000E+00	0.54193E+05	-0.32119E+07	-0.55061E+07
	0.00000E+00	0.00000E+00	0.54193E+05	0.32119E+07	-0.55061E+07

```
 9  0.00000E+00 0.00000E+00 0.54193E+05 0.32119E+07 0.55061E+07
    0.00000E+00 0.00000E+00 0.54193E+05-0.32119E+07 0.55061E+07
    0.00000E+00 0.00000E+00 0.54193E+05-0.32119E+07-0.55061E+07
    0.00000E+00 0.00000E+00 0.54193E+05 0.32119E+07-0.55061E+07

10  0.00000E+00 0.00000E+00 0.54193E+05 0.32119E+07 0.55061E+07
    0.00000E+00 0.00000E+00 0.54193E+05-0.32119E+07 0.55061E+07
    0.00000E+00 0.00000E+00 0.54193E+05-0.32119E+07-0.55061E+07
    0.00000E+00 0.00000E+00 0.54193E+05 0.32119E+07-0.55061E+07

11  0.00000E+00 0.00000E+00 0.54193E+05 0.32119E+07 0.55061E+07
    0.00000E+00 0.00000E+00 0.54193E+05-0.32119E+07 0.55061E+07
    0.00000E+00 0.00000E+00 0.54193E+05-0.32119E+07-0.55061E+07
    0.00000E+00 0.00000E+00 0.54193E+05 0.32119E+07-0.55061E+07

12  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

13  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

14  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

15  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

16  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

17  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

18  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07.

19  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

20  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

21  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

22  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
    0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
```

```
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

 23  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

 24  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

 25  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

 26  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

 27  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

 28  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

 29  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

 30  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

 31  0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07 0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05-0.41951E+07-0.62926E+07
     0.00000E+00 0.00000E+00 0.61935E+05 0.41951E+07-0.62926E+07

 32  0.00000E+00 0.00000E+00 0.30968E+05 0.10488E+07 0.31463E+07
     0.00000E+00 0.00000E+00 0.30968E+05-0.10488E+07 0.31463E+07
     0.00000E+00 0.00000E+00 0.30968E+05-0.10488E+07-0.31463E+07
     0.00000E+00 0.00000E+00 0.30968E+05 0.10488E+07-0.31463E+07

 33  0.00000E+00 0.00000E+00 0.30968E+05 0.10488E+07 0.31463E+07
     0.00000E+00 0.00000E+00 0.30968E+05-0.10488E+07 0.31463E+07
     0.00000E+00 0.00000E+00 0.30968E+05-0.10488E+07-0.31463E+07
     0.00000E+00 0.00000E+00 0.30968E+05 0.10488E+07-0.31463E+07

 34  0.00000E+00 0.00000E+00 0.30968E+05 0.10488E+07 0.31463E+07
     0.00000E+00 0.00000E+00 0.30968E+05-0.10488E+07 0.31463E+07
     0.00000E+00 0.00000E+00 0.30968E+05-0.10488E+07-0.31463E+07
     0.00000E+00 0.00000E+00 0.30968E+05 0.10488E+07-0.31463E+07

 35  0.00000E+00 0.00000E+00 0.30968E+05 0.10488E+07 0.31463E+07
     0.00000E+00 0.00000E+00 0.30968E+05-0.10488E+07 0.31463E+07
     0.00000E+00 0.00000E+00 0.30968E+05-0.10488E+07-0.31463E+07
     0.00000E+00 0.00000E+00 0.30968E+05 0.10488E+07-0.31463E+07
```

36	0.00000E+00	0.00000E+00	0.90322E+04	0.53531E+06	0.15295E+06
	0.00000E+00	0.00000E+00	0.90322E+04	-0.53531E+06	0.15295E+06
	0.00000E+00	0.00000E+00	0.90322E+04	-0.53531E+06	-0.15295E+06
	0.00000E+00	0.00000E+00	0.90322E+04	0.53531E+06	-0.15295E+06
37	0.00000E+00	0.00000E+00	0.10323E+05	0.69918E+06	0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	-0.69918E+06	0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	-0.69918E+06	-0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	0.69918E+06	-0.17479E+06
38	0.00000E+00	0.00000E+00	0.10323E+05	0.69918E+06	0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	-0.69918E+06	0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	-0.69918E+06	-0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	0.69918E+06	-0.17479E+06
39	0.00000E+00	0.00000E+00	0.10323E+05	0.69918E+06	0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	-0.69918E+06	0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	-0.69918E+06	-0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	0.69918E+06	-0.17479E+06
40	0.00000E+00	0.00000E+00	0.10323E+05	0.69918E+06	0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	-0.69918E+06	0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	-0.69918E+06	-0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	0.69918E+06	-0.17479E+06
41	0.00000E+00	0.00000E+00	0.10323E+05	0.69918E+06	0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	-0.69918E+06	0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	-0.69918E+06	-0.17479E+06
	0.00000E+00	0.00000E+00	0.10323E+05	0.69918E+06	-0.17479E+06
42	0.00000E+00	0.00000E+00	0.51613E+04	0.17480E+06	0.87397E+05
	0.00000E+00	0.00000E+00	0.51613E+04	-0.17480E+06	0.87397E+05
	0.00000E+00	0.00000E+00	0.51613E+04	-0.17480E+06	-0.87397E+05
	0.00000E+00	0.00000E+00	0.51613E+04	0.17480E+06	-0.87397E+05

****

E L A S T I C D E F O R M A T I O N

****

NODE	X (mm)	Y (mm)	Z (mm)	RY	RX
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1976E-02
2	0.1922E-16	0.1925E-16	0.3998E+00	-.5992E-05	0.1950E-02
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1973E-02
4	0.1980E-16	0.1189E-17	0.3992E+00	0.1948E-05	0.1948E-02
7	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1981E-02
8	0.2194E-16	0.7990E-18	0.4008E+00	0.5659E-05	0.1956E-02
9	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.1993E-02
10	0.1712E-16	0.4895E-17	0.4034E+00	0.6570E-05	0.1969E-02
11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2006E-02
12	0.1220E-16	0.8682E-17	0.4059E+00	0.5661E-05	0.1982E-02
13	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2015E-02
14	0.6486E-17	0.1154E-16	0.4078E+00	0.3637E-05	0.1991E-02
15	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2020E-02
16	0.1997E-17	0.1272E-16	0.4088E+00	0.5787E-06	0.1996E-02
19	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2020E-02
20	0.0000E+00	0.1648E-16	0.4088E+00	0.0000E+00	0.1996E-02
22	0.8805E-16	0.2505E-16	0.1507E+01	-.1481E-04	0.1630E-02
23	0.1278E-15	-.2377E-16	0.2354E+01	0.1330E-04	0.1146E-02
24	0.1223E-15	-.1316E-15	0.2922E+01	0.7691E-04	0.7548E-03

25	-.2029E-16	-.3437E-15	0.3324E+01	0.1439E-03	0.6174E-03
27	0.8639E-16	0.1197E-17	0.1507E+01	0.1244E-04	0.1639E-02
28	0.1301E-15	-.1877E-16	0.2365E+01	0.4208E-04	0.1171E-02
29	0.1272E-15	-.7264E-16	0.2952E+01	0.9076E-04	0.7872E-03
30	-.8864E-17	-.1582E-15	0.3374E+01	0.1404E-03	0.6412E-03
37	0.8052E-16	0.3964E-17	0.1515E+01	0.2551E-04	0.1653E-02
38	0.1232E-15	0.1511E-16	0.2385E+01	0.5405E-04	0.1196E-02
39	0.9503E-16	0.2003E-16	0.2989E+01	0.9104E-04	0.8184E-03
40	0.1008E-16	0.1218E-15	0.3429E+01	0.1297E-03	0.6690E-03
42	0.7150E-16	0.2407E-16	0.1526E+01	0.2759E-04	0.1669E-02
43	0.1039E-15	0.6004E-16	0.2407E+01	0.5221E-04	0.1216E-02
44	0.6842E-16	0.1005E-15	0.3025E+01	0.8014E-04	0.8408E-03
45	0.1765E-16	0.1661E-15	0.3478E+01	0.1095E-03	0.6919E-03
47	0.5576E-16	0.4386E-16	0.1537E+01	0.2311E-04	0.1682E-02
48	0.7912E-16	0.1027E-15	0.2426E+01	0.4188E-04	0.1232E-02
49	0.5844E-16	0.1590E-15	0.3054E+01	0.6179E-04	0.8572E-03
50	0.1762E-16	0.1775E-15	0.3517E+01	0.8250E-04	0.7092E-03
52	0.3383E-16	0.5859E-16	0.1544E+01	0.1470E-04	0.1692E-02
53	0.5184E-16	0.1335E-15	0.2440E+01	0.2644E-04	0.1242E-02
54	0.4655E-16	0.2105E-15	0.3074E+01	0.3877E-04	0.8680E-03
55	0.1876E-16	0.3333E-15	0.3545E+01	0.5148E-04	0.7207E-03
57	0.6337E-17	0.6663E-16	0.1548E+01	0.4040E-05	0.1697E-02
58	0.2042E-16	0.1478E-15	0.2447E+01	0.8145E-05	0.1248E-02
59	0.2493E-16	0.2483E-15	0.3085E+01	0.1275E-04	0.8740E-03
60	0.1782E-16	0.3938E-15	0.3559E+01	0.1923E-04	0.7273E-03
67	0.0000E+00	0.6083E-16	0.1549E+01	0.0000E+00	0.1698E-02
68	0.0000E+00	0.1528E-15	0.2448E+01	0.0000E+00	0.1248E-02
69	0.0000E+00	0.2504E-15	0.3086E+01	0.0000E+00	0.8749E-03
70	0.0000E+00	0.3813E-15	0.3561E+01	0.0000E+00	0.7278E-03
72	-.7028E-16	-.3730E-15	0.3387E+01	0.1501E-03	0.6224E-03
74	-.5863E-16	-.1728E-15	0.3439E+01	0.1466E-03	0.6413E-03
78	-.4173E-16	0.1353E-15	0.3497E+01	0.1357E-03	0.6697E-03
80	0.2097E-16	0.1880E-15	0.3548E+01	0.1144E-03	0.6930E-03
82	-.1029E-16	0.1788E-15	0.3589E+01	0.8611E-04	0.7105E-03
84	-.1965E-16	0.3319E-15	0.3618E+01	0.5375E-04	0.7222E-03
86	0.1550E-16	0.4100E-15	0.3633E+01	0.2023E-04	0.7290E-03
90	0.0000E+00	0.4221E-15	0.3635E+01	0.0000E+00	0.7293E-03
91	0.0000E+00	0.0000E+00	0.1121E+00	0.1378E+00	0.2043E-02
92	0.0000E+00	0.0000E+00	0.3194E+00	0.1378E+00	0.2033E-02
93	0.0000E+00	0.0000E+00	0.1113E+00	0.1381E+00	0.2051E-02
94	0.0000E+00	0.0000E+00	0.3194E+00	0.1381E+00	0.2041E-02
95	0.0000E+00	0.0000E+00	0.1113E+00	0.1389E+00	0.2068E-02
96	0.0000E+00	0.0000E+00	0.3211E+00	0.1389E+00	0.2058E-02
97	0.0000E+00	0.0000E+00	0.1117E+00	0.1400E+00	0.2087E-02
98	0.0000E+00	0.0000E+00	0.3234E+00	0.1400E+00	0.2077E-02
99	0.0000E+00	0.0000E+00	0.1123E+00	0.1411E+00	0.2103E-02
100	0.0000E+00	0.0000E+00	0.3256E+00	0.1411E+00	0.2093E-02
101	0.0000E+00	0.0000E+00	0.1127E+00	0.1419E+00	0.2115E-02
102	0.0000E+00	0.0000E+00	0.3273E+00	0.1419E+00	0.2105E-02
103	0.0000E+00	0.0000E+00	0.1129E+00	0.1423E+00	0.2121E-02
104	0.0000E+00	0.0000E+00	0.3281E+00	0.1423E+00	0.2111E-02
106	0.0000E+00	0.0000E+00	0.1464E+01	0.1378E+00	0.1626E-02
107	0.0000E+00	0.0000E+00	0.2193E+01	0.1378E+00	0.6834E-03
108	0.0000E+00	0.0000E+00	0.2226E+01	0.1378E+00	-.6121E-03
109	0.0000E+00	0.0000E+00	0.1532E+01	0.1378E+00	-.1489E-02
111	0.0000E+00	0.0000E+00	0.1470E+01	0.1381E+00	0.1637E-02
112	0.0000E+00	0.0000E+00	0.2207E+01	0.1381E+00	0.6965E-03
113	0.0000E+00	0.0000E+00	0.2245E+01	0.1381E+00	-.6056E-03
114	0.0000E+00	0.0000E+00	0.1553E+01	0.1381E+00	-.1492E-02
116	0.0000E+00	0.0000E+00	0.1482E+01	0.1389E+00	0.1654E-02
117	0.0000E+00	0.0000E+00	0.2228E+01	0.1389E+00	0.7097E-03
118	0.0000E+00	0.0000E+00	0.2272E+01	0.1389E+00	-.6040E-03
119	0.0000E+00	0.0000E+00	0.1576E+01	0.1389E+00	-.1501E-02
121	0.0000E+00	0.0000E+00	0.1495E+01	0.1400E+00	0.1671E-02
122	0.0000E+00	0.0000E+00	0.2250E+01	0.1400E+00	0.7208E-03
123	0.0000E+00	0.0000E+00	0.2297E+01	0.1400E+00	-.6052E-03
124	0.0000E+00	0.0000E+00	0.1598E+01	0.1400E+00	-.1512E-02

