

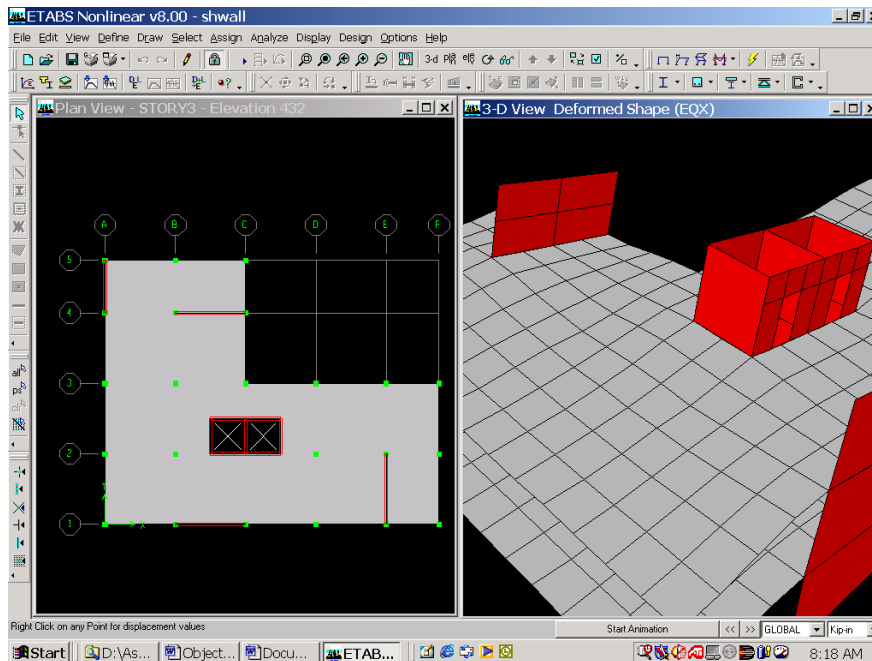
## PHYSICAL OBJECT BASED ANALYSIS AND DESIGN MODELING OF SHEAR WALL SYSTEMS USING ETABS

**Ashraf Habibullah , S.E.**

President and CEO, Computers & Structures, Inc., Berkeley, California

### INTRODUCTION

The accuracy of analytical modeling of complex Shear Wall Systems has always been of concern to the Structural Engineer. The computer models of these systems are usually idealized as line elements instead of continuum elements. Single walls are modeled as cantilevers and walls with openings are modeled as pier/spandrel systems. For simple systems, where lines of stiffness can be defined, these models can give reasonable results. However, it has always been recognized that a continuum model based upon the finite element method is more appropriate and desirable. Nevertheless this option has been impractical for the Structural Engineer to use in practice primarily because such models have traditionally been costly to create, but more importantly, they do not produce information that is directly useable by the Structural Engineer. However, new developments in ETABS using object based modeling of simple and complex shear wall systems, in an integrated single interface environment, has made it very practical for Structural Engineers to use finite element models routinely in their practice.



