

APPENDIX K

EXAMPLE OF A SAP-2000 MODEL FOR A SLAB/WALL SYSTEM

*The Creation of a Computer Model Requires Fundamental Knowledge
of Elasticity, Mechanics and Finite Element Approximations*

K.1 INTRODUCTION

During the past several years, it has come to my attention that a few structural engineers, who are using structural analysis programs, are delegating the responsibility of modeling the structure and preparing the input data for the program to individuals who do not have a basic knowledge of structural mechanics. Also, most individuals, who are preparing the computer model, are not aware of the many approximations made in the development of the finite elements incorporated into the program they are using.

Recently, an experienced, practical, structural engineer from India, with an excellent educational background in modern finite element theory, asked me a question (by e-mail), concerning the best approach to model the interaction of vertical walls and slabs using the shell elements and line constraints which are now incorporated into SAP-2000. With 50 years of experience in research, development and use of finite element computer programs, it was not possible for me to immediately suggest a reasonable model. It required a few weeks of part-time thinking to propose a three-dimensional model that satisfied the fundamentals of equilibrium and displacements compatibilities. Therefore, the purpose of this Appendix is to explain the steps required to create a shell and beam element model to capture the interaction at the slab and wall connection.

K.2 THE PROBLEM

Figure K.1 illustrates a simplified finite element model of a wall/slab system. It is apparent that the vertical wall is large, compared to the slab, and can be modeled with a coarse mesh. The slab is thin and requires a fine mesh to capture accurate bending moments near the wall. Also, note that the wall is thick compared to the slab, and the use of only center line geometry may introduce incorrect results. Therefore, additional line

constraints and semi-rigid beam elements must be introduced in order to accurately connect the slab to the wall.

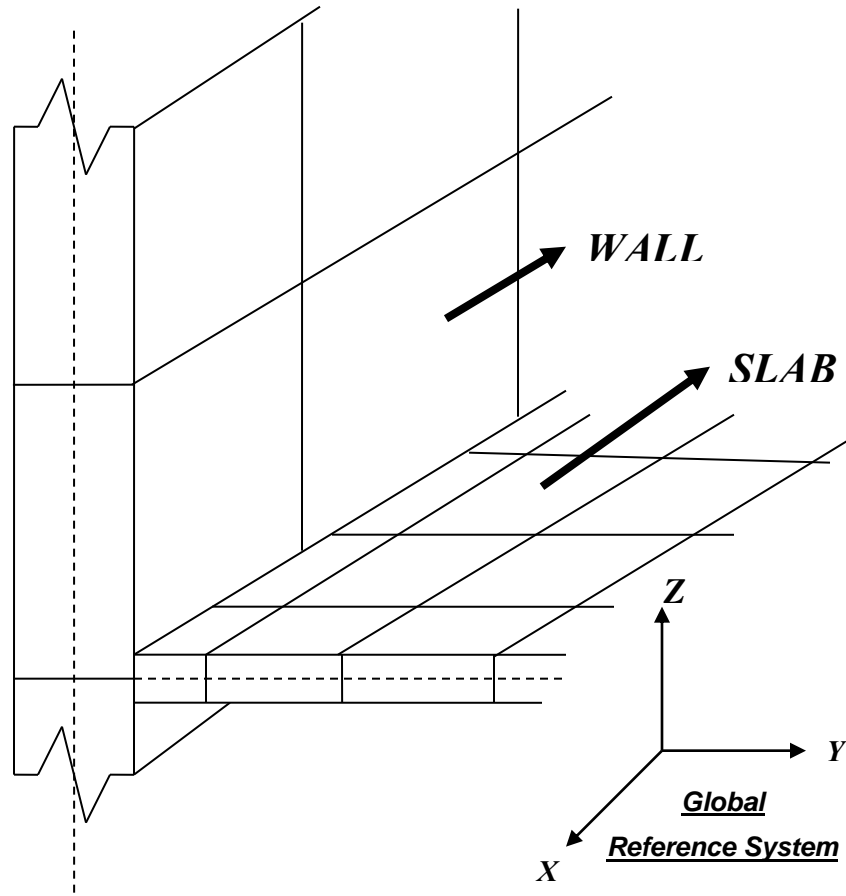


Figure K.1 Finite Element Model of Slab/Wall Interface

K.3 A SHELL/BEAM MODEL OF THE SLAB/WALL SYSTEM

The slab must be connected to the center of the wall where the node points at the interface between the slab and the wall are not at the same location in space. In addition, several different displacement compatibility conditions must be satisfied. However, the user must fully understand that the basic displacement assumptions made during the development of the shell element. Each node of the shell element has 6 global degrees of

freedom - 3 displacements and 3 rotations. However, the rotation normal to the surface of the shell element is not required to be continuous at this complex connection.