126	0.0000E+00	0.0000E+00	0.1507E+01	0.1411E+00	0.1686E-02
127	0.0000E+00	0.0000E+00	0.2269E+01	0.1411E+00	0.7296E-03
128	0.0000E+00	0.0000E+00	0.2319E+01	0.1411E+00	-.6071E-03
129	0.0000E+00	0.0000E+00	0.1615E+01	0.1411E+00	-.1523E-02
131	0.0000E+00	0.0000E+00	0.1515E+01	0.1419E+00	0.1696E-02
132	0.0000E+00	0.0000E+00	0.2283E+01	0.1419E+00	0.7356E-03
133	0.0000E+00	0.0000E+00	0.2334E+01	0.1419E+00	-.6089E-03
134	0.0000E+00	0.0000E+00	0.1627E+01	0.1419E+00	-.1531E-02
136	0.0000E+00	0.0000E+00	0.1520E+01	0.1423E+00	0.1701E-02
137	0.0000E+00	0.0000E+00	0.2290E+01	0.1423E+00	0.7387E-03
138	0.0000E+00	0.0000E+00	0.2342E+01	0.1423E+00	-.6096E-03
139	0.0000E+00	0.0000E+00	0.1633E+01	0.1423E+00	-.1535E-02
141	0.0000E+00	0.0000E+00	0.1456E+01	0.1378E+00	-.1504E-02
143	0.0000E+00	0.0000E+00	0.1477E+01	0.1381E+00	-.1507E-02
145	0.0000E+00	0.0000E+00	0.1500E+01	0.1389E+00	-.1516E-02
147	0.0000E+00	0.0000E+00	0.1520E+01	0.1400E+00	-.1528E-02
149	0.0000E+00	0.0000E+00	0.1537E+01	0.1411E+00	-.1539E-02
151	0.0000E+00	0.0000E+00	0.1548E+01	0.1419E+00	-.1547E-02
153	0.0000E+00	0.0000E+00	0.1554E+01	0.1423E+00	-.1550E-02
226	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
227	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
233	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
234	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
235	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
236	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
237	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
240	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
241	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
247	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
248	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
249	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
250	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
251	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

****

T I E F O R C E S (kN)

****

ELEMENT	FORCE	LIMIT
85	0.24117E-01	0.00000E+00
86	0.12825E-01	0.00000E+00
87	0.48353E-01	0.00000E+00
88	0.20889E+00	0.00000E+00
89	0.53747E+00	0.00000E+00
90	0.23937E-01	0.00000E+00
91	0.11146E-01	0.00000E+00
92	0.47463E-01	0.00000E+00
93	0.21198E+00	0.00000E+00
94	0.54639E+00	0.00000E+00
95	0.23919E-01	0.00000E+00
96	0.10021E-01	0.00000E+00
97	0.47073E-01	0.00000E+00
98	0.21528E+00	0.00000E+00
99	0.55588E+00	0.00000E+00
100	0.23993E-01	0.00000E+00
101	0.93611E-02	0.00000E+00
102	0.47011E-01	0.00000E+00
103	0.21815E+00	0.00000E+00
104	0.56419E+00	0.00000E+00
105	0.24094E-01	0.00000E+00
106	0.89683E-02	0.00000E+00
107	0.47074E-01	0.00000E+00
108	0.22043E+00	0.00000E+00
109	0.57080E+00	0.00000E+00
110	0.24180E-01	0.00000E+00
111	0.87343E-02	0.00000E+00

112	0.47151E-01	0.00000E+00
113	0.22203E+00	0.00000E+00
114	0.57539E+00	0.00000E+00
115	0.24212E-01	0.00000E+00
116	0.85978E-02	0.00000E+00
117	0.47179E-01	0.00000E+00
118	0.22286E+00	0.00000E+00
119	0.57781E+00	0.00000E+00

M A X I M U M T I E F O R C E
Tie No. 119 has the maximum force of 0.57781E+00 kN

****

S T E E L S T U D E N D F O R C E S
(Beginning & End)

****

ELEMENT	FORCE (kN)	TWISTING MOMENT (kN.m)	BENDING MOMENT (kN.m)
43	-0.11997E+00	-0.13803E-14	-0.25606E-14
	0.11997E+00	-0.53278E-09	-0.12189E-01
44	-0.11910E+00	-0.13880E-14	-0.11136E-14
	0.11910E+00	-0.52895E-09	-0.12101E-01
45	-0.11911E+00	-0.14011E-14	0.65829E-15
	0.11910E+00	-0.52896E-09	-0.12101E-01
46	-0.11956E+00	-0.14018E-14	-0.25928E-14
	0.11956E+00	-0.53098E-09	-0.12147E-01
47	-0.12012E+00	-0.14116E-14	-0.11395E-14
	0.12012E+00	-0.53345E-09	-0.12204E-01
48	-0.12056E+00	-0.14187E-14	0.92010E-15
	0.12056E+00	-0.53543E-09	-0.12249E-01
49	-0.12077E+00	-0.14218E-14	-0.13035E-14
	0.12077E+00	-0.53633E-09	-0.12270E-01
50	-0.95848E-01	0.53278E-09	0.12189E-01
	0.95848E-01	-0.30868E-08	-0.70618E-01
51	-0.83023E-01	0.30868E-08	0.70618E-01
	0.83023E-01	-0.52991E-08	-0.12123E+00
52	-0.34670E-01	0.52991E-08	0.12123E+00
	0.34671E-01	-0.62229E-08	-0.14236E+00
53	0.17422E+00	0.62229E-08	0.14236E+00
	-0.17422E+00	-0.15806E-08	-0.36159E-01
54	-0.95165E-01	0.52895E-09	0.12101E-01
	0.95165E-01	-0.30647E-08	-0.70113E-01
55	-0.84019E-01	0.30647E-08	0.70113E-01
	0.84019E-01	-0.53035E-08	-0.12133E+00
56	-0.36555E-01	0.53035E-08	0.12133E+00
	0.36556E-01	-0.62776E-08	-0.14362E+00
57	0.17543E+00	0.62776E-08	0.14362E+00
	-0.17543E+00	-0.16031E-08	-0.36674E-01
58	-0.95185E-01	0.52896E-09	0.12101E-01
	0.95185E-01	-0.30653E-08	-0.70126E-01
59	-0.85164E-01	0.30653E-08	0.70126E-01
	0.85164E-01	-0.53346E-08	-0.12204E+00
60	-0.38091E-01	0.53346E-08	0.12204E+00
	0.38091E-01	-0.63496E-08	-0.14526E+00
61	0.17719E+00	0.63496E-08	0.14526E+00
	-0.17719E+00	-0.16281E-08	-0.37246E-01
62	-0.95566E-01	0.53098E-09	0.12147E-01
	0.95566E-01	-0.30775E-08	-0.70404E-01
63	-0.86205E-01	0.30775E-08	0.70404E-01
	0.86205E-01	-0.53745E-08	-0.12295E+00
64	-0.39194E-01	0.53745E-08	0.12295E+00
	0.39194E-01	-0.64189E-08	-0.14685E+00
65	0.17895E+00	0.64189E-08	0.14685E+00
	-0.17895E+00	-0.16504E-08	-0.37757E-01
66	-0.96021E-01	0.53345E-09	0.12204E-01
	0.96021E-01	-0.30921E-08	-0.70738E-01

67	-0.87052E-01	0.30921E-08	0.70738E-01
	0.87052E-01	-0.54117E-08	-0.12381E+00
68	-0.39978E-01	0.54117E-08	0.12381E+00
	0.39978E-01	-0.64770E-08	-0.14818E+00
69	0.18046E+00	0.64770E-08	0.14818E+00
	-0.18046E+00	-0.16684E-08	-0.38170E-01
70	-0.96382E-01	0.53543E-09	0.12249E-01
	0.96382E-01	-0.31037E-08	-0.71004E-01
71	-0.87648E-01	0.31037E-08	0.71004E-01
	0.87648E-01	-0.54392E-08	-0.12443E+00
72	-0.40497E-01	0.54392E-08	0.12443E+00
	0.40498E-01	-0.65183E-08	-0.14912E+00
73	0.18154E+00	0.65183E-08	0.14912E+00
	-0.18154E+00	-0.16810E-08	-0.38458E-01
74	-0.96553E-01	0.53633E-09	0.12270E-01
	0.96553E-01	-0.31091E-08	-0.71129E-01
75	-0.87955E-01	0.31091E-08	0.71129E-01
	0.87955E-01	-0.54528E-08	-0.12475E+00
76	-0.40777E-01	0.54528E-08	0.12475E+00
	0.40777E-01	-0.65394E-08	-0.14960E+00
77	0.18208E+00	0.65394E-08	0.14960E+00
	-0.18208E+00	-0.16876E-08	-0.38608E-01
78	0.71169E+00	0.15806E-08	0.36159E-01
	-0.71189E+00	-0.13754E-14	-0.14638E-12
79	0.72181E+00	0.16031E-08	0.36674E-01
	-0.72202E+00	-0.13668E-14	-0.49519E-13
80	0.73308E+00	0.16281E-08	0.37246E-01
	-0.73329E+00	-0.13925E-14	0.58003E-14
81	0.74314E+00	0.16504E-08	0.37757E-01
	-0.74335E+00	-0.14246E-14	0.92083E-13
82	0.75125E+00	0.16684E-08	0.38170E-01
	-0.75147E+00	-0.14049E-14	-0.20125E-12
83	0.75693E+00	0.16810E-08	0.38458E-01
	-0.75715E+00	-0.14254E-14	0.30103E-13
84	0.75989E+00	0.16876E-08	0.38608E-01
	-0.76011E+00	-0.14342E-14	-0.10037E-14

****

N O D A L S T R E S S E S F O R M A S O N R Y (MPa)
E X T E R I O R & I N T E R I O R L A Y E R S

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Node No.	SIG-XX (Ext.) (Interior)	SIG-YY (Ext.) (Interior)	TAU-XY (Ext.) (Interior)
1	-0.339903E-02	-0.522635E-01	-0.183337E-01
	0.339903E-02	0.522635E-01	0.183337E-01
2	-0.152885E-01	-0.269439E+00	-0.138207E-01
	0.152885E-01	0.269439E+00	0.138207E-01
3	-0.620302E-02	-0.510770E-01	0.708052E-02
	0.620302E-02	0.510770E-01	-0.708052E-02
4	-0.309824E-01	-0.264931E+00	0.896065E-02
	0.309824E-01	0.264931E+00	-0.896065E-02
5	-0.865257E-02	-0.505288E-01	0.238721E-01
	0.865257E-02	0.505288E-01	-0.238721E-01
6	-0.450467E-01	-0.263493E+00	0.246346E-01
	0.450467E-01	0.263493E+00	-0.246346E-01
7	-0.101941E-01	-0.505544E-01	0.278535E-01
	0.101941E-01	0.505544E-01	-0.278535E-01
8	-0.533197E-01	-0.262243E+00	0.283407E-01
	0.533197E-01	0.262243E+00	-0.283407E-01
9	-0.111199E-01	-0.504908E-01	0.241144E-01
	0.111199E-01	0.504908E-01	-0.241144E-01
10	-0.584422E-01	-0.261982E+00	0.242254E-01
	0.584422E-01	0.261982E+00	-0.242254E-01

11	-0.117232E-01	-0.505444E-01	0.155075E-01
	0.117232E-01	0.505444E-01	-0.155075E-01
12	-0.616771E-01	-0.262117E+00	0.155010E-01
	0.616771E-01	0.262117E+00	-0.155010E-01
13	-0.114380E-01	-0.502916E-01	0.394387E-02
	0.114380E-01	0.502916E-01	-0.394387E-02
14	-0.605657E-01	-0.261182E+00	0.469242E-02
	0.605657E-01	0.261182E+00	-0.469242E-02
15	-0.111507E-01	-0.502071E-01	0.719631E-03
	0.111507E-01	0.502071E-01	-0.719631E-03
16	-0.588933E-01	-0.260413E+00	0.843850E-03
	0.588933E-01	0.260413E+00	-0.843850E-03
17	-0.256749E-01	-0.669302E+00	0.159552E-01
	0.256749E-01	0.669302E+00	-0.159552E-01
18	-0.275943E-01	-0.719974E+00	0.658548E-01
	0.275943E-01	0.719974E+00	-0.658548E-01
19	-0.220725E-01	-0.423103E+00	0.929700E-01
	0.220725E-01	0.423103E+00	-0.929700E-01
20	-0.620618E-02	-0.983726E-02	0.680408E-01
	0.620618E-02	0.983726E-02	-0.680408E-01
21	-0.694574E-01	-0.655632E+00	0.269117E-01
	0.694574E-01	0.655632E+00	-0.269117E-01
22	-0.780907E-01	-0.706788E+00	0.578715E-01
	0.780907E-01	0.706788E+00	-0.578715E-01
23	-0.612643E-01	-0.426897E+00	0.744078E-01
	0.612643E-01	0.426897E+00	-0.744078E-01
24	-0.240631E-01	-0.504660E-01	0.617789E-01
	0.240631E-01	0.504660E-01	-0.617789E-01
25	-0.110748E+00	-0.647337E+00	0.333994E-01
	0.110748E+00	0.647337E+00	-0.333994E-01
26	-0.129586E+00	-0.699921E+00	0.477954E-01
	0.129586E+00	0.699921E+00	-0.477954E-01
27	-0.105008E+00	-0.432303E+00	0.556476E-01
	0.105008E+00	0.432303E+00	-0.556476E-01
28	-0.585030E-01	-0.600172E-01	0.548690E-01
	0.585030E-01	0.600172E-01	-0.548690E-01
29	-0.135307E+00	-0.644311E+00	0.321178E-01
	0.135307E+00	0.644311E+00	-0.321178E-01
30	-0.161766E+00	-0.698226E+00	0.379033E-01
	0.161766E+00	0.698226E+00	-0.379033E-01
31	-0.134603E+00	-0.435631E+00	0.411187E-01
	0.134603E+00	0.435631E+00	-0.411187E-01
32	-0.849881E-01	-0.618031E-01	0.428238E-01
	0.849881E-01	0.618031E-01	-0.428238E-01
33	-0.150343E+00	-0.643849E+00	0.256611E-01
	0.150343E+00	0.643849E+00	-0.256611E-01
34	-0.181771E+00	-0.698746E+00	0.277448E-01
	0.181771E+00	0.698746E+00	-0.277448E-01
35	-0.153629E+00	-0.437536E+00	0.289379E-01
	0.153629E+00	0.437536E+00	-0.289379E-01
36	-0.102128E+00	-0.620080E-01	0.304624E-01
	0.102128E+00	0.620080E-01	-0.304624E-01
37	-0.159413E+00	-0.644073E+00	0.162034E-01
	0.159413E+00	0.644073E+00	-0.162034E-01
38	-0.193749E+00	-0.699563E+00	0.172003E-01
	0.193749E+00	0.699563E+00	-0.172003E-01
39	-0.164931E+00	-0.438701E+00	0.178217E-01
	0.164931E+00	0.438701E+00	-0.178217E-01
40	-0.111075E+00	-0.616331E-01	0.189570E-01
	0.111075E+00	0.616331E-01	-0.189570E-01
41	-0.158849E+00	-0.643329E+00	0.599856E-02
	0.158849E+00	0.643329E+00	-0.599856E-02
42	-0.194544E+00	-0.699148E+00	0.677156E-02
	0.194544E+00	0.699148E+00	-0.677156E-02
43	-0.168104E+00	-0.438424E+00	0.848706E-02
	0.168104E+00	0.438424E+00	-0.848706E-02
44	-0.111794E+00	-0.604705E-01	0.846735E-02

