Demonstration Problem Manual

For the

MYSTRAN General Purpose Finite Element

Structural Analysis Computer Program

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Preface

This manual is not a complete reference for all types of MYSTRAN analyses but does contain example problems to demonstrate the use of MYSTRAN for solving unique kinds of problems. At the present time, only examples that use the unique Craig-Bampton model generation and synthesis capability are covered. Additional examples will be added as needed to explain how to use the program for solving problems not generally covered by the popular NASTRAN computer program known to most users of finite element analysis computer programs

1 Demo Problem 1 – Craig-Bampton model generation and synthesis into an overall structure model

1.1 Example Problem Definition

1.1.1 Introduction

This example demonstrates two different features in MYSTRAN:

- Generation of Craig-Bampton (CB) models from physical finite element model (FEM).

- Synthesis of CB models with optional physical FEM's to obtain system modes.

Figure 1.1 shows a model made up of a basic structure and 2 substructures. The model can certainly be analyzed as a physical FEM using SOL 3 to obtain the modes of the combined structure. It actually will be so analyzed as a comparison with the CB synthesis model results, but the main purpose of this example is to demonstrate how a structure like the one in Figure 1.1 can be modeled with substructures using the CB substructure technique. The CB reduction technique will be referred to as a modal synthesis or substructure technique to distinguish from the ordinary FEM technique wherein all degrees of freedom (DOF) are physical displacements and rotations at grid points

The simple structure in Figure 1.1 is small enough that using substructure techniques are not economical but is used to demonstrate the techniques that would be used on much larger structural models. The CB technique is a mathematical reduction of the ordinary FEM model having all physical DOF to an approximate model consisting of the physical DOF at the boundary of the substructure (where it connects to other substructures) plus some fixed boundary modal DOF. The technique is exactly equivalent to obtaining the modes (eigenvalues) from the ordinary FEM with all physical DOF if all of the boundary modes are included. However, the economy in using the CB approach is that the user can truncate the boundary modal DOF to some acceptably small fraction of all of the complete set without appreciable loss of accuracy. From a physical point of view, this statement is equivalent to saying that the substructure probably has many higher modes of vibration that are not of interest to the user and do not contribute significantly to the responses of interest to the user.

The first step in a modal synthesis is to break the complete structure into separate substructures. In many cases this is a process of convenience in that separate entities may be responsible for different parts of a structure and would have their own FEM's of their structure's designs. However, there are also modeling concerns, as listed below, in breaking the complete structure into separate substructures:

- It is more economical to separate the substructures at locations where there are a relatively few physical boundary DOF.

- In order to take advantage of modal truncation the separate substructures should be able to be adequately represented using only a small number of modal DOF.

In Figure 1.1 we have already taken into account the considerations above and have made the decision to separate the model into 3 parts:

- A basic structure consisting of the frame of CBAR's connected to the grids numbered in the range 111 to 222. This will be kept as a physical FEM in the analysis rather than reducing it to a CB model.

- Substructure 1, modeled as 1 CBAR from grids 3101 to 3102. This physical FEM will be reduced to a CB model containing only the boundary DOF's (6 components of motion at grid 3101) plus some modal DOF's.

- Substructure 2, modeled as a frame of CBAR’s connecting grids 3201 through 3204. This physical FEM will be reduced to a CB model containing only the boundary DOF’s (in this case the 3 translation components of motion at grids 3201, 3202, 3203) plus some modal DOF’s

Sections 1.1.2 and 1.1.3 will explain the input/output data for the 2 CB models. Section 1.1.4 will explain the model to obtain the system modes using these 2 CB models and the physical FEM of the basic structure. Finally, section 1.1.5 will show that the CB synthesis results are the same as those from a completely physical FEM model.

1.1.2 Generation of Craig-Bampton model of substructure 1

Section 1.4 has the input data for the generation of a CB model of substructure 1. Note the following regarding the input data deck (see Figure 1.1 for a picture of this substructure):

- SOL 31 is for CB model generation
- OUTPUT4 calls for CB matrices KXX, MXX, RBM0 (NASTRAN matrices KRRGN, MRRGN, RBMCG) to be output to binary OUTPUT4 formatted files
- METHOD = 2 selects an EIGR with set ID = 2 to find the eigenvalues (so modes found will be fixed base relative to the boundary DOF’s identified by the SUPORT Bulk Data entry)
- Model has 2 GRID’s and 1 CBAR
- Coordinate system 19 is used for the global system for the 2 grids. This is only done to demonstrate the flexibility of MYSTRAN to deal with coordinate systems other then basic in CB analyses
- The only mass is a concentrated mass at grid 3102
- SUPORT identifies the boundary DOF for this substructure to be the 3 translation components of displacement at grid 3101
- PARAM CUSERIN requests MYSTRAN to print out equivalent CUSERIN Bulk Data entries for this substructure

The output is shown on the following pages in section 1.4. Note the following:

- Grid Point Weight Generator output shows the rigid body mass properties of substructure 1 relative to its basic coordinate system.
- *INFORMATION: message listed shows that matrices KXX, MXX, RBM0 have been written to binary file CB1d-SUBSTR-1-CB-MODEL.OP1 which will be used in the synthesis run (section 1.6)
- Based on Bulk data PARAM CUSERIN, the Bulk Data entries needed in the synthesis run for this CB substructure is listed. Some of the entries will have to be modified (e.g. CID0 must be defined) for the synthesis run in section 1.6
- Only 3 eigenvalues were found although 4 were requested. Since the model has only 3 mass DOF, there are only 3 finite eigenvalues. Normally we would not be asking for all modes in a CB analysis but are doing so here so that the system modes can be compared to a run in which a complete FEM model is used (section 1.7)

- Output of displacements was requested in Case Control and the output is shown next. Note that for CB analyses, “displacement” output is of the rows of the Displacement Output Transformation Matrix (Displ OTM) described in Appendix D to Reference 1

1.1.3 Generation of Craig-Bampton model of substructure 2

Section 1.5 has the input data for the generation of a CB model of substructure 2. Note the following regarding the input data deck (see Figure 1.1 for a picture of this substructure):

- SOL 31 is for CB model generation

- OUTPUT4 calls for CB matrices KXX, MXX, RBM0 (NASTRAN matrices KRRGN, MRRGN, RBMCG) to be output to binary OUTPUT4 formatted files

- METHOD = 2 selects an EIGR with set ID = 2 to find the eigenvalues (so modes found will be fixed base relative to the boundary DOF’s identified by the SUPORT Bulk Data entry)

- Model has 4 GRID’s and 6 CBAR’s

- Coordinate systems 291 through 294 are used for the global system for the 4 grids. This is only done to demonstrate the flexibility of MYSTRAN to deal with coordinate systems other then basic in CB analyses

- The only mass is a concentrated mass at grid 3204

- SUPORT identifies the boundary DOF for this substructure which is to be the 3 translation components of displacement at grids 3201, 3202, 3203

- PARAM CUSERIN requests MYSTRAN to print out equivalent CUSERIN Bulk Data entries for this substructure

The output is shown on the following pages in section 1.5. Note the following:

- Grid Point Weight Generator output shows the rigid body mass properties of substructure 2 relative to its basic coordinate system.