Before a finite element model can be created, the following facts must be summarized:

1. The out-of-plane bending deformations of the shell element are cubic functions and the in-plane membrane displacements are parabolic functions. Therefore, a constraint that attempt to force all displacements and rotations to be compatible between the slab and wall should not be enforced.
2. The x-rotation of the center line of the wall should be equal to the x-rotation at the intersection of the wall and slab. This will directly transfer the x-bending moments in the slab to the wall.
3. The x, y and z displacements, at the intersection of the wall and slab, should be slaved to the displacements at the center line of the wall.
4. There is not a logical reason to require the y-rotation and the z-rotation at the centerline of wall to be set equal to the same rotations at the edge of the slab. These types of rotational constraints will definitely stiffen the connection.

A finite element model that satisfies these compatibility conditions is shown in Fig. K.2

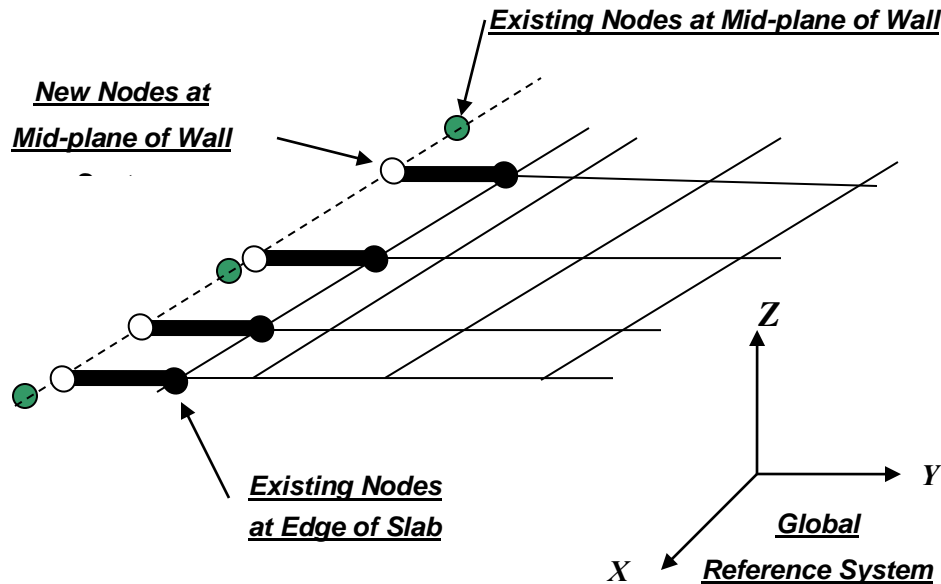


Figure K.2 *Beam/Shell Element Model of Slab/Wall Interface*

Note that the edge of the slab is connected to new nodes located at the mid plane of the wall. The y-rotation and the z-rotation at the mid-plane of the wall and edge of the slab must not be equal. In order to accomplish this it is only necessary to modify the properties of the beam element by introducing the following properties:

1. If the torsional moment of inertia is set to zero, or if a torsional release is introduced in each beam, then the y-rotation at both ends of the beam will not be equal.
2. If a z-moment end-release is introduced in the beams at the edge of the slab, the normal rotation of the slab and wall will not be equal.

In addition, the new and existing nodes at the mid-surface of the wall can be connected using the standard line constraint in the general structural analysis program SAP2000.

The cross-section of the (semi-rigid) link beam in both directions be approximately equal to the thickness of the wall. The user should experiment with these properties by a factor of 10 in order to verify that there will not be a significant change in the design forces as a result of these approximations.

K.4 SHELL ELEMENT MODIFICATION

It is apparent that the introduction of the normal rotation, to improve the membrane behavior of the SAP2000 shell element, causes problems in the area of slab/wall connections. Full compatibility of all six degrees between the wall and slab produces a stiffer connection as the slab mesh is refined. It may be possible for the existing shell element be modified to allow any of the four normal rotations to be released as it is possible with the beam element. The user would have the ability to specify which nodes at the element level are released. Within the program the standard application of the well-known static condensation algorithm would be applied to eliminate the normal rotation specified by the user.

If the normal rotation release option existed the beam element would be eliminated from the slab/wall model shown in Figure K.2. The beams would be replaced by thick shell elements with all four rotations released. Also, the normal rotations at the mid-plane of the wall elements, at the intersection with the slab, would be release.