	0.111794E+00	0.604705E-01	-0.846735E-02
45	-0.154500E+00	-0.642464E+00	0.115774E-02
	0.154500E+00	0.642464E+00	-0.115774E-02
46	-0.192229E+00	-0.698708E+00	0.137069E-02
	0.192229E+00	0.698708E+00	-0.137069E-02
47	-0.172424E+00	-0.437880E+00	0.255369E-02
	0.172424E+00	0.437880E+00	-0.255369E-02
48	-0.147471E+00	-0.692235E-01	0.771302E-03
	0.147471E+00	0.692235E-01	-0.771302E-03
49	-0.129111E-01	0.131420E-01	0.466365E-01
	0.129111E-01	-0.131420E-01	-0.466365E-01
50	-0.134047E-01	0.172972E-02	0.539242E-01
	0.134047E-01	-0.172972E-02	-0.539242E-01
51	-0.536196E-01	-0.112589E-02	0.562180E-01
	0.536196E-01	0.112589E-02	-0.562180E-01
52	-0.792470E-01	-0.121750E-02	0.438071E-01
	0.792470E-01	0.121750E-02	-0.438071E-01
53	-0.959338E-01	-0.114518E-02	0.311590E-01
	0.959338E-01	0.114518E-02	-0.311590E-01
54	-0.103989E+00	-0.977934E-03	0.196250E-01
	0.103989E+00	0.977934E-03	-0.196250E-01
55	-0.108360E+00	-0.684770E-03	0.726103E-02
	0.108360E+00	0.684770E-03	-0.726103E-02
56	-0.139047E+00	-0.308683E-02	-0.172666E-02
	0.139047E+00	0.308683E-02	0.172666E-02

****
T Y P E O F F A I L U R E
****

HORIZONTAL CRACK

ELEMENT OF MAX. STRESS = 9
INTEGRATION POINT = 4
CRACKING LOAD = 0.14388E+01 kPa

Case 1-B

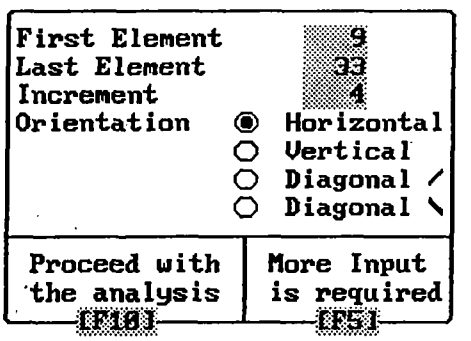
Introduction

Case 1-B is the same design example described in Case 1-A but instead of generating the crack one step at a time, the crack is manually forced across the width of the masonry wall. The objective of this case study is to demonstrate how to expedite the analysis by manually forcing a crack pattern that is part of the wall. Although the steps to generate the finite element mesh, the boundary conditions and the member properties are not shown, the same input as in Case 1-A is still required. From the DATA CHECK menu, the user can then generate the mesh and merge the regions. The analysis is then performed as explained in the next section.

Manually generate a crack

Before proceeding with the generation of the crack, the user must first initiate the first crack by selecting 1st CRACK from the ANALYSIS menu. After the completion of this step, the user needs to select CRACK PATTERN key and thus invoke Screen-1 shown below.

Screen-1



The user must enter the appropriate element numbers and the orientation of the crack before selecting [F10]. This analysis is expected to yield results similar to the ones obtained in Case 1-A. The difference between the two types of analyses is in the interpretation of the crack; for Case 1-A, the crack occurs only on the exterior face (tension zone) whereas for Case 1-B, the whole element is assumed to have cracked.

Results & Discussion

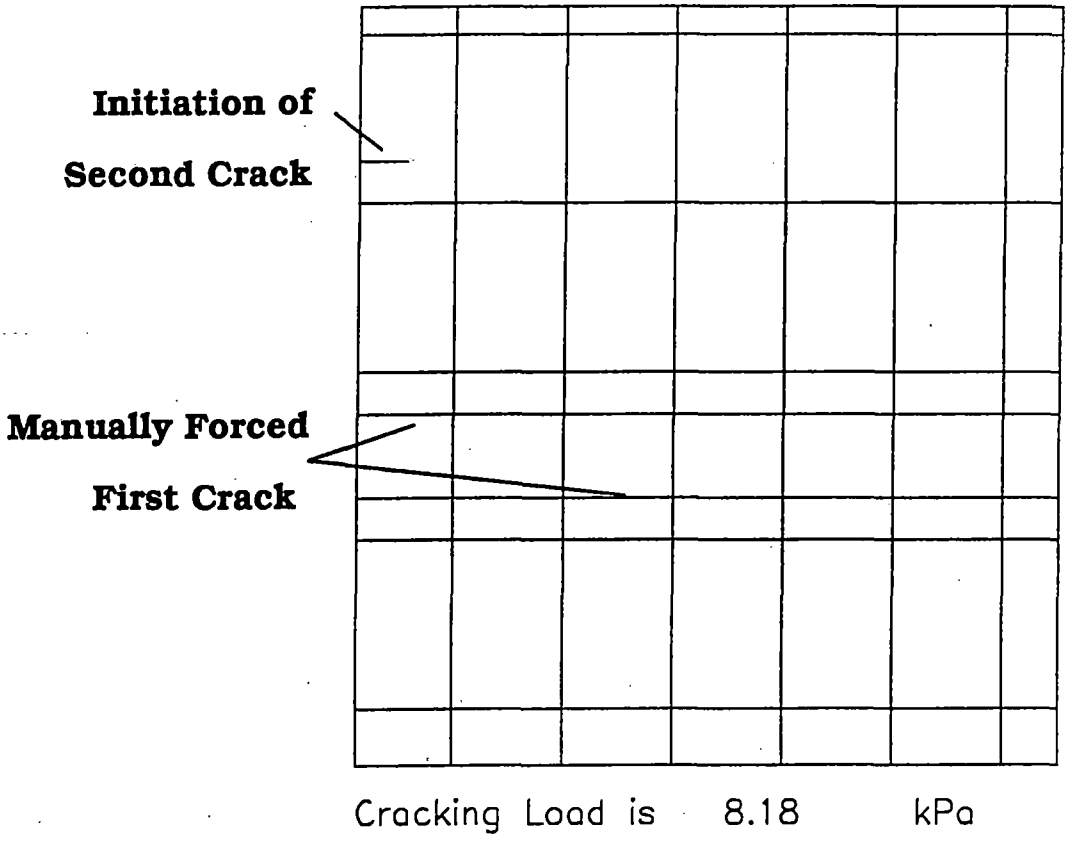
Once the analysis is complete, the results can be seen using the PLOT MENU. For the load that initiates the second crack, the results in the form of crack pattern and cracking load are displayed in Figure C1-8. Table IV gives the maximum stud shear force and bending moment, and the maximum tie force at the initiation of the first and second crack. Naturally, before propagation of the first crack, the results are identical. By comparing the results given in Table III and IV, one can conclude that

the results for initiation and propagation of the second crack after manually forcing the first crack are in good agreement with the step by step procedure. However, it should be noted that, although the location of the second crack is similar to the one obtained from Case 1-A, the initiation of the second is not identical, see Figure C1-8.

Table IV Summary of the maximum stud and tie forces at the initiation of the first crack and second crack.

	At the initiation of the first crack (1.44 kPa)	At the initiation of the second crack (8.18 kPa)
Maximum Stud Bending (kN m)	0.15	2.72
Maximum Stud Shear Force (kN)	0.76	4.34
Maximum Tie Force (kN)	0.58	2.57
Tie Number	119	117

Figure C1-8 Location of a manually forced first crack and location and load for initiation of second crack.



Case 2-A

Problem Description

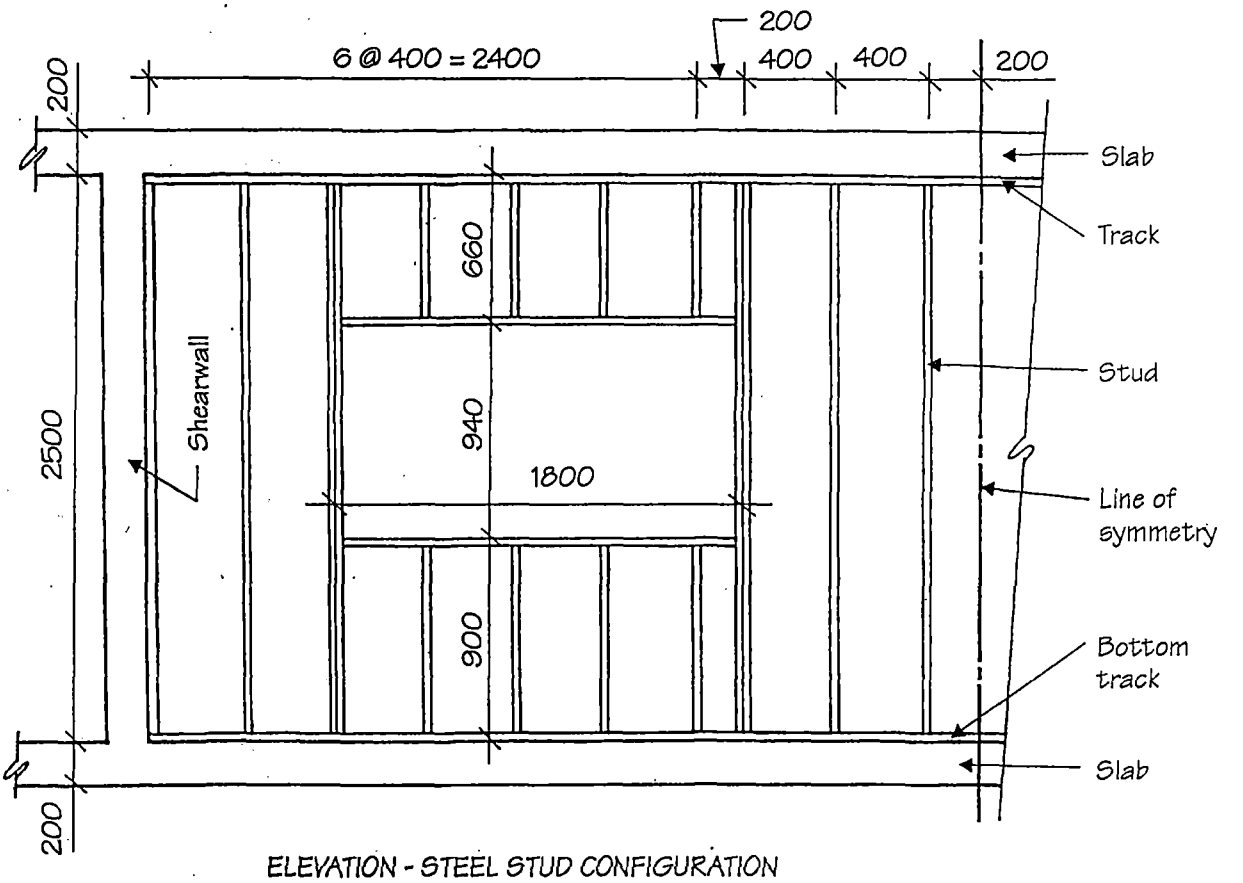
The MVSS wall shown in Figs. C2-1 and C2-2 is analyzed in the second case study. The brick veneer is 7.2 m long, 2.7 m high and 90 mm thick. The backup wall is made up of 92 mm studs that are 0.4 m apart. There are two 1.8 m long by 0.94 m high windows located on the left and right hand sides of the wall.

Case 2-A represents a MVSS wall that was investigated and found to be missing some of its steel ties. The jamb studs were also found not connected together. Since the wall is assumed to be symmetric, only half of the geometry is needed for the analysis. The properties used for the analysis are given in Table V. The procedure to generate the finite element model and perform the analysis is outlined next.

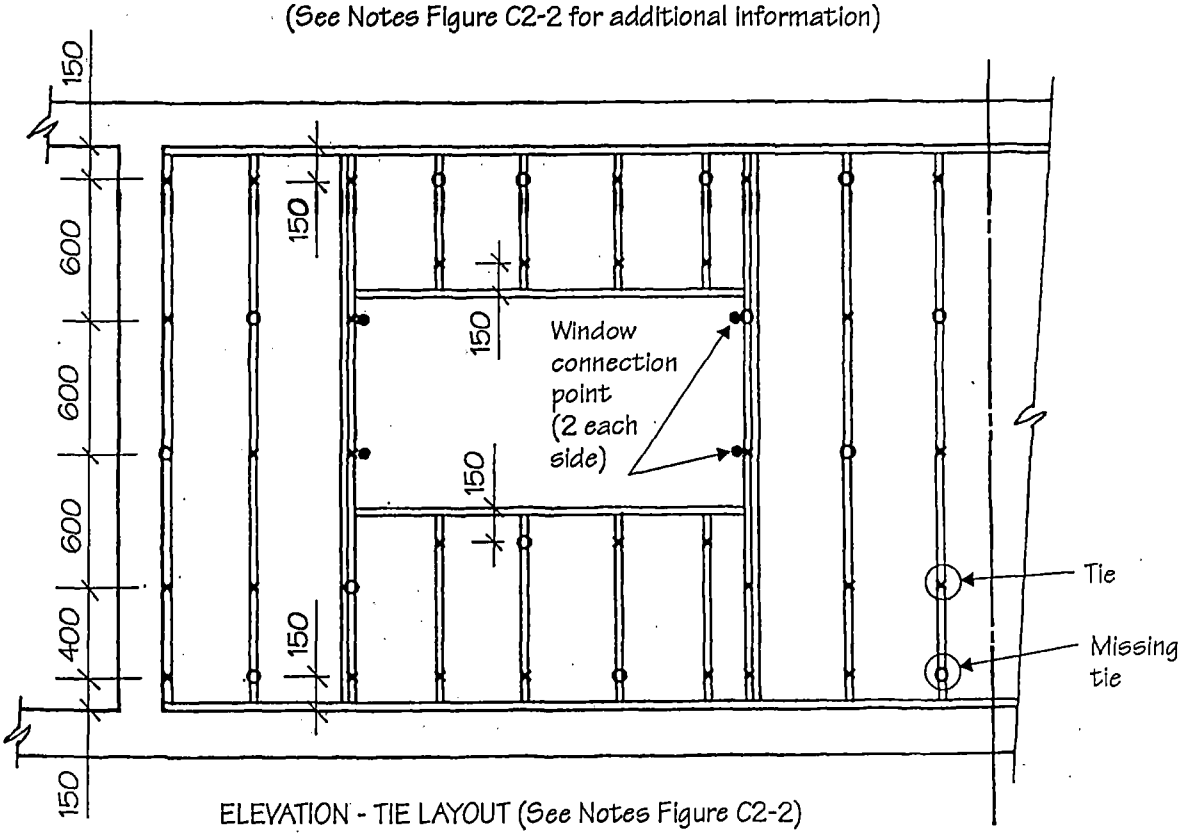
Table V Geometrical and mechanical properties for case study 2.