- *INFORMATION: message listed shows that matrices KXX, MXX, RBM0 have been written to binary file CB1d-SUBSTR-2-CB-MODEL.OP1 which will be used in the synthesis run (section 1.6)

- Based on Bulk data PARAM CUSERIN, the Bulk Data entries needed in the synthesis run for this CB substructure is listed. Some of the entries will have to be modified (e.g. CID0 must be defined) for the synthesis run in section 1.6

- Only 3 eigenvalues were found although 4 were requested. Since the model has only 3 mass DOF, there are only 3 finite eigenvalues. Normally we would not be asking for all modes in a CB analysis but are doing so here so that the system modes can be compared to a run in which a complete FEM model is used (section 1.7)

- Output of displacements was requested in Case Control and the output is shown next. Note that for CB analyses, “displacement” output is of the rows of the Displacement Output Transformation Matrix (Displ OTM) described in Appendix D to Reference 1

1.1.4 System modes using the 2 CB models and the basic structure FEM

Section 1.6 has the input data for the system modes model. In this run we will use the CB model data generated in the runs described in the 2 previous sections along with a physical model FEM of the basic structure. Note the following about the input data:

- IN4 statements in Exec Control define the files that contain the stiffness and mass data generated in the 2 CB runs described in the last 2 sections. There must be one of these IN4 statements for every CB model included in the synthesis run
- SOL 3 requests an eigenvalue run with METHOD = 2 selecting Bulk data EIGRL entry with set ID 2
- The 1st portion of the Bulk Data is a standard FEM model of the basic structure containing 8 grids and 12 CBAR's and concentrated masses at all 8 grids
- The 2nd portion of the input data is the CB model definition for substructure 1. It uses the CUSERIN, PUSERIN, etc data written to the F06 file in section 1.4 to describe the substructure 1 CB model connection and "property" data (more on this below)
- The 3rd portion of the input data is the CB model definition for substructure 2. It uses the CUSERIN, PUSERIN, etc data written to the F06 file in section 1.5 to describe the substructure 2 CB model connection and "property" data (more on this below)
- Each CB model must have its basic coordinate system defined relative to the basic coordinate system of the overall system model. All other CB unique coordinate systems must be defined relative to this CB basic coordinate system.
- In this example, RBE2 rigid elements are used to connect CB boundary grids to the basic structure grids. This is not at all necessary, only a preference of the author. The CUSERIN connection data for each substructure could have alternately referred to grids from the basic structure where the CB model attached. For example, CUSERIN 100 would have referred to grid 112 instead of 3101 and then the RBE2 1001 and GRID 3101 would have been omitted from the substructure 1 CB model definition. Note that this would also have required that GRID 112 have the coordinate system 19 that was used in CB model 1 as the global coordinate system.

Since some of the input data for the CB models is not standard NASTRAN type of input, the description below is given to help explain that input data.

The CUSERIN Bulk Data connection <u>parent</u> entry specifies:

- Field 1: CUSERIN
- Field 2: element ID
- Field 3: property ID
- Field 4: number of boundary grids (the number that are in the R-set when the CB model was generated)
- Field 6: number of SPOINT's (1 for each modal DOF in the CB model)

- Field 6: ID of the coordinate system which defines the basic system used when the CB model was generated. It must define this coordinate system relative to the basic coordinate system of the overall system model

Subsequent CUSERIN continuation entries define

- grids/components that define the support (boundary) DOF for this substructure
- ID's of SPOINT's for MYSTRAN to use as the DOF identifiers for the modal DOF (these must begin on a new continuation entry; i.e. they can not be on the same continuation entry as the grid/component definition)

The PUSERIN "property" entry does not define physical properties (as is the case with other finite elements); rather it specifies information about the files that contain the KRRGN and MRRGN matrices for the CB element. It also specifies the names of the these matrices as they were written to the OUTPUT4 file when the CB model was generated. There is one more matrix defined; RBM0, which is a 6x6 rigid body mass matrix relative to the basic coordinate system origin for the CB model (RBM0 generated in the run that creates the CB model). If the RBM0 matrix is not present the synthesis of the substructures will still yield the correct results for everything except the overall mass properties (6x6 rigid mass matrix) reported from the "Grid Point Weight Generator" subroutine.

Specifically, the PUSERIN Bulk Data entry specifies:

- Field 1: PUSERIN
- Field 2: property ID referenced in field 3 of the CUSERIN entry
- Field 3: ID of a IN4 Executive Control Deck entry which has the name of the file containing the KXX, MXX, RBM0 (NASTRAN KRRGN, MRRGN and RBMCG) matrices
- Field 4: Name of the KRRGN matrix (can be up to 8 characters long)
- Field 5: Name of the MRRGN matrix (can be up to 8 characters long)
- Field 6: Name of the RBM0 matrix (can be up to 8 characters long) if there is one

The KXX, MXX, RBM0 (NASTRAN KRRGN, MRRGN, RBMCG) matrices are read into MYSTRAN in NASTRAN INPUTT4 format. The command statements to do this are part of the Executive Control Deck, the format of which is shown in the listing in section 1.6. The commands to read in the matrices are: IN4 i = *filename*, where i is the file ID in field 3 of the PUSERIN property entry for the CUSERIN element and *filename* is the name of the file in which the matrices were written when the CB model was generated

The output for this modal synthesis run is the standard type of output one would expect from a SOL 3 modal analysis. Note the following:

- The Grid Point Weight Generator gives the rigid body mass properties of the complete model. Unless the CB matrices RBM0 had been input (IN4 Exec Control command), the overall model mass properties would not have been correct and would not match those shown in the next section in which a completely physical FEM model is run
- The eigenvalues are system values and will be directly comparable to those in section 1.7. They will, in fact, be exactly the same since we have used all of the finite modes for each substructure (not a normal circumstance, only done here for demonstration purposes)

- The eigenvectors show the “mode shapes” for the CB synthesis DOF’s, which, in this model, uses physical grids for the basic structure and CB boundary DOF’s plus modal DOF’s for the fixed base modes of each substructure. The meaning of an eigenvector like this for the CB fixed base modes is the following. The magnitudes shown in system eigenvector i for the CB DOF’s (scalar points 10001,2,3 and 20001,2,3) are the relative magnitudes of the substructure CB eigenvactors in their contribution to system eigenvector i.

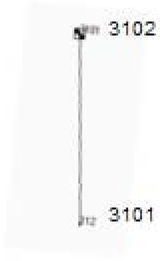
1.1.5 System modes using complete structure FEM

In order to demonstrate that the CB substructure techniques used in the last section can yield the same eigenvalues as would be used if it were analyzed as a full FEM model, section 1.7 is included. It shows the results of a run using a complete physical FEM of the basic structure with the 2 substructures run as one complete model. The input shown is that used in a standard analysis of a FEM with SOL 3 and requesting 10 eigenvalues. The output shows the rigid body mass properties of the complete model, the 10 eigenvalues and 1 of the eigenvactors. The eigenvalue data in section 1.7 is to be compared with those in section 1.6 (using CB models for the 2 substructures). The eigenvector data will, however, be different as the system DOF’s for the two runs are not the same. In the case of the complete FEM, the DOF’s are all 6 component displacement components at physical grids. For the CB synthesis run the DOF’s are physical grids for the basic structure but the DOF’s for the substructures have physical grids for the boundary DOF’s and modal DOF’s for the remainder of the CB model. Analysts familiar with modal synthesis will be aware of this distinction.