Masonry Veneer	Modulus of Elasticity, Ep	28 000 MPa
	Modulus of Elasticity, En	20315 MPa
	Poisson's Ratio	0.2
	Modulus of Rigidity, Gxy	9663 MPa
	Density, ρ	2000 kg / m^3
	Tensile strength normal to bed joints	0.25 MPa
	Tensile strength parallel to bed joint	0.50 MPa
Steel Stud Backup Wall	Modulus of Elasticity, E	203 000 MPa
	Shear Modulus, G	78 000 MPa
	Poisson's Ratio	0.3
	Moment of Inertia, I	234 000 mm^4/stud
	St. Venant Constant, J	49.1 mm^4/stud
Steel Tie	Axial stiffness	274 N/mm
	Ultimate strength	1090 N
Bottom Track	Shear stiffness of bottom stud to track connection	555 N/mm
Top Track	Shear stiffness of top stud to track connection	245 N/mm
Window	Modulus of Elasticity, E	200 000 MPa
	Poisson's Ratio	0.2
	Modulus of Rigidity, Gxy	83333 MPa
	Tensile strength normal to bed joints	100 MPa
	Tensile strength parallel to bed joint	100 MPa

Figure C2-1 This sketch illustrates the as-built conditions of the MVSS wall used for case study 2-A.

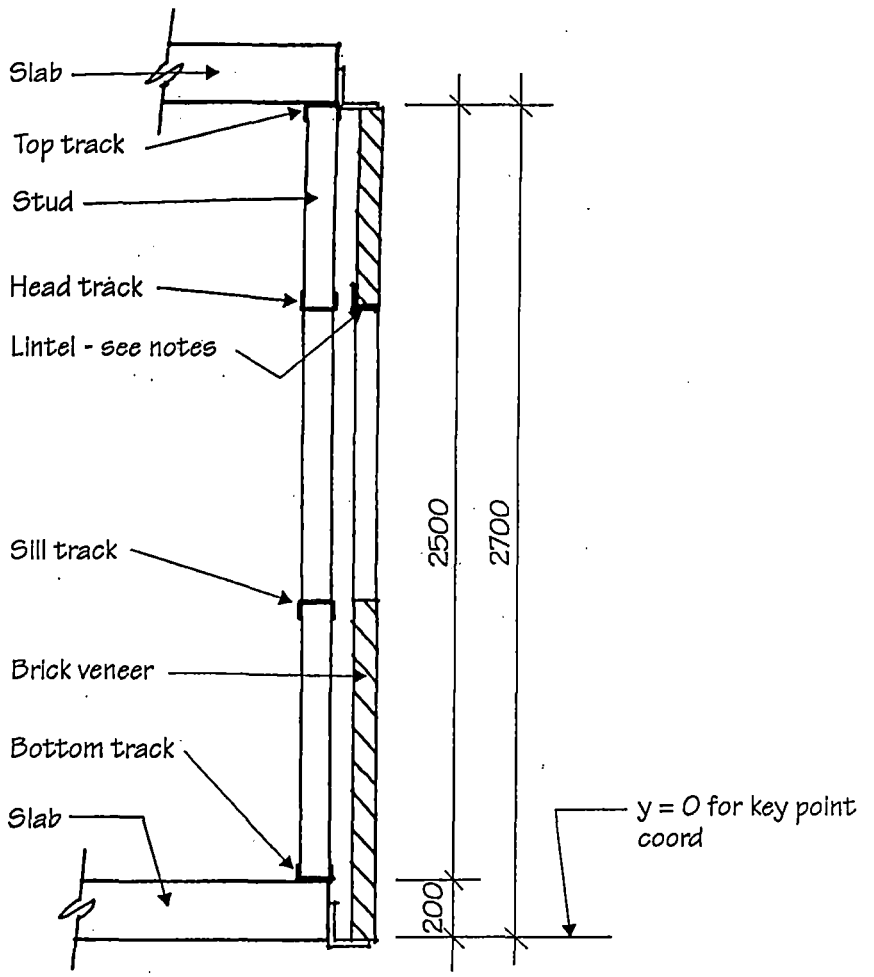


ELEVATION - STEEL STUD CONFIGURATION
(See Notes Figure C2-2 for additional information)



ELEVATION - TIE LAYOUT (See Notes Figure C2-2)

Figure C2-2 Section views of MVSS wall used for case study 2-A.



SECTION - STUD AND BRICK VENEER

NOTES FOR FIGURES C2-1 AND C2-2

1. Studs - 92 mm x 0.91 (3-5/8" x 20 gauge)
   Top and bottom track - 92 mm x 0.91 (3-5/8" x 20 gauge)
2. Top track - 12 mm end gap screwed both sides
   Bottom track - minimum end gap screwed both sides
3. Jamb studs are not connected together. Brick ties are connected to the inner jamb stud only. The outer jamb stud is inactive structurally.
4. The strength and stiffness of the loose angle lintel is ignored in the finite element analysis.
5. The last stud adjacent to the shearwall is anchored to the shearwall. There is no connection between the brick veneer and the shearwall.
6. The sill and head track are assumed to have the same section properties as the stud.

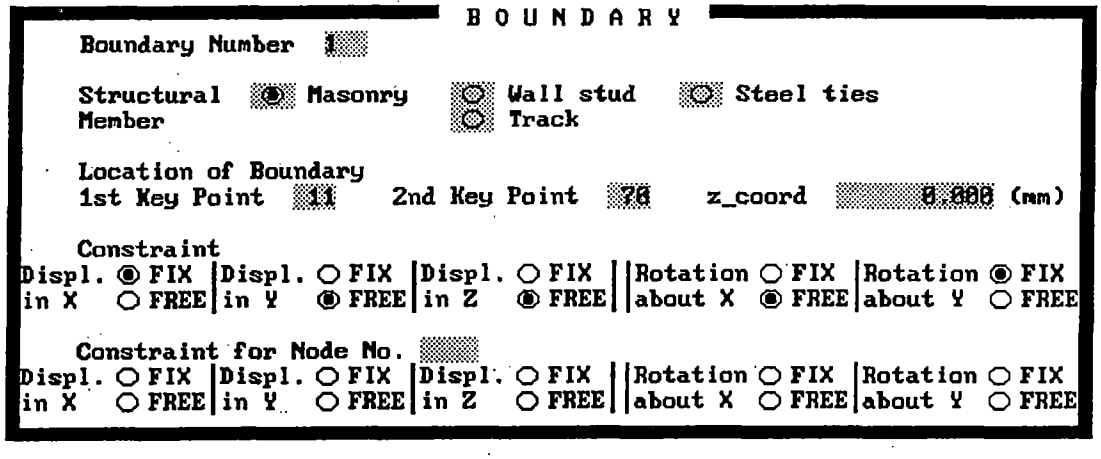
Define Geometry

Before proceeding with any entry, the user is again encouraged to sketch the geometry of the wall system in order to ensure compatibility of node locations between the brick veneer and the backup wall. To avoid excessive reproduction of screens, the geometric input for each region is given in Tables VI and VII. The user should note that the actual entry is similar to Case 1-A.

Define the Boundary Conditions

The brick veneer will have two boundary conditions, the first one is for the base where it is simply supported and the second one is for the right hand side where a symmetric deformation needs to be imposed. Because the tracks are modeled as springs, two boundary conditions (considered to be fixed) are needed to constrain the free end of the spring. Moreover, the steel stud located at the left hand side needs to be constrained to represent attachment to a concrete shear wall. The input for all the boundary conditions is shown below:

Screen-1



The user must enter or select [F10] to save input before defining the next boundary number. This boundary is along the line of symmetry of the masonry wall.

Table VI **Summary of the region number, material set number, member type, area and number of elements used to define the geometry of Case 2-A.**

Region No.	Material Set No.	Structural Member	Area				No of Elements between 1st and 2nd KP	No of Elements between 2nd and 3rd KP
			1st Key Point	2nd Key Point	3rd Key Point	4th Key Point		
1	1	Masonry	1	2	3	4	2	1
2	1	Masonry	2	5	6	3	4	1
3	1	Masonry	5	7	8	6	1	1
4	1	Masonry	7	9	10	8	2	1
5	1	Masonry	9	11	12	10	1	1
6	1	Masonry	4	3	14	13	2	1
7	1	Masonry	3	6	15	14	4	1
8	1	Masonry	6	8	16	15	1	1
9	1	Masonry	8	10	17	16	2	1
10	1	Masonry	10	12	18	17	1	1
11	1	Masonry	13	14	20	19	2	1
12	1	Masonry	14	15	21	20	4	1
13	1	Masonry	15	16	22	21	1	1
14	1	Masonry	16	17	23	22	2	1
15	1	Masonry	17	18	24	23	1	1
16	1	Masonry	19	20	26	25	2	1
17	1	Masonry	20	21	27	26	4	1
18	1	Masonry	21	22	28	27	1	1
19	1	Masonry	22	23	29	28	2	1
20	1	Masonry	23	24	30	29	1	1
21	1	Masonry	25	26	32	31	2	1
22	1	Masonry	26	27	33	32	4	1
23	1	Masonry	27	28	34	33	1	1
24	1	Masonry	28	29	35	34	2	1
25	1	Masonry	29	30	36	35	1	1
26	1	Masonry	31	32	38	37	2	1
27	1	Masonry	34	35	40	39	2	1
28	1	Masonry	35	36	41	40	1	1
29	1	Masonry	37	38	43	42	2	1
30	1	Masonry	39	40	45	44	2	1
31	1	Masonry	40	41	46	45	1	1
32	1	Masonry	42	43	48	47	2	1
33	1	Masonry	44	45	50	49	2	1
34	1	Masonry	45	46	51	50	1	1
35	1	Masonry	47	48	53	52	2	1
36	1	Masonry	48	55	54	53	4	1
37	1	Masonry	55	49	56	54	1	1
38	1	Masonry	49	50	57	56	2	1
39	1	Masonry	50	51	58	57	1	1

Table VI Continued

Region No.	Material Set No.	Structural Member	Area				No of Elements between 1st and 2nd KP	No of Elements between 2nd and 3rd KP
			1st Key Point	2nd Key Point	3rd Key Point	4th Key Point		
40	1	Masonry	52	53	60	59	2	1
41	1	Masonry	53	54	61	60	4	1
42	2	Masonry	197	198	199	200	1	1
43	1	Masonry	56	57	63	62	2	1
44	1	Masonry	57	58	64	63	1	1
45	1	Masonry	59	60	66	65	2	1
46	1	Masonry	60	61	67	66	4	1
47	1	Masonry	61	62	68	67	1	1
48	1	Masonry	62	63	69	68	2	1
49	1	Masonry	63	64	70	69	1	1
50	1	Vert. S.S.	71	72	79	78	1	1
51	1	Vert. S.S.	73	74	81	80	4	1
52	1	Vert. S.S.	75	77	83	82	2	1
53	1	Vert. S.S.	78	79	85	84	1	1
54	1	Vert. S.S.	80	81	87	86	4	1
55	1	Vert. S.S.	82	83	89	88	2	1
56	1	Vert. S.S.	84	85	91	90	1	1
57	1	Vert. S.S.	86	87	93	92	4	1
58	1	Vert. S.S.	88	89	95	94	2	1
59	1	Vert. S.S.	90	91	97	96	1	1
60	1	Vert. S.S.	92	93	99	98	4	1
61	1	Vert. S.S.	94	95	101	100	2	1
62	1	Vert. S.S.	96	98	104	102	2	1
63	1	Vert. S.S.	100	101	106	105	2	1
64	1	Vert. S.S.	102	104	108	107	2	1
65	1	Vert. S.S.	105	106	110	109	2	1
66	1	Vert. S.S.	107	108	113	111	2	1
67	1	Vert. S.S.	109	110	115	114	2	1
68	1	Vert. S.S.	111	112	117	116	1	1
69	1	Vert. S.S.	113	120	121	118	4	1
70	1	Vert. S.S.	114	115	122	119	2	1
71	1	Vert. S.S.	116	117	124	123	1	1
72	1	Vert. S.S.	118	121	126	125	4	1
73	1	Vert. S.S.	119	122	128	127	2	1
74	1	Vert. S.S.	123	124	130	129	1	1
75	1	Vert. S.S.	125	126	132	131	4	1
76	1	Vert. S.S.	127	128	134	133	2	1
77	1	Hor. S.S.	98	99	120	113	4	1
78	1	Hor. S.S.	99	100	114	120	1	1
79	1	Vert. S.S.	73	75	133	131	1	1
80	1	Bot. Track	71	72	136	135	1	1
81	1	Bot. Track	73	74	138	137	4	1

Table VI Continued

Region No.	Material Set No.	Structural Member	Area				No of Elements between 1st and 2nd KP	No of Elements between 2nd and 3rd KP
			1st Key Point	2nd Key Point	3rd Key Point	4th Key Point		
82	1	Bot. Track	75	77	140	139	2	1
83	1	Top Track	129	130	142	141	1	1
84	1	Top Track	131	132	144	143	4	1
85	1	Top Track	133	134	146	145	2	1
86	2	Steel Ties	104	105	195	196	1	1
87	1	Steel Ties	13	78	84	19	0	1
88	1	Steel Ties	14	147	148	80	2	0
89	1	Steel Ties	82	149	150	22	1	1
90	1	Steel Ties	159	89	128	124	1	1
91	1	Steel Ties	107	108	60	123	1	1
92	1	Steel Ties	103	38	104	151	1	0
93	1	Steel Ties	39	40	106	105	1	0
94	1	Steel Ties	152	54	121	153	3	0
95	1	Steel Ties	160	62	127	161	1	0
96	1	Steel Ties	154	155	156	157	1	0
97	1	Steel Ties	158	81	93	27	0	1
98	1	Steel Ties	162	163	164	165	0	0
99	2	Masonry	200	199	195	196	1	1
100	2	Masonry	196	195	194	193	1	1

Table VII Summary of the region number, the key points and the location of the key points that are used to define the geometry of Case 2-A.

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
1			
1	0	0	0
2	800	0	90
3	800	200	0
4	0	200	90
2			
2	800	0	90
5	2400	0	0
6	2400	200	0
3	800	200	0

Table VII Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
3			
5	2400	0	0
7	2600	0	90
8	2600	200	0
6	2400	200	0
4			
7	2600	0	90
9	3400	0	0
10	3400	200	0
8	2600	200	0
5			
9	3400	0	0
11	3600	0	90
12	3600	200	0
10	3400	200	0
6			
4	0	200	90
3	800	200	0
14	800	350	0
13	0	350	0
7			
3	800	200	0
6	2400	200	0
15	2400	350	90
14	800	350	0
8			
6	2400	200	0
8	2600	200	0
16	2600	350	90
15	2400	350	90
9			
8	2600	200	0
10	3400	200	0
17	3400	350	0
16	2600	350	90
10			
10	3400	200	0
12	3600	200	0
18	3600	350	90
17	3400	350	0

Table VII Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
11			
13	0	350	0
14	800	350	0
20	800	750	90
19	0	750	0
12			
14	800	350	0
15	2400	350	90
21	2400	750	0
20	800	750	90
13			
15	2400	350	90
16	2600	350	90
22	2600	750	0
21	2400	750	0
14			
16	2600	350	90
17	3400	350	0
23	3400	750	0
22	2600	750	0
15			
17	3400	350	0
18	3600	350	90
24	3600	750	90
23	3400	750	0
16			
19	0	750	0
20	800	750	90
26	800	950	90
25	0	950	0
17			
20	800	750	90
21	2400	750	0
27	2400	950	0
26	800	950	90
18			
21	2400	750	0
22	2600	750	0
28	2600	950	90
27	2400	950	0

Table VII Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
19			
22	2600	750	0
23	3400	750	0
29	3400	950	90
28	2600	950	90
20			
23	3400	750	0
24	3600	750	90
30	3600	950	0
29	3400	950	90
21			
25	0	950	0
26	800	950	90
32	800	1100	0
31	0	1100	90
22			
26	800	950	90
27	2400	950	0
33	2400	1100	90
32	800	1100	0
23			
27	2400	950	0
28	2600	950	90
34	2600	1100	90
33	2400	1100	90
24			
28	2600	950	90
29	3400	950	90
35	3400	1100	0
34	2600	1100	90
25			
29	3400	950	90
30	3600	950	0
36	3600	1100	90
35	3400	1100	0
26			
31	0	1100	90
32	800	1100	0
38	800	1350	0
37	0	1350	90

Table VII Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
27			
34	2600	1100	90
35	3400	1100	0
40	3400	1350	0
39	2600	1350	0
28			
35	3400	1100	0
36	3600	1100	90
41	3600	1350	0
40	3400	1350	0
29			
37	0	1350	90
38	800	1350	0
43	800	1950	0
42	0	1950	90
30			
39	2600	1350	0
40	3400	1350	0
45	3400	1950	0
44	2600	1950	90
31			
40	3400	1350	0
41	3600	1350	0
46	3600	1950	90
45	3400	1950	0
32			
42	0	1950	90
43	800	1950	0
48	800	2040	0
47	0	2040	90
33			
44	2600	1950	90
45	3400	1950	0
50	3400	2040	90
49	2600	2040	0
34			
45	3400	1950	0
46	3600	1950	90
51	3600	2040	90
50	3400	2040	90

Table VII Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
35			
47	0	2040	90
48	800	2040	0
53	800	2190	90
52	0	2190	90
36			
48	800	2040	0
55	2400	2040	90
54	2400	2190	0
53	800	2190	90
37			
55	2400	2040	90
49	2600	2040	0
56	2600	2190	0
54	2400	2190	0
38			
49	2600	2040	0
50	3400	2040	90
57	3400	2190	90
56	2600	2190	0
39			
50	3400	2040	90
51	3600	2040	90
58	3600	2190	0
57	3400	2190	90
40			
52	0	2190	90
53	800	2190	90
60	800	2550	0
59	0	2550	90
41			
53	800	2190	90
54	2400	2190	0
61	2400	2550	90
60	800	2550	0
42			
197	800	1100	250
198	2600	1100	250
199	2600	1350	340
200	800	1350	340

Table VII Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
43			
56	2600	2190	0
57	3400	2190	90
63	3400	2550	90
62	2600	2550	0
44			
57	3400	2190	90
58	3600	2190	0
64	3600	2550	90
63	3400	2550	90
45			
59	0	2550	90
60	800	2550	0
66	800	2700	0
65	0	2700	0
46			
60	800	2550	0
61	2400	2550	90
67	2400	2700	0
66	800	2700	0
47			
61	2400	2550	90
62	2600	2550	0
68	2600	2700	0
67	2400	2700	0
48			
62	2600	2550	0
63	3400	2550	90
69	3400	2700	0
68	2600	2700	0
49			
63	3400	2550	90
64	3600	2550	90
70	3600	2700	0
69	3400	2700	0
50			
71	0	200	600
72	400	200	600
79	400	350	600
78	0	350	600

Table VII Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
51			
73	800	200	600
74	2400	200	600
81	2400	350	600
80	800	350	600
52			
75	2600	200	600
77	3400	200	600
83	3400	350	600
82	2600	350	600
53			
78	0	350	600
79	400	350	600
85	400	750	600
84	0	750	600
54			
80	800	350	600
81	2400	350	600
87	2400	750	600
86	800	750	600
55			
82	2600	350	600
83	3400	350	600
89	3400	750	600
88	2600	750	600
56			
84	0	750	600
85	400	750	600
91	400	950	600
90	0	950	600
57			
86	800	750	600
87	2400	750	600
93	2400	950	600
92	800	950	600
58			
88	2600	750	600
89	3400	750	600
95	3400	950	600
94	2600	950	600

Table VII Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
59			
90	0	950	600
91	400	950	600
97	400	1100	600
96	0	1100	600
60			
92	800	950	600
93	2400	950	600
99	2400	1100	600
98	800	1100	600
61			
94	2600	950	600
95	3400	950	600
101	3400	1100	600
100	2600	1100	600
62			
96	0	1100	600
98	800	1100	600
104	800	1350	600
102	0	1350	600
63			
100	2600	1100	600
101	3400	1100	600
106	3400	1350	600
105	2600	1350	600
64			
102	0	1350	600
104	800	1350	600
108	800	1950	600
107	0	1950	600
65			
105	2600	1350	600
106	3400	1350	600
110	3400	1950	600
109	2600	1950	600
66			
107	0	1950	600
108	800	1950	600
113	800	2040	600
111	0	2040	600

Table VII Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
67			
109	2600	1950	600
110	3400	1950	600
115	3400	2040	600
114	2600	2040	600
68			
111	0	2040	600
112	400	2040	600
117	400	2190	600
116	0	2190	600
69			
113	800	2040	600
120	2400	2040	600
121	2400	2190	600
118	800	2190	600
70			
114	2600	2040	600
115	3400	2040	600
122	3400	2190	600
119	2600	2190	600
71			
116	0	2190	600
117	400	2190	600
124	400	2550	600
123	0	2550	600
72			
118	800	2190	600
121	2400	2190	600
126	2400	2550	600
125	800	2550	600
73			
119	2600	2190	600
122	3400	2190	600
128	3400	2550	600
127	2600	2550	600
74			
123	0	2550	600
124	400	2550	600
130	400	2700	600
129	0	2700	600

Table VII Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
75			
125	800	2550	600
126	2400	2550	600
132	2400	2700	600
131	800	2700	600
76			
127	2600	2550	600
128	3400	2550	600
134	3400	2700	600
133	2600	2700	600
77			
98	800	1100	600
99	2400	1100	600
120	2400	2040	600
113	800	2040	600
78			
99	2400	1100	600
100	2600	1100	600
114	2600	2040	600
120	2400	2040	600
79			
73	800	200	600
75	2600	200	600
133	2600	2700	600
131	800	2700	600
80			
71	0	200	600
72	400	200	600
136	400	200	1000
135	0	200	1000
81			
73	800	200	600
74	2400	200	600
138	2400	200	1000
137	800	200	1000
82			
75	2600	200	600
77	3400	200	600
140	3400	200	1000
139	2600	200	1000

Table VII Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
83			
129	0	2700	600
130	400	2700	600
142	400	2700	1000
141	0	2700	1000
84			
131	800	2700	600
132	2400	2700	600
144	2400	2700	1000
143	800	2700	1000
85			
133	2600	2700	600
134	3400	2700	600
146	3400	2700	1000
145	2600	2700	1000
86			
104	800	1350	600
105	2600	1350	600
195	2600	1950	250
196	800	1950	250
87			
13	0	350	0
78	0	350	600
84	0	750	600
19	0	750	0
88			
14	800	350	0
147	1600	350	0
148	1600	350	600
80	800	350	600
89			
82	2600	350	600
149	3000	350	600
150	3000	750	0
22	2600	750	0
90			
159	400	750	0
89	3400	750	600
128	3400	2550	600
124	400	2550	600

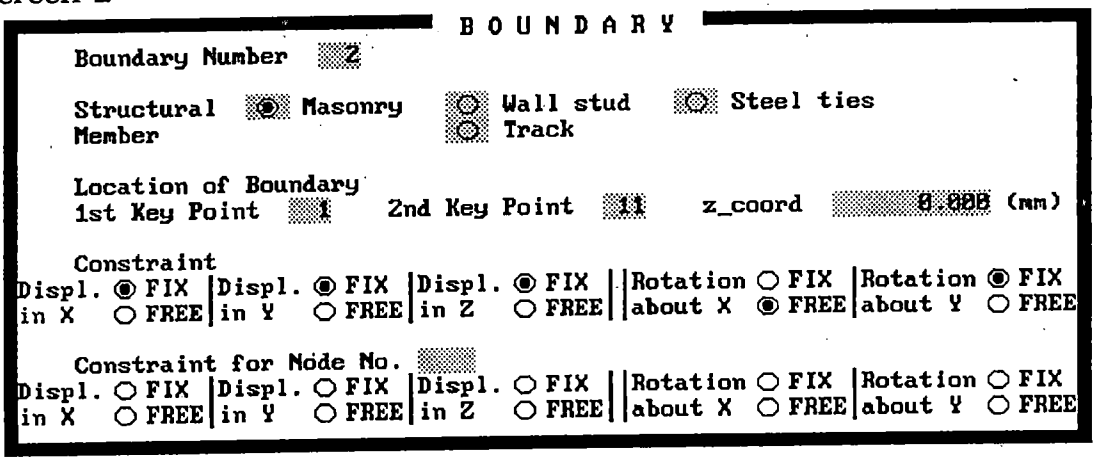
Table VII Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
91			
107	0	1950	600
108	800	1950	600
60	800	2550	0
123	0	2550	600
92			
103	400	1350	0
38	800	1350	0
104	800	1350	600
151	400	1350	600
93			
39	2600	1350	0
40	3400	1350	0
106	3400	1350	600
105	2600	1350	600
94			
152	1200	2190	0
54	2400	2190	0
121	2400	2190	600
153	1200	2190	600
95			
160	2000	2550	0
62	2600	2550	0
127	2600	2550	600
161	2000	2550	600
96			
154	1200	950	0
155	2000	950	0
156	2000	950	600
157	1200	950	600
97			
158	2400	350	0
81	2400	350	600
93	2400	950	600
27	2400	950	0
98			
162	3000	1950	0
163	3000	1950	600
164	3000	1950	600
165	3000	1950	0

Table VII Continued

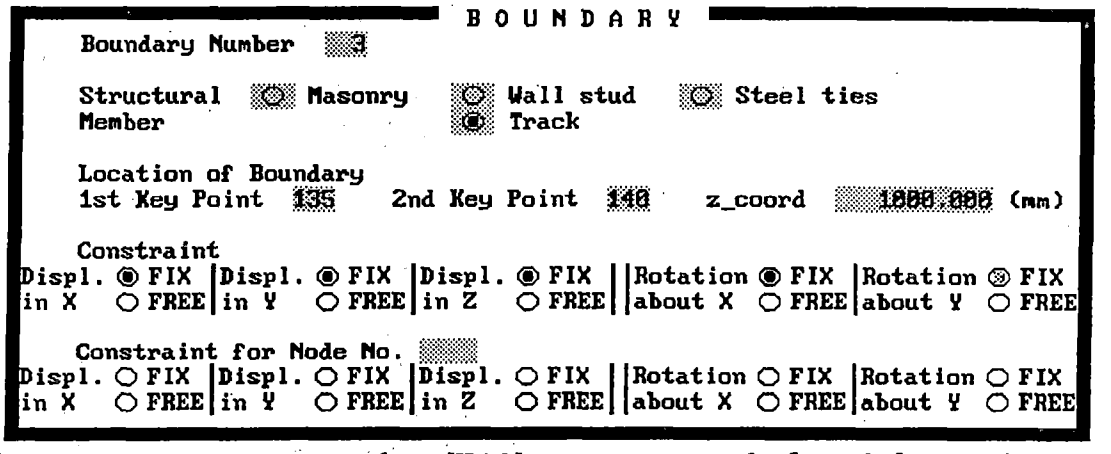
Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
99			
200	800	1350	340
199	2600	1350	340
195	2600	1950	250
196	800	1950	250
100			
196	800	1950	250
195	2600	1950	250
194	2600	2040	340
193	800	2040	340

Screen-2



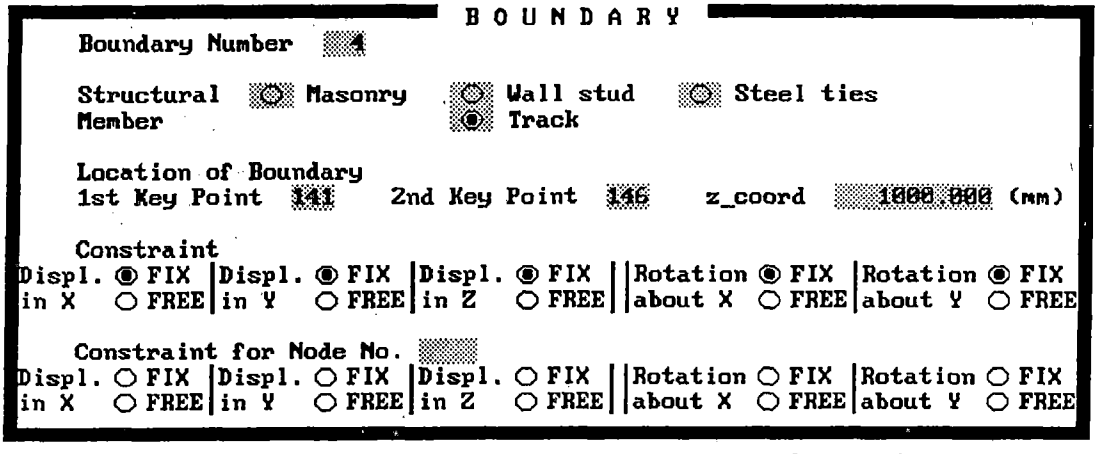
The user must enter or select [F10] to save input before defining the next boundary number. This boundary simulates the simply support base of the masonry wall.