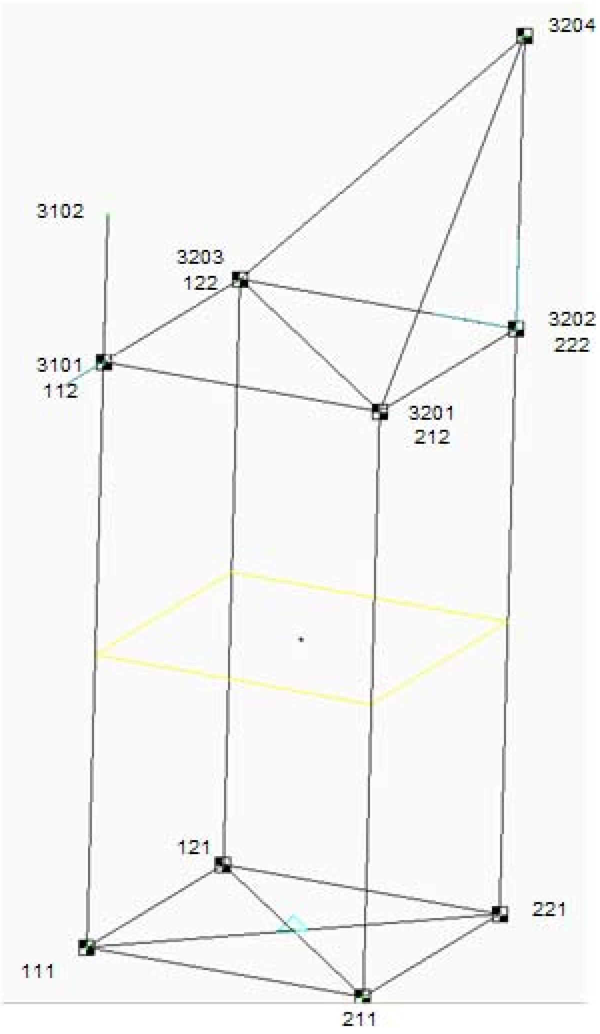
1.2 Summary

The eigenvalues in section 1.7, which is a complete FEM model, form the baseline for comparison with the eigenvalues in section 1.6, which uses CB models for substructures 1 and 2. Since all of the finite mass modes were included in generating the substructure CB models, it should be expected that the eigenvalues in section 1.6 should be the same as those in section 1.7. As shown in these two sections the 10 eigenvalues found for the combined structure are identical. In a practical CB synthesis, only some of the modes of each CB model would be used and then the CB synthesis eigenvalues would not be identical to those from the completely physical FEM model. However, if the analyst is careful in modeling the problem at hand the important eigenvalues in the CB synthesis should be a very good approximation to the ones that would have been obtained from a run using a completely physical FEM.

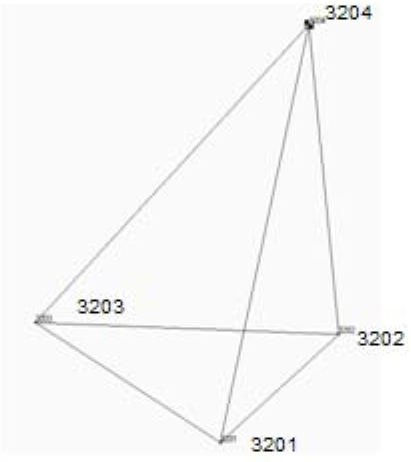
1.3 *Fig 1.1 – Simple example problem: Basic structure and 2 substructures*



Substructure 1



Basic structure with substructures attached



Substructure 2

1.4 Substructure 1 – Generate CB model

(input deck CB1d-SUBSTR-1-CB-MODEL.DAT)

```
ID CB1, RUN (b)
SOL 31
$
OUTPUT4   KXX      , MXX      ,RBM0     ,       ,       //-1/21 $
$
CEND
TITLE = CB PROBLEM - SUBSTR 1, GENERATE CB MODEL
SUBTI = SUBSTR GLOBAL IS COORD SYSTEM 19
LABEL = V VEC FOR BAR IS X19 DIR WHICH IS OA MODEL BASIC X0
ECHO = UNSORT
METHOD = 2
DISP   = ALL
BEGIN BULK
$
EIGR    2       MGIV                    1       4                       +E1
+E1     MASS
$
GRID    3101             0.      0.      0.     19
GRID    3102            25.      0.      0.     19
CORD2R   19             0.      0.      0.      1.      0.      0.      +C19
+C19    0.      0.      1.
CBAR    3101    3101    3101    3102    1.      0.      0.
PBAR    3101    301     1.      20.     20.     40.
MAT1    301     30.+6           .3
$
CONM2   3102    3102            400.
$
SUPORT  3101    123456
$
PARAM   CUSERIN  100     190     10001   100
PARAM   GRDPNT   0
PARAM   GRIDSEQ  GRID
PARAM   WTMASS   .002591
PARAM   PRTDOF   2
PARAM   PRTSET   1
PARAM   PRTMXX   1
$
ENDDATA
```

```
      O U T P U T   F R O M   G R I D   P O I N T   W E I G H T   G E N E R A T O R
                        REFERENCE POINT IS BASIC COORD SYSTEM ORIGIN

                                TOTAL MASS =  4.000000E+02

                                       X             Y             Z
                 C.G. location :  2.500000E+01  0.000000E+00  0.000000E+00
                  (relative to reference point in basic coordinate system)


       6x6 Rigid body mass matrix - about reference point in basic coordinate system
***                                                                                     ***
*  4.000000E+02  0.000000E+00  0.000000E+00  *  0.000000E+00  0.000000E+00  0.000000E+00  *
*  0.000000E+00  4.000000E+02  0.000000E+00  *  0.000000E+00  0.000000E+00  1.000000E+04  *
*  0.000000E+00  0.000000E+00  4.000000E+02  *  0.000000E+00 -1.000000E+04  0.000000E+00  *
*  ************  ************  ************  *  ************  ************  ************  *
*  0.000000E+00  0.000000E+00  0.000000E+00  *  0.000000E+00  0.000000E+00  0.000000E+00  *
*  0.000000E+00  0.000000E+00  0.000000E+00  *  0.000000E+00  2.500000E+05  0.000000E+00  *
*  0.000000E+00  0.000000E+00  0.000000E+00  *  0.000000E+00  0.000000E+00  2.500000E+05  *
***                                                                                     ***


              M.O.I. matrix - about reference point in basic coordinate system
                       ***                                        ***
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       *  0.000000E+00  2.500000E+05  0.000000E+00  *
                       *  0.000000E+00  0.000000E+00  2.500000E+05  *
                       ***                                        ***


                   M.O.I. matrix - about c.g. in basic coordinate system
                       ***                                        ***
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       ***                                        ***


                     M.O.I. matrix - about c.g. in principal directions
                       ***                                        ***
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       ***                                        ***


               Transformation from basic coordinates to principal directions
                       ***                                        ***
                       *  1.000000E+00  0.000000E+00  0.000000E+00  *
                       *  0.000000E+00  1.000000E+00  0.000000E+00  *
                       *  0.000000E+00  0.000000E+00  1.000000E+00  *
                       ***                                        ***
```

```
*INFORMATION: THE FOLLOWING   3 MATRICES WILL BE WRITTEN TO  1 OUTPUT4 FILES IN THE ORDER LISTED BELOW:

               OUTPUT4 file on unit  21 has been created as: CB1d-SUBSTR-1-CB-MODEL.OP1 and will contain the matrices:
                       ( 1) KXX             :        9 rows and        9 cols
                       ( 2) MXX             :        9 rows and        9 cols
                       ( 3) RBM0            :        6 rows and        6 cols
```

```
********************************************************************************
 $ B.D. entries for USERIN element      100 for use in a system model
 $ KXX and MXX matrices are in file: CB1d-SUBSTR-1-CB-MODEL.OP1
 $
 $--1---|---2---|---3---|---4---|---5---|---6---|---7---|---8---|---9---|--10---|
 GRID    3101    "CID0"  0.00    0.00    0.00    19
 $
 CORD2R  19      "CID0"  0.      0.      0.      1.00    0.00    0.00
         0.00    0.00    1.00
 $
 SPOINT  10001   THRU    10003
 $
 CUSERIN 100     190     1       3       "CID0"
         3101    123456
         10001   THRU    10003
 $
 PUSERIN 190     100     KXX             MXX
 $
 $ "CID0"   is to be replaced with the coord sys ID that is used to define the
 $ basic coord sys of this USERIN elem rel to the system model basic coord sys.
 $ If the above grid entries is used, RBE2's should be included to connect
 $ them to the corresponding grids in the system model
 $
 ********************************************************************************
```

```
                        E I G E N V A L U E   A N A L Y S I S   S U M M A R Y   (MGIV    )

                             NUMBER OF EIGENVALUES EXTRACTED  . . . . . .         3

                             LARGEST OFF-DIAGONAL GENERALIZED MASS TERM     0.0E+00 (Vecs renormed to 1.0 for gen masses)

                                                                    . . .         1
                                       MODE PAIR . . . . . . . . . . .
                                                                    . . .         1

                             NUMBER OF OFF DIAGONAL GENERALIZED MASS
                             TERMS FAILING CRITERION OF  0.0E+00. . . . .         0


                                         R E A L   E I G E N V A L U E S
 MODE  EXTRACTION      EIGENVALUE           RADIANS              CYCLES            GENERALIZED         GENERALIZED
NUMBER   ORDER                                                                        MASS              STIFFNESS

     1       1        1.111540E+05        3.333977E+02        5.306188E+01        1.000000E+00        1.111540E+05
     2       2        1.111540E+05        3.333977E+02        5.306188E+01        1.000000E+00        1.111540E+05
     3       3        1.157854E+06        1.076036E+03        1.712565E+02        1.000000E+00        1.157854E+06
```

```
OUTPUT FOR CRAIG-BAMPTON DOF        1 OF       15 (boundary acceleration for grid    3101 component 1)
CB PROBLEM - SUBSTR 1, GENERATE CB MODEL
SUBSTR GLOBAL IS COORD SYSTEM 19
V VEC FOR BAR IS X19 DIR WHICH IS OA MODEL BASIC X0

                                                C B   D I S P L A C E M E N T   O T M
                                             (in global coordinate system at each grid)
          GRID     COORD      T1            T2            T3            R1            R2            R3
                    SYS
          3101       19  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
          3102       19 -8.996528E-06  0.000000E+00  0.000000E+00  0.000000E+00 -5.397917E-07  0.000000E+00

OUTPUT FOR CRAIG-BAMPTON DOF        2 OF       15 (boundary acceleration for grid    3101 component 2)
CB PROBLEM - SUBSTR 1, GENERATE CB MODEL
SUBSTR GLOBAL IS COORD SYSTEM 19
V VEC FOR BAR IS X19 DIR WHICH IS OA MODEL BASIC X0

                                                C B   D I S P L A C E M E N T   O T M
                                             (in global coordinate system at each grid)
          GRID     COORD      T1            T2            T3            R1            R2            R3
                    SYS
          3101       19  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
          3102       19  0.000000E+00 -8.996528E-06  0.000000E+00  5.397917E-07  0.000000E+00  0.000000E+00

OUTPUT FOR CRAIG-BAMPTON DOF        3 OF       15 (boundary acceleration for grid    3101 component 3)
CB PROBLEM - SUBSTR 1, GENERATE CB MODEL
SUBSTR GLOBAL IS COORD SYSTEM 19
V VEC FOR BAR IS X19 DIR WHICH IS OA MODEL BASIC X0

                                                C B   D I S P L A C E M E N T   O T M
                                             (in global coordinate system at each grid)
          GRID     COORD      T1            T2            T3            R1            R2            R3
                    SYS
          3101       19  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
          3102       19  0.000000E+00  0.000000E+00 -8.636667E-07  0.000000E+00  0.000000E+00  0.000000E+00

                 .
                                                           .
                                                           .
                                                           .
                                                           .
```