Screen-3



The user must enter or select [F10] to save input before defining the next boundary number. This boundary is mainly to constrain the free end of the spring used to model the bottom track resistance.

Screen-4



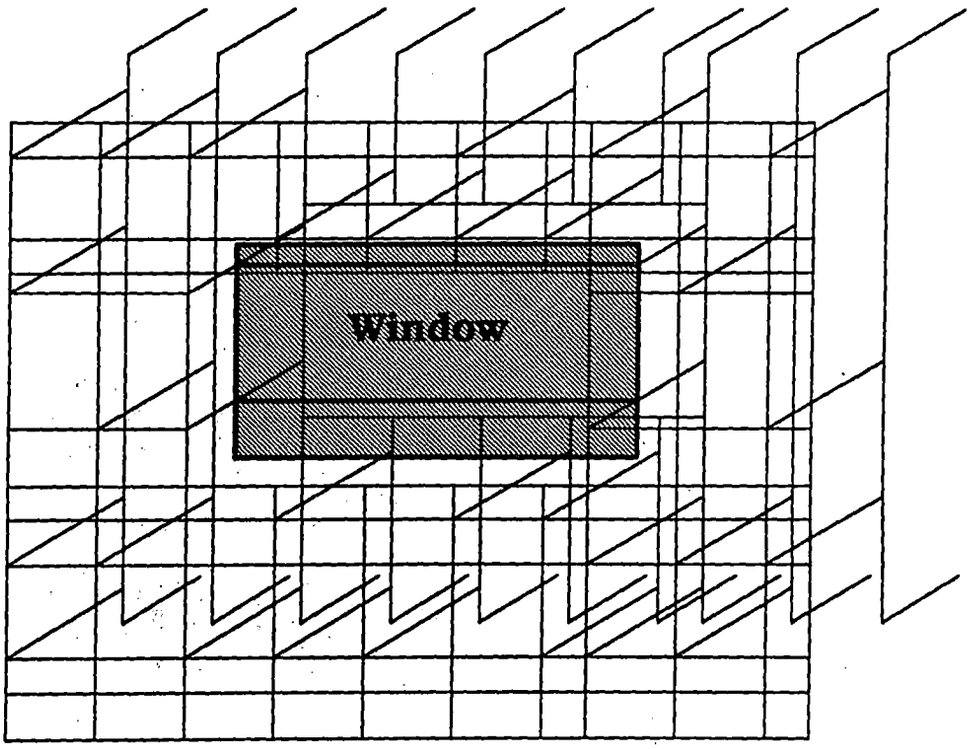
The user must enter or select [F10] to save input before defining the next boundary number. This boundary is mainly to constrain the free end of the spring used to model the top track resistance.

Screen-5

```
                              BOUNDARY

    Boundary Number  5

    Structural  ○ Masonry   ◉ Wall stud   ○ Steel ties
    Member                  ○ Track

    Location of Boundary
    1st Key Point  71    2nd Key Point  129    z_coord  600.000 (mm)

    Constraint
Displ. ◉ FIX |Displ. ◉ FIX |Displ. ◉ FIX ||Rotation ◉ FIX |Rotation ◉ FIX
in X   ○ FREE|in Y   ○ FREE|in Z   ○ FREE||about X ○ FREE|about Y ○ FREE

    Constraint for Node No.
Displ. ○ FIX |Displ. ○ FIX |Displ. ○ FIX ||Rotation ○ FIX |Rotation ○ FIX
in X   ○ FREE|in Y   ○ FREE|in Z   ○ FREE||about X ○ FREE|about Y ○ FREE
```

The user must enter or select [F10] to save input before defining the next boundary number. This boundary is for the steel stud that is joined to the concrete shear wall. At this point, the entry of the boundary conditions is complete. The user can select the Data Check menu to generate the mesh and then select the PLOT menu to display it. The boundary can be plotted by selecting the Boundary key from the PLOT menu. Figure C2-3 displays the generated mesh.

Figure C2-3 Finite Element Discretization of the MVSS wall used in Case 2-A.



Define the Member properties
The user needs to enter the member properties as defined in Table V.

Define the Applied Load
In this case, the load is applied to the masonry veneer and is invoked by selecting 100% load applied to the masonry from the Input Applied Load menu.

Perform Data Check
Before proceeding with the analysis, the user must generate and merge the mesh by selecting GENERATE and MERGE from the DATA CHECK menu.

Perform the Analysis
The analysis is performed by simply selecting 1st CRACK from the ANALYSIS menu and then NEXT CRACK to follow the propagation of the crack.

Results and Discussion
The results are given in Table VIII and the initiations of the first and second crack are displayed in Figs. C2-4 and C2-5. By examining the results of Table VIII, it appears that, for this particular MVSS wall, the share of the load carried by the backup wall does not increase dramatically even after the development of the first horizontal crack.

Table VIII Summary of the maximum stud and tie forces at the initiation of the first crack and second crack.

	At the initiation of the first crack (0.196 kPa)	At the initiation of the second crack (0.350 kPa)
Maximum Stud Bending (kN m)	0.05	0.17
Maximum Stud Twisting (kN m)	0.02	0.03
Maximum Stud Shear Force (kN)	0.16	0.27
Maximum Tie Force (kN)	0.17	0.37
Tie Number	234	238

Figure C2-4 Location and load for initiation of the first crack.

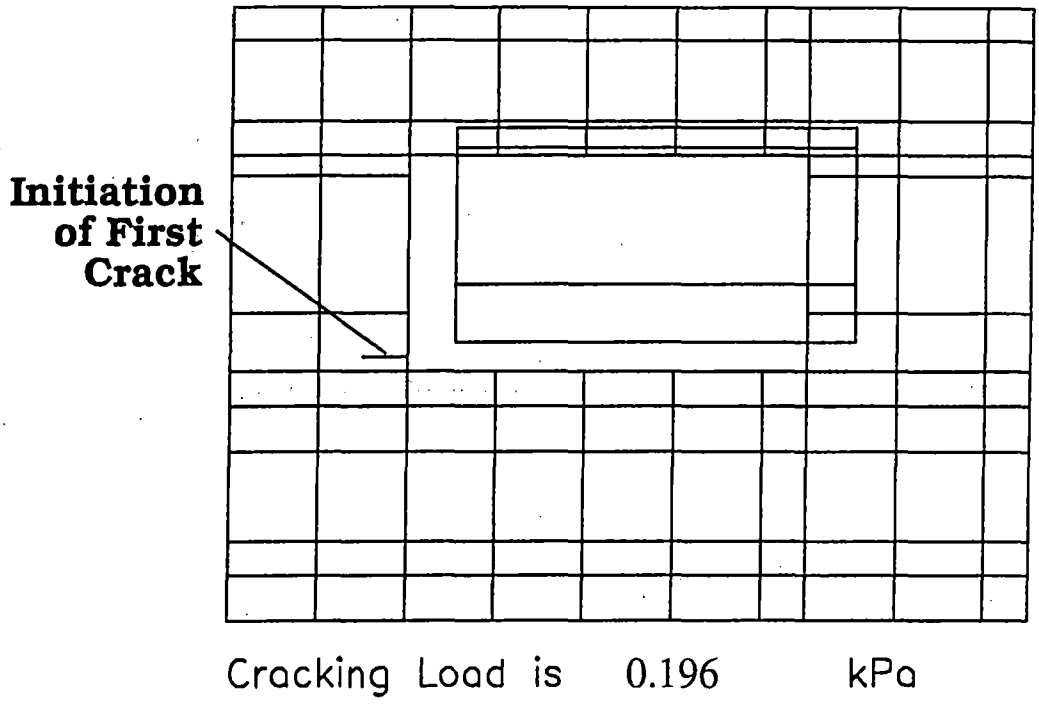
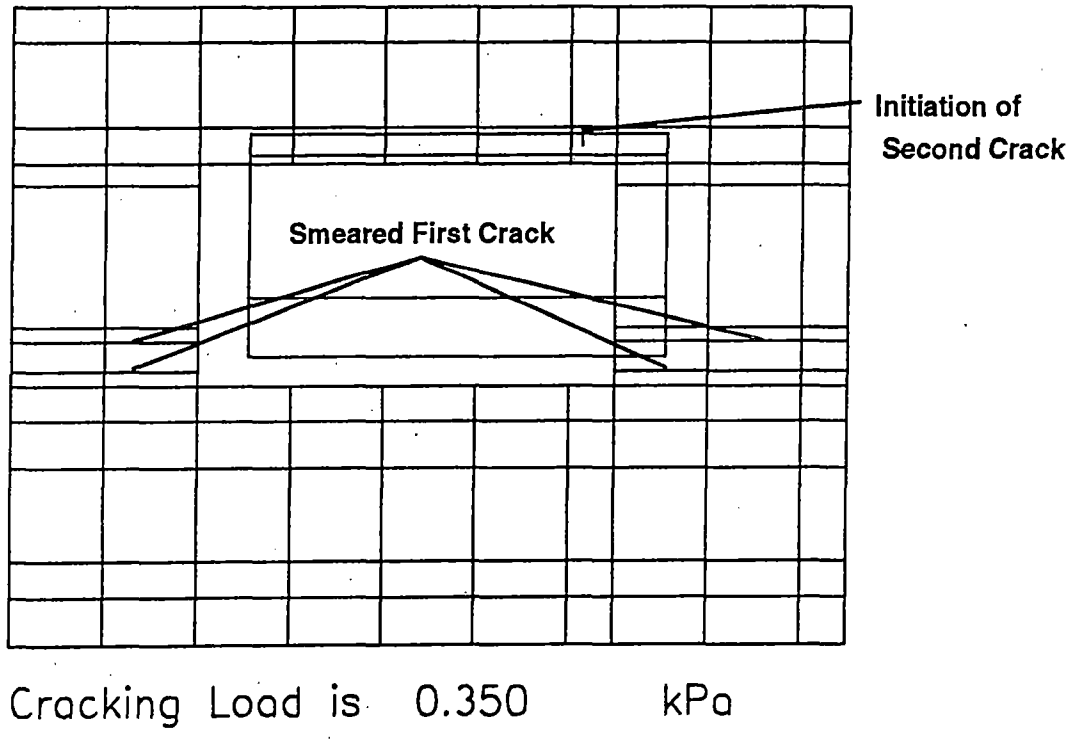


Figure C2-5 Location of First Crack and Location and Load for Initiation of the Second Crack.



Case 2-B

Problem Description

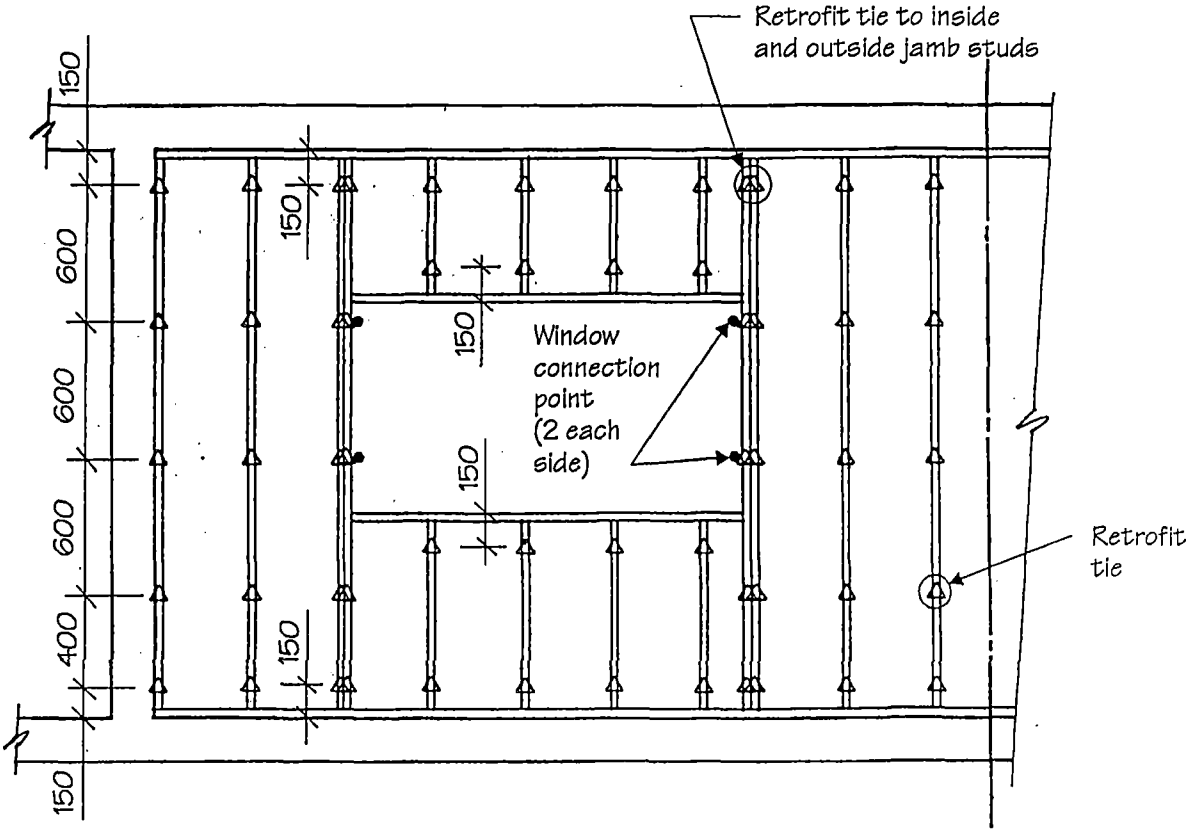
Case 2-B is similar to Case 2-A with the exception that the missing and existing steel ties have been replaced with new ones as shown in Fig. C2-6. The previously ineffective extra studs at the window jambs have been structurally joined to the framing studs to double the capacities of the jamb stud. Again the wall is assumed to be symmetric and, therefore, only half of the geometry is needed for the analysis. The properties used for the analysis are given in Table IX.