1.5 Substructure 2 – Generate CB model

(input deck CB1d-SUBSTR-2-CB-MODEL.DAT)

```
ID CB1, RUN (c)
SOL 31
$
OUTPUT4   KXX      , MXX      ,RBM0     ,       ,       //-1/21 $
$
TIME 7
CEND
TITLE = CB PROBLEM - SUBSTR 2, GENERATE CB MODEL
SUBTI = SUBSTR GLOBAL IS COORD SYSTEM 29
LABEL = BARS 3201-3 V IS OA MODEL BASIC Z0, BARS 3204-6 V IS OA MODEL BASIC Y0
ECHO = UNSORT
METHOD = 2
DISP   = ALL
BEGIN BULK
$
EIGR    2       MGIV                    1       4                       +E1
+E1     MASS
$
GRID    3201             50.     0.        0.    291
GRID    3202              0.     0.        0.    292
GRID    3203              0.     0.       50.    293
GRID    3204              0.    50.        0.    294
$
CORD2R  291             0.      0.      0.      1.      0.      0.      +C29
+C29    0.      1.      0.
$
CORD2R  292             0.      0.      0.      0.      1.      0.      +C29
+C29    0.      0.      1.
$
CORD2R  293             0.      0.      0.      0.      0.      1.      +C29
+C29    1.      0.      0.
$
CORD2R  294             0.      0.      0.      0.      0.      1.      +C29
+C29    1.      0.      0.
$
CBAR    3201    3201    3201    3202    1.      0.      0.
CBAR    3202    3201    3202    3203    0.      0.      1.
CBAR    3203    3201    3203    3201    0.      1.      0.
$
CBAR    3204    3201    3201    3204    0.      0.      1.
CBAR    3205    3201    3202    3204    0.      1.      0.
CBAR    3206    3201    3203    3204    1.      0.      0.
$
PBAR    3201    302     1.      20.     20.     40.
MAT1    302     30.+6           .3
$
CONM2   3201    3204            600.
$
SUPORT  3201    123     3202    123     3203    123
$
PARAM   CUSERIN  200     290     20001   200
PARAM   GRDPNT   0
```

```
PARAM   GRIDSEQ  GRID
PARAM   WTMASS   .002591
PARAM   PRTDOF   2
PARAM   PRTSET   1
PARAM   PRTMXX   1
$
ENDDATA
```

```
       O U T P U T   F R O M   G R I D   P O I N T   W E I G H T   G E N E R A T O R
                        REFERENCE POINT IS BASIC COORD SYSTEM ORIGIN

                                TOTAL MASS =  6.000000E+02

                                       X             Y             Z
                 C.G. location :  0.000000E+00  5.000000E+01  0.000000E+00
                  (relative to reference point in basic coordinate system)


       6x6 Rigid body mass matrix - about reference point in basic coordinate system
***                                                                                     ***
*  6.000000E+02  0.000000E+00  0.000000E+00  *  0.000000E+00  0.000000E+00 -3.000000E+04  *
*  0.000000E+00  6.000000E+02  0.000000E+00  *  0.000000E+00  0.000000E+00  0.000000E+00  *
*  0.000000E+00  0.000000E+00  6.000000E+02  *  3.000000E+04  0.000000E+00  0.000000E+00  *
*  ************  ************  ************  *  ************  ************  ************  *
*  0.000000E+00  0.000000E+00  0.000000E+00  *  1.500000E+06  0.000000E+00  0.000000E+00  *
*  0.000000E+00  0.000000E+00  0.000000E+00  *  0.000000E+00  0.000000E+00  0.000000E+00  *
*  0.000000E+00  0.000000E+00  0.000000E+00  *  0.000000E+00  0.000000E+00  1.500000E+06  *
***                                                                                     ***


              M.O.I. matrix - about reference point in basic coordinate system
                       ***                                          ***
                       *  1.500000E+06  0.000000E+00  0.000000E+00  *
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       *  0.000000E+00  0.000000E+00  1.500000E+06  *
                       ***                                          ***


                   M.O.I. matrix - about c.g. in basic coordinate system
                       ***                                          ***
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       ***                                          ***


                     M.O.I. matrix - about c.g. in principal directions
                       ***                                          ***
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       *  0.000000E+00  0.000000E+00  0.000000E+00  *
                       ***                                          ***


               Transformation from basic coordinates to principal directions
                       ***                                          ***
                       *  1.000000E+00  0.000000E+00  0.000000E+00  *
                       *  0.000000E+00  1.000000E+00  0.000000E+00  *
                       *  0.000000E+00  0.000000E+00  1.000000E+00  *
                       ***                                          ***
```

```
*INFORMATION: THE FOLLOWING   3 MATRICES WILL BE WRITTEN TO  1 OUTPUT4 FILES IN THE ORDER LISTED BELOW:

               OUTPUT4 file on unit  21 has been created as: CB1d-SUBSTR-2-CB-MODEL.OP1 and will contain the matrices:
                       ( 1) KXX            :       12 rows and       12 cols
                       ( 2) MXX            :       12 rows and       12 cols
                       ( 3) RBM0           :        6 rows and        6 cols
```

```
********************************************************************************
 $ B.D. entries for USERIN element      200 for use in a system model
 $ KXX and MXX matrices are in file: CB1d-SUBSTR-2-CB-MODEL.OP1
 $
 $--1---|---2---|---3---|---4---|---5---|---6---|---7---|---8---|---9---|--10---|
 GRID    3201    "CID0"  50.0    0.00    0.00    291
 GRID    3202    "CID0"  0.00    0.00    0.00    292
 GRID    3203    "CID0"  0.00    0.00    50.0    293
 $
 CORD2R  291     "CID0"  0.      0.      0.      0.00    1.00    0.00
         0.00    0.00    1.00
 CORD2R  292     "CID0"  0.      0.      0.      1.00    0.00    0.00
         0.00    1.00    0.00
 CORD2R  293     "CID0"  0.      0.      0.      0.00    0.00    1.00
         1.00    0.00    0.00
 $
 SPOINT  20001   THRU    20003
 $
 CUSERIN 200     290     3       3       "CID0"
         3201    123     3202    123     3203    123
         20001   THRU    20003
 $
 PUSERIN 290     200     KXX             MXX
 $
 $ "CID0"   is to be replaced with the coord sys ID that is used to define the
 $ basic coord sys of this USERIN elem rel to the system model basic coord sys.
 $ If the above grid entries is used, RBE2's should be included to connect
 $ them to the corresponding grids in the system model
 $
 ********************************************************************************
```

```
                        E I G E N V A L U E   A N A L Y S I S   S U M M A R Y   (MGIV    )

                             NUMBER OF EIGENVALUES EXTRACTED  . . . . . .         3

                             LARGEST OFF-DIAGONAL GENERALIZED MASS TERM     2.5E-11 (Vecs renormed to 1.0 for gen masses)

                                                                    . . .         3
                                       MODE PAIR . . . . . . . . . . .
                                                                    . . .         1

                             NUMBER OF OFF DIAGONAL GENERALIZED MASS
                             TERMS FAILING CRITERION OF  0.0E+00. . . . .         3


                                         R E A L   E I G E N V A L U E S
 MODE  EXTRACTION      EIGENVALUE           RADIANS              CYCLES            GENERALIZED         GENERALIZED
NUMBER   ORDER                                                                         MASS              STIFFNESS

     1       1        8.209320E+04        2.865191E+02        4.560093E+01        1.000000E+00        8.209320E+04
     2       2        1.470796E+05        3.835096E+02        6.103745E+01        1.000000E+00        1.470796E+05
     3       3        7.295666E+05        8.541467E+02        1.359417E+02        1.000000E+00        7.295666E+05
```

```
OUTPUT FOR CRAIG-BAMPTON DOF        1 OF       21 (boundary acceleration for grid    3201 component 1)
CB PROBLEM - SUBSTR 2, GENERATE CB MODEL
SUBSTR GLOBAL IS COORD SYSTEM 29
BARS 3201-3 V IS OA MODEL BASIC Z0, BARS 3204-6 V IS OA MODEL BASIC Y0

                                                C B   D I S P L A C E M E N T   O T M
                                             (in global coordinate system at each grid)
          GRID     COORD      T1            T2            T3            R1            R2            R3
                    SYS
          3201      291  0.000000E+00  0.000000E+00  0.000000E+00  3.863993E-10 -6.960263E-09  4.572454E-08
          3202      292  0.000000E+00  0.000000E+00  0.000000E+00 -8.427715E-08  1.606673E-08  2.200350E-10
          3203      293  0.000000E+00  0.000000E+00  0.000000E+00  2.034509E-08 -8.242526E-09 -9.579740E-08
          3204      294  8.954192E-06  2.284642E-06  2.155154E-06  5.610407E-08 -1.791753E-08 -1.976135E-07

OUTPUT FOR CRAIG-BAMPTON DOF        2 OF       21 (boundary acceleration for grid    3201 component 2)
CB PROBLEM - SUBSTR 2, GENERATE CB MODEL
SUBSTR GLOBAL IS COORD SYSTEM 29
BARS 3201-3 V IS OA MODEL BASIC Z0, BARS 3204-6 V IS OA MODEL BASIC Y0

                                                C B   D I S P L A C E M E N T   O T M
                                             (in global coordinate system at each grid)
          GRID     COORD      T1            T2            T3            R1            R2            R3
                    SYS
          3201      291  0.000000E+00  0.000000E+00  0.000000E+00 -2.270768E-11  7.125241E-11 -3.715046E-10
          3202      292  0.000000E+00  0.000000E+00  0.000000E+00  2.636055E-10 -2.636055E-10  0.000000E+00
          3203      293  0.000000E+00  0.000000E+00  0.000000E+00 -7.125241E-11  2.270768E-11  3.715046E-10
          3204      294 -2.916436E-08 -1.191538E-08 -2.916436E-08 -6.656870E-10  0.000000E+00  6.656870E-10

OUTPUT FOR CRAIG-BAMPTON DOF        3 OF       21 (boundary acceleration for grid    3201 component 3)
CB PROBLEM - SUBSTR 2, GENERATE CB MODEL
SUBSTR GLOBAL IS COORD SYSTEM 29
BARS 3201-3 V IS OA MODEL BASIC Z0, BARS 3204-6 V IS OA MODEL BASIC Y0

                                                C B   D I S P L A C E M E N T   O T M
                                             (in global coordinate system at each grid)
          GRID     COORD      T1            T2            T3            R1            R2            R3
                    SYS
          3201      291  0.000000E+00  0.000000E+00  0.000000E+00 -2.109567E-10  5.870611E-09 -4.005508E-08
          3202      292  0.000000E+00  0.000000E+00  0.000000E+00  7.696471E-08 -1.315541E-08 -2.058377E-10
          3203      293  0.000000E+00  0.000000E+00  0.000000E+00 -1.839181E-08  7.560184E-09  8.689709E-08
          3204      294 -8.163419E-06 -2.027860E-06 -1.803074E-06 -4.751698E-08  1.676144E-08  1.798959E-07                  .
                                                                   .
                                                                   .
                                                                   .
                                                                   .
```

1.6 FEM basic structure and CUSERIN substructures

(input deck CB1d-BASIC-STR-W-CUSERIN-SUBSTRS.DAT)

```
ID CB1,RUN (d)
SOL 3
$
IN4 100 = CB1d-SUBSTR-1-CB-MODEL.OP1  $ INPUTT4 form for matrices for substr 1
IN4 200 = CB1d-SUBSTR-2-CB-MODEL.OP1  $ INPUTT4 form for matrices for substr 2
$
CEND
TITLE = CB PROBLEM - BASIC STR AND 2 SUBSTR'S
SUBTI = SUBSTR'S LOCATED IN SEPARATE COORD SYSTEMS. SUBSTR GLOBAL ARE SEVERAL SYS DEFINED IN EACH SUBSTR DECK
ECHO = UNSORT
SPC    = 1
METHOD = 2
DISP   = ALL
BEGIN BULK
$
EIGRL   2                        10                             MASS
$******************************************************************************
$ Basic str
$ ---------
GRID    100                0.      0.   -50.
$
GRID    111              -25.    -25.   -50.
GRID    211               25.    -25.   -50.
GRID    221               25.     25.   -50.
GRID    121              -25.     25.   -50.
$
GRID    112              -25.    -25.    50.
GRID    212               25.    -25.    50.
GRID    222               25.     25.    50.
GRID    122              -25.     25.    50.
$
CBAR    1001    1101    111     211     0.      0.      1.
CBAR    1002    1101    211     221     0.      0.      1.
CBAR    1003    1101    221     121     0.      0.      1.
CBAR    1004    1101    121     111     0.      0.      1.
$
CBAR    1005    1102    112     212     0.      0.      1.
CBAR    1006    1102    212     222     0.      0.      1.
CBAR    1007    1102    222     122     0.      0.      1.
CBAR    1008    1102    122     112     0.      0.      1.
$
CBAR    1009    1103    111     112     1.      0.      0.
CBAR    1010    1103    211     212     1.      0.      0.
CBAR    1011    1103    221     222     1.      0.      0.
CBAR    1012    1103    121     122     1.      0.      0.
$
PBAR    1101    100     1.      80.     80.     80.
PBAR    1102    100     1.      80.     80.     80.
PBAR    1103    100     1.      80.     80.     80.
$
MAT1    100     10.+06          .3
$
```

```
RBE2    1000    100     123456  111     211     221     121
$
CONM2   1001    111             500.
CONM2   1002    211             500.
CONM2   1003    221             500.
CONM2   1004    121             500.
CONM2   1005    112             500.
CONM2   1006    212             500.
CONM2   1007    222             500.
CONM2   1008    122             500.
$
SPC1    1       123456  100
$
$*******************************************************************************
$ Substr #1
$ ----------
$ CORD2R 10 defines the basic system for substr 1 relative to OA model basic
$
CORD2R  10              -25.    -25.    50.     -20.    -25.    50.     +C10
+C10    -25.    -25.    60.
$
CORD2R  19      10      0.      0.      0.      1.      0.      0.      +C19
+C19    0.      0.      1.
$
GRID    3101    10       0.      0.      0.     19
$
SPOINT  10001   THRU    10003
$
CUSERIN 100     190     1       3       10
        3101    123456
        10001   THRU    10003
$
PUSERIN 190     100     KXX     MXX     RBM0
$
RBE2    1001    112     123456  3101
$
$*******************************************************************************
$ Substr #2
$ ----------
$ CORD2R 20 defines the basic system for substr 2 relative to OA model basic
$ CORD2R 291, 292, 293, 294 are global systems for substr 2
$
CORD2R  20               25.     25.     50.     20.     25.     50.    +C20
+C20     25.     20.     50.
$
CORD2R  291     20      0.      0.      0.      1.      0.      0.      +C29
+C29    0.      1.      0.
$
CORD2R  292     20      0.      0.      0.      0.      1.      0.      +C29
+C29    0.      0.      1.
$
CORD2R  293     20      0.      0.      0.      0.      0.      1.      +C29
```

```
+C29    1.      0.      0.
$
GRID    3201    20       50.     0.       0.     291
GRID    3202    20        0.     0.       0.     292
GRID    3203    20        0.     0.      50.     293
$
SPOINT  20001   THRU    20003
$
CUSERIN 200     290     3       3       20
        3201    123     3202    123     3203    123
        20001   THRU    20003
$
PUSERIN 290     200     KXX     MXX     RBM0
$
RBE2    2001    212     123     3201
RBE2    2002    222     123     3202
RBE2    2003    122     123     3203
$
$******************************************************************************
PARAM   GRDPNT   0
PARAM   WTMASS   .002591
PARAM   PRTDOF   2
PARAM   PRTSET   1
$
ENDDATA
                  .
```

```
       O U T P U T   F R O M   G R I D   P O I N T   W E I G H T   G E N E R A T O R
                       (reference point is basic coord system origin)

                                Total mass =  5.000000E+03

                                       X             Y             Z
                 C.G. location :  1.000000E+00  1.000000E+00  1.800000E+01
                  (relative to reference point in basic coordinate system)


       6x6 Rigid body mass matrix - about reference point in basic coordinate system
***                                                                                     ***
*  5.000000E+03  0.000000E+00  0.000000E+00  *  0.000000E+00  9.000000E+04 -5.000000E+03  *
*  0.000000E+00  5.000000E+03  0.000000E+00  * -9.000000E+04  0.000000E+00  5.000000E+03  *
*  0.000000E+00  0.000000E+00  5.000000E+03  *  5.000000E+03 -5.000000E+03  0.000000E+00  *
*  ************  ************  ************  *  ************  ************  ************  *
*  0.000000E+00  0.000000E+00  0.000000E+00  *  2.137500E+07 -6.250000E+05 -7.500000E+05  *
*  0.000000E+00  0.000000E+00  0.000000E+00  * -6.250000E+05  2.137500E+07 -7.500000E+05  *
*  0.000000E+00  0.000000E+00  0.000000E+00  * -7.500000E+05 -7.500000E+05  6.250000E+06  *
***                                                                                     ***


              M.O.I. matrix - about reference point in basic coordinate system
                       ***                                       ***
                       *  2.137500E+07 -6.250000E+05 -7.500000E+05  *
                       * -6.250000E+05  2.137500E+07 -7.500000E+05  *
                       * -7.500000E+05 -7.500000E+05  6.250000E+06  *
                       ***                                       ***


                   M.O.I. matrix - about c.g. in basic coordinate system
                       ***                                       ***
                       *  1.975000E+07 -6.200000E+05 -6.600000E+05  *
                       * -6.200000E+05  1.975000E+07 -6.600000E+05  *
                       * -6.600000E+05 -6.600000E+05  6.240000E+06  *
                       ***                                       ***


                     M.O.I. matrix - about c.g. in principal directions
                       ***                                       ***
                       *  6.172763E+06 -2.328306E-10 -1.449802E-10  *
                       * -4.656613E-10  1.919724E+07  1.118346E-09  *
                       * -1.325357E-10  1.142523E-09  2.037000E+07  *
                       ***                                       ***


               Transformation from basic coordinates to principal directions
                       ***                                       ***
                       *  5.080514E-02  5.080514E-02  9.974155E-01  *
                       *  7.052793E-01  7.052793E-01 -7.184932E-02  *
                       * -7.071068E-01  7.071068E-01  5.220893E-16  *
                       ***                                       ***
```

```
                                  E I G E N V A L U E   A N A L Y S I S   S U M M A R Y   (LANCZOS  Mode 2 DPB     Shift eigen =  0.00E+00)

                                     NUMBER OF EIGENVALUES EXTRACTED  . . . . . .        10

                                     LARGEST OFF-DIAGONAL GENERALIZED MASS TERM    -7.0E-11 (Vecs renormed to 1.0 for gen masses)

                                                                           . . .         4
                                               MODE PAIR . . . . . . . . . .
                                                                           . . .         2

                                     NUMBER OF OFF DIAGONAL GENERALIZED MASS
                                     TERMS FAILING CRITERION OF  1.0E-04. . . . .        0


                                               R E A L   E I G E N V A L U E S
         MODE  EXTRACTION      EIGENVALUE          RADIANS             CYCLES            GENERALIZED         GENERALIZED
        NUMBER   ORDER                                                                       MASS              STIFFNESS

             1         1        2.682498E+03        5.179284E+01        8.243086E+00        1.000000E+00        2.682498E+03
             2         2        2.726318E+03        5.221415E+01        8.310141E+00        1.000000E+00        2.726318E+03
             3         3        5.121950E+03        7.156780E+01        1.139037E+01        1.000000E+00        5.121950E+03
             4         4        2.254593E+04        1.501530E+02        2.389760E+01        1.000000E+00        2.254593E+04
             5         5        4.873465E+04        2.207593E+02        3.513493E+01        1.000000E+00        4.873465E+04
             6         6        5.145711E+04        2.268416E+02        3.610296E+01        1.000000E+00        5.145711E+04
             7         7        5.822092E+04        2.412901E+02        3.840251E+01        1.000000E+00        5.822092E+04
             8         8        8.792938E+04        2.965289E+02        4.719404E+01        1.000000E+00        8.792938E+04
             9         9        1.045087E+05        3.232780E+02        5.145130E+01        1.000000E+00        1.045087E+05
            10        10        2.864546E+05        5.352146E+02        8.518204E+01        1.000000E+00        2.864546E+05
```

```
OUTPUT FOR EIGENVECTOR        1
 CB PROBLEM - BASIC STR AND 2 SUBSTR'S
 SUBSTR'S LOCATED IN SEPARATE COORD SYSTEMS. SUBSTR GLOBAL ARE SEVERAL SYS DEFINED IN EACH SUBSTR DECK

                                                         E I G E N V E C T O R
                                              (in global coordinate system at each grid)
           GRID     COORD      T1            T2            T3            R1            R2            R3
                     SYS
            100        0  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
            111        0  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
            112        0  2.257796E-01  2.257796E-01  5.556862E-02 -1.831903E-03  1.831903E-03  1.369739E-16
            121        0  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
            122        0  2.253124E-01  2.244884E-01  5.061107E-03 -1.544883E-03  1.930698E-03  1.247654E-05
            211        0  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
            212        0  2.244884E-01  2.253124E-01  5.061107E-03 -1.930698E-03  1.544883E-03 -1.247654E-05
            221        0  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
            222        0  2.248731E-01  2.248731E-01 -6.717091E-02 -1.902515E-03  1.902515E-03  1.456876E-16
           3101       19  2.257796E-01  2.257796E-01  5.556862E-02 -1.831903E-03  1.831903E-03  1.369739E-16
           3201      291  5.061107E-03 -2.244884E-01 -2.253124E-01  0.000000E+00  0.000000E+00  0.000000E+00
           3202      292 -2.248731E-01 -2.248731E-01 -6.717091E-02  0.000000E+00  0.000000E+00  0.000000E+00
           3203      293 -2.244884E-01  5.061107E-03 -2.253124E-01  0.000000E+00  0.000000E+00  0.000000E+00
          10001        0  6.837237E-03  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
          10002        0  6.837237E-03  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
          10003        0  1.313670E-04  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
          20001        0 -1.770954E-02  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
          20002        0 -2.673628E-15  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
          20003        0  3.163012E-04  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00                   .
                                                                    .
                                                                    .
                                                                    .
                                                                    .
```