Table IX Geometrical and mechanical properties for case study 2-B.

Masonry Veneer	Modulus of Elasticity, Ep	28 000 MPa
	Modulus of Elasticity, En	20315 MPa
	Poisson's Ratio	0.2
	Modulus of Rigidity, G_{xy}	9663 MPa
	Density, ρ	2000 kg / m^3
	Tensile strength normal to bed joints	0.25 MPa
	Tensile strength parallel to bed joint	0.50 MPa
Steel Stud Backup Wall	Modulus of Elasticity, E	203 000 MPa
	Shear Modulus, G	78 000 MPa
	Poisson's Ratio	0.3
	Moment of Inertia, I	234 000 mm^4/stud
	St. Venant Constant, J	49.1 mm^4/stud
Steel Tie	Axial stiffness	376 N/mm
	Ultimate strength	1830 N
Bottom Track	Shear stiffness of bottom stud to track connection	555 N/mm
Top Track	Shear stiffness of top stud to track connection	245 N/mm
Window	Modulus of Elasticity, E	200 000 MPa
	Poisson's Ratio	0.2
	Modulus of Rigidity, G_{xy}	83333 MPa
	Tensile strength normal to bed joints	100 MPa
	Tensile strength parallel to bed joint	100 MPa

The procedure to generate the finite element model and perform the analysis is similar to Case 2-A. Figure C2-7 shows the finite element mesh generated for Case 2-B.

Figure C2-6 This sketch illustrates the retrofit condition of the MVSS wall used for case study 2-B.



ELEVATION - TIE LAYOUT (See also Figures C2-1 and C2-2)

NOTES FOR FIGURE C2-6

1. Retrofit ties have a stiffness of 376 N/mm and an ultimate strength of 1830 N.
2. The strength of original ties has been ignored in the finite element analysis.
3. Because the inside and the outside jamb studs are not inter-connected, retrofit ties are attached to both to insure they work together.

Figure C2-7 Finite Element Discretization of the MVSS wall used in Case 2-B.

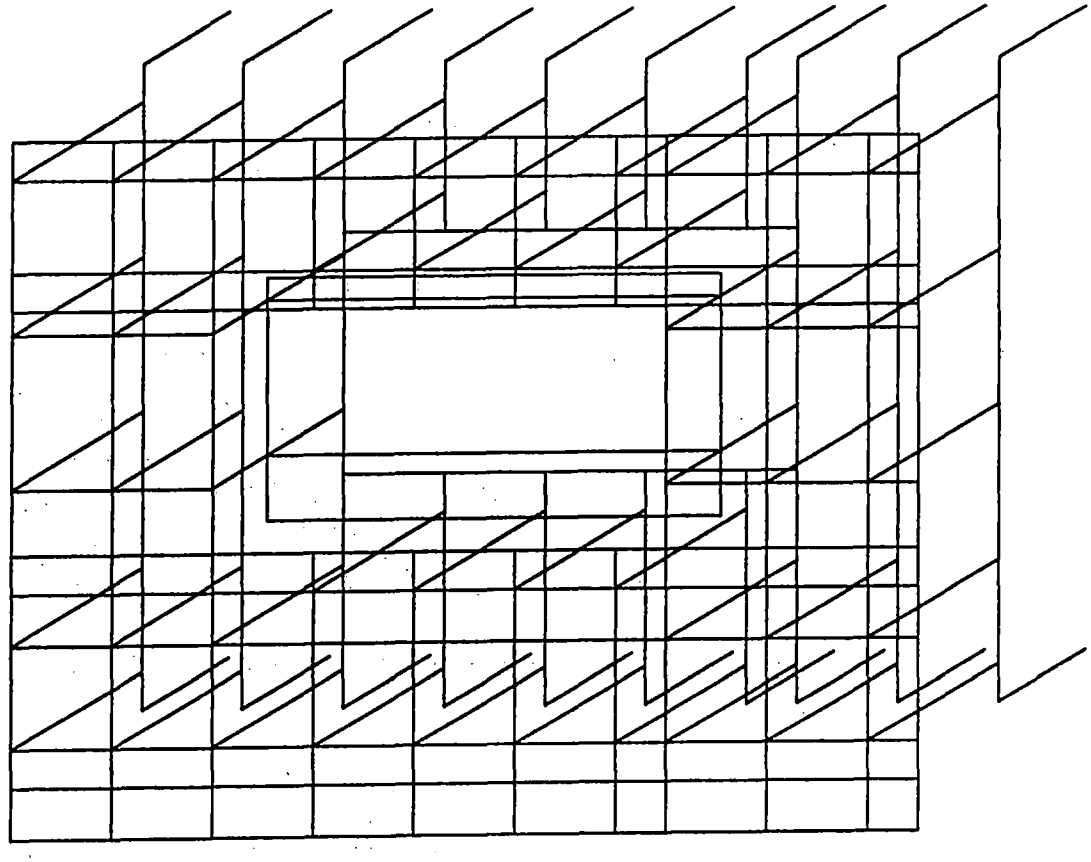


Table X **Summary of the region number, material set number, member type, area and number of elements used to define the geometry of Case 2-B.**

Region No.	Material Set No.	Structural Member	Area				No of Elements between 1st and 2nd KP	No of Elements between 2nd and 3rd KP
			1st Key Point	2nd Key Point	3rd Key Point	4th Key Point		
1	1	Masonry	1	2	3	4	2	1
2	1	Masonry	2	5	6	3	4	1
3	1	Masonry	5	7	8	6	1	1
4	1	Masonry	7	9	10	8	2	1
5	1	Masonry	9	11	12	10	1	1
6	1	Masonry	4	3	14	13	2	1
7	1	Masonry	3	6	15	14	4	1
8	1	Masonry	6	8	16	15	1	1
9	1	Masonry	8	10	17	16	2	1
10	1	Masonry	10	12	18	17	1	1
11	1	Masonry	13	14	20	19	2	1
12	1	Masonry	14	15	21	20	4	1
13	1	Masonry	15	16	22	21	1	1
14	1	Masonry	16	17	23	22	2	1
15	1	Masonry	17	18	24	23	1	1
16	1	Masonry	19	20	26	25	2	1
17	1	Masonry	20	21	27	26	4	1
18	1	Masonry	21	22	28	27	1	1
19	1	Masonry	22	23	29	28	2	1
20	1	Masonry	23	24	30	29	1	1
21	1	Masonry	25	26	32	31	2	1
22	1	Masonry	26	27	33	32	4	1
23	1	Masonry	27	28	34	33	1	1
24	1	Masonry	28	29	35	34	2	1
25	1	Masonry	29	30	36	35	1	1
26	1	Masonry	31	32	38	37	2	1
27	1	Masonry	34	35	40	39	2	1
28	1	Masonry	35	36	41	40	1	1
29	1	Masonry	37	38	43	42	2	1
30	1	Masonry	39	40	45	44	2	1
31	1	Masonry	40	41	46	45	1	1
32	1	Masonry	42	43	48	47	2	1
33	1	Masonry	44	45	50	49	2	1
34	1	Masonry	45	46	51	50	1	1
35	1	Masonry	47	48	53	52	2	1
36	1	Masonry	48	55	54	53	4	1
37	1	Masonry	55	49	56	54	1	1
38	1	Masonry	49	50	57	56	2	1
39	1	Masonry	50	51	58	57	1	1

Table X Continued

Region No.	Material Set No.	Structural Member	Area				No of Elements between 1st and 2nd KP	No of Elements between 2nd and 3rd KP
			1st Key Point	2nd Key Point	3rd Key Point	4th Key Point		
40	1	Masonry	52	53	60	59	2	1
41	1	Masonry	53	54	61	60	4	1
42	2	Masonry	197	198	199	200	1	1
43	1	Masonry	56	57	63	62	2	1
44	1	Masonry	57	58	64	63	1	1
45	1	Masonry	59	60	66	65	2	1
46	1	Masonry	60	61	67	66	4	1
47	1	Masonry	61	62	68	67	1	1
48	1	Masonry	62	63	69	68	2	1
49	1	Masonry	63	64	70	69	1	1
50	1	Vert. S.S.	71	72	79	78	1	1
51	1	Vert. S.S.	73	74	81	80	4	1
52	1	Vert. S.S.	75	77	83	82	2	1
53	1	Vert. S.S.	78	79	85	84	1	1
54	1	Vert. S.S.	80	81	87	86	4	1
55	1	Vert. S.S.	82	83	89	88	2	1
56	1	Vert. S.S.	84	85	91	90	1	1
57	1	Vert. S.S.	86	87	93	92	4	1
58	1	Vert. S.S.	88	89	95	94	2	1
59	1	Vert. S.S.	90	91	97	96	1	1
60	1	Vert. S.S.	92	93	99	98	4	1
61	1	Vert. S.S.	94	95	101	100	2	1
62	1	Vert. S.S.	96	98	104	102	2	1
63	1	Vert. S.S.	100	101	106	105	2	1
64	1	Vert. S.S.	102	104	108	107	2	1
65	1	Vert. S.S.	105	106	110	109	2	1
66	1	Vert. S.S.	107	108	113	111	2	1
67	1	Vert. S.S.	109	110	115	114	2	1
68	1	Vert. S.S.	111	112	117	116	1	1
69	1	Vert. S.S.	113	120	121	118	4	1
70	1	Vert. S.S.	114	115	122	119	2	1
71	1	Vert. S.S.	116	117	124	123	1	1
72	1	Vert. S.S.	118	121	126	125	4	1
73	1	Vert. S.S.	119	122	128	127	2	1
74	1	Vert. S.S.	123	124	130	129	1	1
75	1	Vert. S.S.	125	126	132	131	4	1
76	1	Vert. S.S.	127	128	134	133	2	1
77	1	Horiz. S.S.	98	99	120	113	4	1
78	1	Horiz. S.S.	99	100	114	120	1	1
79	1	Vert. S.S.	86	88	127	125	1	3
80	1	Bot, Track	71	72	136	135	1	1

Table X Continued

Region No.	Material Set No.	Structural Member	Area				No of Elements between 1st and 2nd KP	No of Elements between 2nd and 3rd KP
			1st Key Point	2nd Key Point	3rd Key Point	4th Key Point		
81	1	Bot, Track	73	74	138	137	4	1
82	1	Bot, Track	75	77	140	139	2	1
83	1	Top Track	129	130	142	141	1	1
84	1	Top Track	131	132	144	143	4	1
85	1	Top Track	133	134	146	145	2	1
86	2	Steel Ties	200	105	195	196	1	1
87	1	Steel Ties	13	80	86	19	2	1
88	1	Steel Ties	82	17	89	88	2	1
89	1	Steel Ties	102	38	125	123	2	2
90	1	Steel Ties	39	106	128	127	2	2
91	1	Steel Ties	86	22	127	125	1	3
92	1	Steel Ties	175	81	93	176	3	1
93	1	Steel Ties	152	121	126	177	3	1
94	1	Vert. S.S.	73	75	82	80	1	1
95	1	Vert. S.S.	80	82	88	86	1	1
96	1	Vert. S.S.	125	127	133	131	1	1
97	2	Masonry	200	199	195	196	1	1
98	2	Masonry	196	195	194	193	1	1

Table XI **Summary of the region number, the key points and the location of the key points that are used to define the geometry of Case 2-B.**

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
1			
1	0	0	0
2	800	0	90
3	800	200	0
4	0	200	90
2			
2	800	0	90
5	2400	0	0
6	2400	200	0
3	800	200	0
3			
5	2400	0	0
7	2600	0	90
8	2600	200	0
6	2400	200	0
4			
7	2600	0	90
9	3400	0	0
10	3400	200	0
8	2600	200	0
5			
9	3400	0	0
11	3600	0	90
12	3600	200	0
10	3400	200	0
6			
4	0	200	90
3	800	200	0
14	800	350	0
13	0	350	0
7			
3	800	200	0
6	2400	200	0
15	2400	350	90
14	800	350	0
8			
6	2400	200	0
8	2600	200	0
16	2600	350	90
15	2400	350	90

Table XI Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
9			
8	2600	200	0
10	3400	200	0
17	3400	350	0
16	2600	350	90
10			
10	3400	200	0
12	3600	200	0
18	3600	350	90
17	3400	350	0
11			
13	0	350	0
14	800	350	0
20	800	750	90
19	0	750	0
12			
14	800	350	0
15	2400	350	90
21	2400	750	0
20	800	750	90
13			
15	2400	350	90
16	2600	350	90
22	2600	750	0
21	2400	750	0
14			
16	2600	350	90
17	3400	350	0
23	3400	750	0
22	2600	750	0
15			
17	3400	350	0
18	3600	350	90
24	3600	750	90
23	3400	750	0
16			
19	0	750	0
20	800	750	90
26	800	950	90
25	0	950	0