1.7 FEM basic structure and FEM substructures

(input deck CB1d-BASIC-STR-W-FEM-SUBSTRS.DAT)

```
ID CB1,RUN (a)
SOL 3
CEND
TITLE = CB PROBLEM - PHYSICAL FEM MODELS FOR BASIC STR AND SUBSTR'S
SUBTI = SUBSTR'S LOCATED IN SEPARATE COORD SYSTEMS. SUBSTR GLOBAL IS ONE SYS DEFINED IN EACH SUBSTR DECK
ECHO = UNSORT
SPC    = 1
METHOD = 2
DISP   = ALL
BEGIN BULK
$
EIGRL   2                        10                             MASS
$******************************************************************************
$ Basic str
$ ---------
GRID    100                0.      0.   -50.
$
GRID    111              -25.    -25.   -50.
GRID    211               25.    -25.   -50.
GRID    221               25.     25.   -50.
GRID    121              -25.     25.   -50.
$
GRID    112              -25.    -25.    50.
GRID    212               25.    -25.    50.
GRID    222               25.     25.    50.
GRID    122              -25.     25.    50.
$
CBAR    1001    1101    111     211     0.      0.      1.
CBAR    1002    1101    211     221     0.      0.      1.
CBAR    1003    1101    221     121     0.      0.      1.
CBAR    1004    1101    121     111     0.      0.      1.
$
CBAR    1005    1102    112     212     0.      0.      1.
CBAR    1006    1102    212     222     0.      0.      1.
CBAR    1007    1102    222     122     0.      0.      1.
CBAR    1008    1102    122     112     0.      0.      1.
$
CBAR    1009    1103    111     112     1.      0.      0.
CBAR    1010    1103    211     212     1.      0.      0.
CBAR    1011    1103    221     222     1.      0.      0.
CBAR    1012    1103    121     122     1.      0.      0.
$
PBAR    1101    100     1.      80.     80.     80.
PBAR    1102    100     1.      80.     80.     80.
PBAR    1103    100     1.      80.     80.     80.
$
MAT1    100     10.+06          .3
$
RBE2    1000    100     123456  111     211     221     121
$
CONM2   1001    111             500.
CONM2   1002    211             500.
```

```
CONM2   1003    221             500.
CONM2   1004    121             500.
CONM2   1005    112             500.
CONM2   1006    212             500.
CONM2   1007    222             500.
CONM2   1008    122             500.
$
SPC1    1       123456  100
$
$*******************************************************************************
$ Substr #1
$ ----------
$ CORD2R 10 defines the basic system for substr 1 relative to OA model basic
$
CORD2R  10              -25.    -25.    50.     -20.    -25.    50.     +C10
+C10    -25.    -25.    60.
$
CORD2R  19      10      0.      0.      0.      1.      0.      0.      +C19
+C19    0.      0.      1.
$ GRID    3101    10       0.      0.      0.     19
GRID    3102    10      25.      0.      0.     19
CBAR    3101    3101    3101    3102    0.      0.      1.
PBAR    3101    301     1.      20.     20.     40.
MAT1    301     30.+6           .3
$
RBE2    1001    112     123456  3101
$
CONM2   3102    3102            400.
$
$*******************************************************************************
$ Substr #2
$ ----------
$ CORD2R 20 defines the basic system for substr 2 relative to OA model basic
$ CORD2R 291, 292, 293, 294 are global systems for substr 2
$
CORD2R  20               25.     25.     50.     20.     25.     50.    +C20
+C20     25.     20.     50.
$
CORD2R  291     20      0.      0.      0.      1.      0.      0.      +C29
+C29    0.      1.      0.
$
CORD2R  292     20      0.      0.      0.      0.      1.      0.      +C29
+C29    0.      0.      1.
$
CORD2R  293     20      0.      0.      0.      0.      0.      1.      +C29
+C29    1.      0.      0.
$
CORD2R  294     20      0.      0.      0.      0.      0.      1.      +C29
+C29    1.      0.      0.
$
GRID    3201    20       50.     0.       0.    291
GRID    3202    20        0.     0.       0.    292
```

```
GRID    3203    20        0.     0.      50.    293
GRID    3204    20        0.    50.       0.    294
$
CBAR    3201    3201    3201    3202    1.      0.      0.
CBAR    3202    3201    3202    3203    0.      0.      1.
CBAR    3203    3201    3203    3201    0.      1.      0.
$
CBAR    3204    3201    3201    3204    0.      0.      1.
CBAR    3205    3201    3202    3204    0.      1.      0.
CBAR    3206    3201    3203    3204    1.      0.      0.
$
PBAR    3201    302     1.      20.     20.     40.
MAT1    302     30.+6           .3
 *INFORMATION: MAT1 ENTRY      302 HAD FIELD FOR G  BLANK. MYSTRAN CALCULATED G  =  1.153846E+07
$
RBE2    2001    212     123     3201
RBE2    2002    222     123     3202
RBE2    2003    122     123     3203
$
CONM2   3201    3204            600.
$
$****************************************************************************
PARAM   GRDPNT   0
PARAM   GRIDSEQ  GRID
PARAM   WTMASS   .002591
PARAM   PRTDOF   2
PARAM   PRTSET   1
$
ENDDATA
```

```
       O U T P U T   F R O M   G R I D   P O I N T   W E I G H T   G E N E R A T O R
                        REFERENCE POINT IS BASIC COORD SYSTEM ORIGIN

                                TOTAL MASS =  5.000000E+03

                                       X             Y             Z
                 C.G. location :  1.000000E+00  1.000000E+00  1.800000E+01
                  (relative to reference point in basic coordinate system)


       6x6 Rigid body mass matrix - about reference point in basic coordinate system
***                                                                                        ***
*  5.000000E+03  0.000000E+00  0.000000E+00  *  0.000000E+00  9.000000E+04 -5.000000E+03  *
*  0.000000E+00  5.000000E+03  0.000000E+00  * -9.000000E+04  0.000000E+00  5.000000E+03  *
*  0.000000E+00  0.000000E+00  5.000000E+03  *  5.000000E+03 -5.000000E+03  0.000000E+00  *
*  ************  ************  ************  *  ************  ************  ************  *
*  0.000000E+00  0.000000E+00  0.000000E+00  *  2.137500E+07 -6.250000E+05 -7.500000E+05  *
*  0.000000E+00  0.000000E+00  0.000000E+00  * -6.250000E+05  2.137500E+07 -7.500000E+05  *
*  0.000000E+00  0.000000E+00  0.000000E+00  * -7.500000E+05 -7.500000E+05  6.250000E+06  *
***                                                                                        ***


              M.O.I. matrix - about reference point in basic coordinate system
                       ***                                         ***
                       *  2.137500E+07 -6.250000E+05 -7.500000E+05  *
                       * -6.250000E+05  2.137500E+07 -7.500000E+05  *
                       * -7.500000E+05 -7.500000E+05  6.250000E+06  *
                       ***                                         ***


                   M.O.I. matrix - about c.g. in basic coordinate system
                       ***                                         ***
                       *  1.975000E+07 -6.200000E+05 -6.600000E+05  *
                       * -6.200000E+05  1.975000E+07 -6.600000E+05  *
                       * -6.600000E+05 -6.600000E+05  6.240000E+06  *
                       ***                                         ***


                     M.O.I. matrix - about c.g. in principal directions
                       ***                                         ***
                       *  6.172763E+06  0.000000E+00 -6.017513E-13  *
                       *  1.164153E-10  1.919724E+07  3.742019E-09  *
                       * -2.910383E-11  3.725290E-09  2.037000E+07  *
                       ***                                         ***


               Transformation from basic coordinates to principal directions
                       ***                                         ***
                       * -5.080514E-02 -5.080514E-02 -9.974155E-01  *
                       *  7.052793E-01  7.052793E-01 -7.184932E-02  *
                       *  7.071068E-01 -7.071068E-01  0.000000E+00  *
                       ***                                         ***
```

```
                                E I G E N V A L U E   A N A L Y S I S   S U M M A R Y   (LANCZOS  Mode 2 DPB     Shift eigen =  0.00E+00)

                                     NUMBER OF EIGENVALUES EXTRACTED  . . . . . .        10

                                     LARGEST OFF-DIAGONAL GENERALIZED MASS TERM    -3.8E-11 (Vecs renormed to 1.0 for gen masses)

                                                                           . . .          3
                                               MODE PAIR . . . . . . . . . .
                                                                           . . .          1

                                     NUMBER OF OFF DIAGONAL GENERALIZED MASS
                                     TERMS FAILING CRITERION OF  1.0E-04. . . . .         0


                                                 R E A L   E I G E N V A L U E S
         MODE  EXTRACTION      EIGENVALUE            RADIANS             CYCLES            GENERALIZED         GENERALIZED
        NUMBER   ORDER                                                                          MASS              STIFFNESS

             1       1        2.682498E+03        5.179284E+01        8.243086E+00        1.000000E+00        2.682498E+03
             2       2        2.726318E+03        5.221415E+01        8.310141E+00        1.000000E+00        2.726318E+03
             3       3        5.121950E+03        7.156780E+01        1.139037E+01        1.000000E+00        5.121950E+03
             4       4        2.254593E+04        1.501530E+02        2.389760E+01        1.000000E+00        2.254593E+04
             5       5        4.873465E+04        2.207593E+02        3.513493E+01        1.000000E+00        4.873465E+04
             6       6        5.145711E+04        2.268416E+02        3.610296E+01        1.000000E+00        5.145711E+04
             7       7        5.822092E+04        2.412901E+02        3.840251E+01        1.000000E+00        5.822092E+04
             8       8        8.792938E+04        2.965289E+02        4.719404E+01        1.000000E+00        8.792938E+04
             9       9        1.045087E+05        3.232780E+02        5.145130E+01        1.000000E+00        1.045087E+05
            10      10        2.864546E+05        5.352146E+02        8.518204E+01        1.000000E+00        2.864546E+05
```

```
OUTPUT FOR EIGENVECTOR        1
CB PROBLEM - PHYSICAL FEM MODELS FOR BASIC STR AND SUBSTR'S
SUBSTR'S LOCATED IN SEPARATE COORD SYSTEMS. SUBSTR GLOBAL IS ONE SYS DEFINED IN EACH SUBSTR DECK

                                                         E I G E N V E C T O R
                                              (in global coordinate system at each grid)
           GRID     COORD      T1            T2            T3            R1            R2            R3
                     SYS
            100        0  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
            111        0  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
            112        0  2.257796E-01  2.257796E-01  5.556862E-02 -1.831903E-03  1.831903E-03  4.998794E-16
            121        0  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
            122        0  2.253124E-01  2.244884E-01  5.061107E-03 -1.544883E-03  1.930698E-03  1.247654E-05
            211        0  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
            212        0  2.244884E-01  2.253124E-01  5.061107E-03 -1.930698E-03  1.544883E-03 -1.247654E-05
            221        0  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
            222        0  2.248731E-01  2.248731E-01 -6.717091E-02 -1.902515E-03  1.902515E-03  5.179320E-16
           3101       19  2.257796E-01  2.257796E-01  5.556862E-02 -1.831903E-03  1.831903E-03  4.998794E-16
           3102       19  2.782932E-01  2.782932E-01  5.569766E-02 -2.234869E-03  2.234869E-03  5.000330E-16
           3201      291  5.061107E-03 -2.244884E-01 -2.253124E-01 -1.633467E-05  1.467460E-03 -1.573769E-03
           3202      292 -2.248731E-01 -2.248731E-01 -6.717091E-02  1.535535E-03 -1.535535E-03  5.193797E-16
           3203      293 -2.244884E-01  5.061107E-03 -2.253124E-01 -1.467460E-03  1.633467E-05  1.573769E-03
           3204      294 -3.070889E-01 -7.139002E-02 -3.070889E-01 -1.671972E-03  5.420716E-16  1.671972E-0
```