Table XI Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
17			
20	800	750	90
21	2400	750	0
27	2400	950	0
26	800	950	90
18			
21	2400	750	0
22	2600	750	0
28	2600	950	90
27	2400	950	0
19			
22	2600	750	0
23	3400	750	0
29	3400	950	90
28	2600	950	90
20			
23	3400	750	0
24	3600	750	90
30	3600	950	0
29	3400	950	90
21			
25	0	950	0
26	800	950	90
32	800	1100	0
31	0	1100	90
22			
26	800	950	90
27	2400	950	0
33	2400	1100	90
32	800	1100	0
23			
27	2400	950	0
28	2600	950	90
34	2600	1100	90
33	2400	1100	90
24			
28	2600	950	90
29	3400	950	90
35	3400	1100	0
34	2600	1100	90

Table XI Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
25			
29	3400	950	90
30	3600	950	0
36	3600	1100	90
35	3400	1100	0
26			
31	0	1100	90
32	800	1100	0
38	800	1350	0
37	0	1350	90
27			
34	2600	1100	90
35	3400	1100	0
40	3400	1350	0
39	2600	1350	0
28			
35	3400	1100	0
36	3600	1100	90
41	3600	1350	0
40	3400	1350	0
29			
37	0	1350	90
38	800	1350	0
43	800	1950	0
42	0	1950	90
30			
39	2600	1350	0
40	3400	1350	0
45	3400	1950	0
44	2600	1950	90
31			
40	3400	1350	0
41	3600	1350	0
46	3600	1950	90
45	3400	1950	0
32			
42	0	1950	90
43	800	1950	0
48	800	2040	0
47	0	2040	90

Table XI Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
33			
44	2600	1950	90
45	3400	1950	0
50	3400	2040	90
49	2600	2040	0
34			
45	3400	1950	0
46	3600	1950	90
51	3600	2040	90
50	3400	2040	90
35			
47	0	2040	90
48	800	2040	0
53	800	2190	90
52	0	2190	90
36			
48	800	2040	0
55	2400	2040	90
54	2400	2190	0
53	800	2190	90
37			
55	2400	2040	90
49	2600	2040	0
56	2600	2190	0
54	2400	2190	0
38			
49	2600	2040	0
50	3400	2040	90
57	3400	2190	90
56	2600	2190	0
39			
50	3400	2040	90
51	3600	2040	90
58	3600	2190	0
57	3400	2190	90
40			
52	0	2190	90
53	800	2190	90
60	800	2550	0
59	0	2550	90

Table XI Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
41			
53	800	2190	90
54	2400	2190	0
61	2400	2550	90
60	800	2550	0
42			
197	800	1100	250
198	2600	1100	250
199	2600	1350	340
200	800	1350	250
43			
56	2600	2190	0
57	3400	2190	90
63	3400	2550	90
62	2600	2550	0
44			
57	3400	2190	90
58	3600	2190	0
64	3600	2550	90
63	3400	2550	90
45			
59	0	2550	90
60	800	2550	0
66	800	2700	0
65	0	2700	0
46			
60	800	2550	0
61	2400	2550	90
67	2400	2700	0
66	800	2700	0
47			
61	2400	2550	90
62	2600	2550	0
68	2600	2700	0
67	2400	2700	0
48			
62	2600	2550	0
63	3400	2550	90
69	3400	2700	0
68	2600	2700	0

Table XI Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
49			
63	3400	2550	90
64	3600	2550	90
70	3600	2700	0
69	3400	2700	0
50			
71	0	200	600
72	400	200	600
79	400	350	600
78	0	350	600
51			
73	800	200	600
74	2400	200	600
81	2400	350	600
80	800	350	600
52			
75	2600	200	600
77	3400	200	600
83	3400	350	600
82	2600	350	600
53			
78	0	350	600
79	400	350	600
85	400	750	600
84	0	750	600
54			
80	800	350	600
81	2400	350	600
87	2400	750	600
86	800	750	600
55			
82	2600	350	600
83	3400	350	600
89	3400	750	600
88	2600	750	600
56			
84	0	750	600
85	400	750	600
91	400	950	600
90	0	950	600

Table XI Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
57			
86	800	750	600
87	2400	750	600
93	2400	950	600
92	800	950	600
58			
88	2600	750	600
89	3400	750	600
95	3400	950	600
94	2600	950	600
59			
90	0	950	600
91	400	950	600
97	400	1100	600
96	0	1100	600
60			
92	800	950	600
93	2400	950	600
99	2400	1100	600
98	800	1100	600
61			
94	2600	950	600
95	3400	950	600
101	3400	1100	600
100	2600	1100	600
62			
96	0	1100	600
98	800	1100	600
104	800	1350	600
102	0	1350	600
63			
100	2600	1100	600
101	3400	1100	600
106	3400	1350	600
105	2600	1350	600
64			
102	0	1350	600
104	800	1350	600
108	800	1950	600
107	0	1950	600

Table XI Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
65			
105	2600	1350	600
106	3400	1350	600
110	3400	1950	600
109	2600	1950	600
66			
107	0	1950	600
108	800	1950	600
113	800	2040	600
111	0	2040	600
67			
109	2600	1950	600
110	3400	1950	600
115	3400	2040	600
114	2600	2040	600
68			
111	0	2040	600
112	400	2040	600
117	400	2190	600
116	0	2190	600
69			
113	800	2040	600
120	2400	2040	600
121	2400	2190	600
118	800	2190	600
70			
114	2600	2040	600
115	3400	2040	600
122	3400	2190	600
119	2600	2190	600
71			
116	0	2190	600
117	400	2190	600
124	400	2550	600
123	0	2550	600
72			
118	800	2190	600
121	2400	2190	600
126	2400	2550	600
125	800	2550	600

Table XI Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
73			
119	2600	2190	600
122	3400	2190	600
128	3400	2550	600
127	2600	2550	600
74			
123	0	2550	600
124	400	2550	600
130	400	2700	600
129	0	2700	600
75			
125	800	2550	600
126	2400	2550	600
132	2400	2700	600
131	800	2700	600
76			
127	2600	2550	600
128	3400	2550	600
134	3400	2700	600
133	2600	2700	600
77			
98	800	1100	600
99	2400	1100	600
120	2400	2040	600
113	800	2040	600
78			
99	2400	1100	600
100	2600	1100	600
114	2600	2040	600
120	2400	2040	600
79			
86	800	750	600
88	2600	750	600
127	2600	2550	600
125	800	2550	600
80			
71	0	200	600
72	400	200	600
136	400	200	1000
135	0	200	1000

Table XI Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
81			
73	800	200	600
74	2400	200	600
138	2400	200	1000
137	800	200	1000
82			
75	2600	200	600
77	3400	200	600
140	3400	200	1000
139	2600	200	1000
83			
129	0	2700	600
130	400	2700	600
142	400	2700	1000
141	0	2700	1000
84			
131	800	2700	600
132	2400	2700	600
144	2400	2700	1000
143	800	2700	1000
85			
133	2600	2700	600
134	3400	2700	600
146	3400	2700	1000
145	2600	2700	1000
86			
200	800	1350	250
105	2600	1350	600
195	2600	1950	250
196	800	1950	250
87			
13	0	350	0
80	800	350	600
86	800	750	600
19	0	750	0
88			
82	2600	350	600
17	3400	350	0
89	3400	750	600
88	2600	750	600

Table XI Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
89			
102	0	1350	600
38	800	1350	0
125	800	2550	600
123	0	2550	600
90			
39	2600	1350	0
106	3400	1350	600
128	3400	2550	600
127	2600	2550	600
91			
86	800	750	600
22	2600	750	0
127	2600	2550	600
125	800	2550	600
92			
175	1200	350	0
81	2400	350	600
93	2400	950	600
176	1200	950	0
93			
152	1200	2190	0
121	2400	2190	600
126	2400	2550	600
177	1200	2550	0
94			
73	800	200	600
75	2600	200	600
82	2600	350	600
80	800	350	600
95			
80	800	350	600
82	2600	350	600
88	2600	750	600
86	800	750	600
96			
125	800	2550	600
127	2600	2550	600
133	2600	2700	600
131	800	2700	600

Table XI Continued

Region Number			
Key Point	x-coord (mm)	y-coord (mm)	z-coord (mm)
97			
200	800	1350	250
199	2600	1350	340
195	2600	1950	250
196	800	1950	250
98			
196	800	1950	250
195	2600	1950	250
194	2600	2040	250
193	800	2040	340

Results and Discussion

The location for the first and second cracks are shown, respectively, in Figs. C2-9 and C2-10. A summary of the results is also given in Table XII. Comparing Case 2-A and Case 2-B, one observes that the contributions of the retrofit steel ties and stiffer jamb members did not significantly affect the cracking load. However, forces in the steel studs and ties were somewhat affected. Also, the different load transfer after propagation of the first crack resulted in a different location and lower load for initiation of the second crack.

Table XII Summary of the maximum stud and tie forces at the initiation of the first crack and second crack.

	At the initiation of the first crack (0.208 kPa)	At the initiation of the second crack (0.310 kPa)
Maximum Stud Bending (kN m)	0.03	0.09
Maximum Stud Twisting (kN m)	0.01	0.02
Maximum Stud Shear Force (kN)	0.09	0.14
Maximum Tie Force (kN)	0.15	0.35
Tie Number	222	236

Figure C2-9 Location and Load for Initiation of the First Crack.

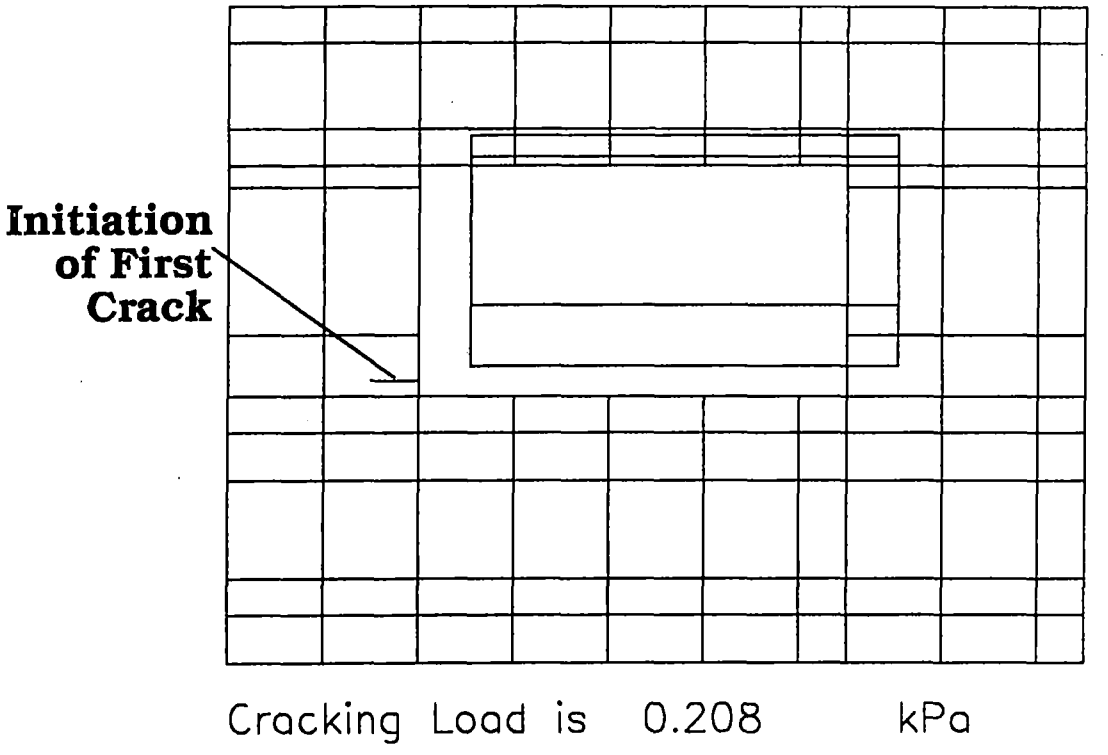
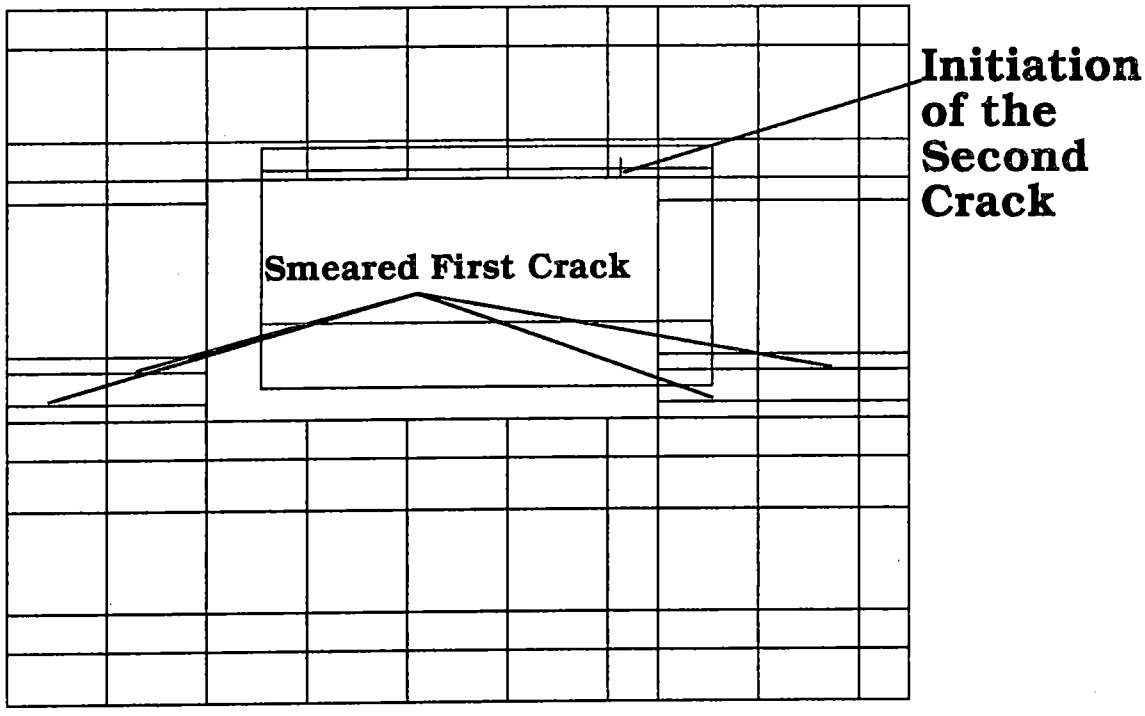


Figure C2-10 Location of First Crack and Location and Load for Initiation of the Second Crack.



Cracking Load is 0.310 kPa