**3-D Shear Wall Building - Object Based Physical Model  
Auto Meshing with Line Constraints**

**Figure 1**

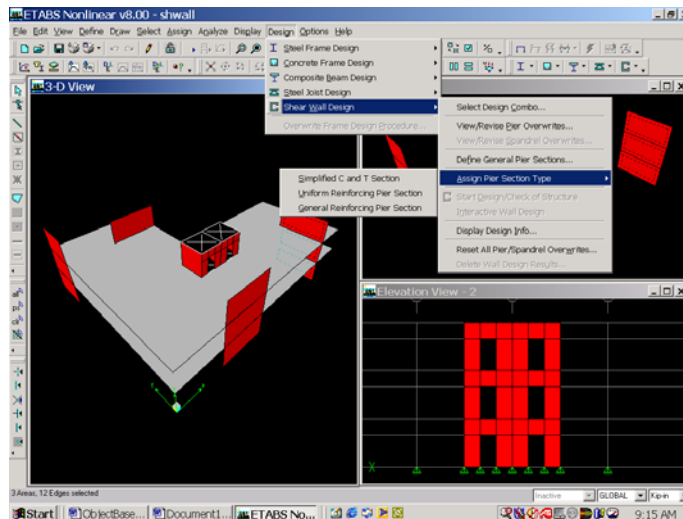
## ADDRESSING THE MESH TRANSITION FIASCO THE AUTOMATED LINE CONSTRAINT

In the use of the finite element analysis the most time consuming task is usually the creation and modification of the finite element mesh of the system. In the object-based environment of ETABS the Structural Engineer need only create the few large objects that represent the physical wall panels and openings and does not explicitly create a finite element mesh and associated elements. See Elevator Core in Figure 1, where the top floor plate has been hidden for clarity. The finite element analytical model is created automatically using parameters assigned by the Engineer as internal properties of the objects.

**In ETABS, mesh compatibility between adjacent objects is enforced via automated line constraints that eliminate the need for the user to worry about mesh transitioning for mismatching meshes at interfaces of adjacent objects. These displacement interpolating line constraints are automatically created as part of the finite element analytical model at intersections of objects where mismatched mesh geometries are discovered.**

The same object based technology is equally applicable to floor slabs, thereby allowing the user to create finite element models of complete 3-D building systems. A typical floor is modeled as one large Area Object as shown in Figure 2. The whole floor plate is one L-Shaped Area Object and Opening objects have been placed over floor objects to punch holes for the elevator core. The finite element mesh is defined by properties that are assigned to the objects. Line Constraints automatically appear at interfaces of intersecting floor and wall objects to enforce displacement compatibility when mesh geometries do not match. As illustrated in the deformed shape of the Elevator Core in Figure 1, in many places the wall meshing does not match the floor meshing. The elements on all sides of the common edges, however, show no incompatibilities.

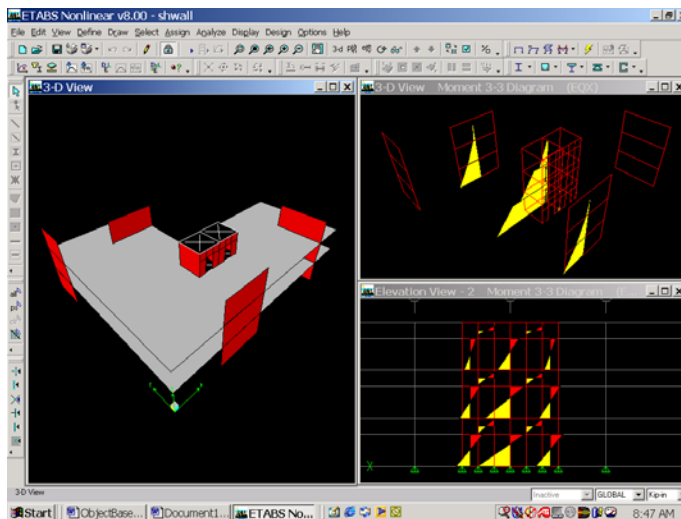
What makes this technology really powerful is that while making modifications to the model the Engineer need only be concerned about the few large physical objects of the structure. The modified finite element analytical model gets recreated automatically with any changes to the base objects.



**Shear Wall Design Options In ETABS**  
**Figure 2**

## DESIGN FORCES FROM THE FINITE ELEMENT ANALYSIS

Automated grouping of objects allows the user to create piers and spandrels that will produce integrated moments and shears across sections of walls for design purposes. For instance 3D integrated design section forces (Moments, Shears, etc.) for a channel shaped wall, made up of three wall objects can be automatically generated from the finite element mesh just by assigning the three wall objects to a pier. The integration is done by summing the nodal forces obtained from the product of the stiffness matrix and the displacements of the elements and not by integrating the stresses of the finite elements. This way the forces that are obtained are always in static equilibrium with the applied loads irrespective of the refinement of the mesh. See Figure 3.



**Integrated Bending Moments  
For the Finite Element Model of Elevator Core  
Figure 3**

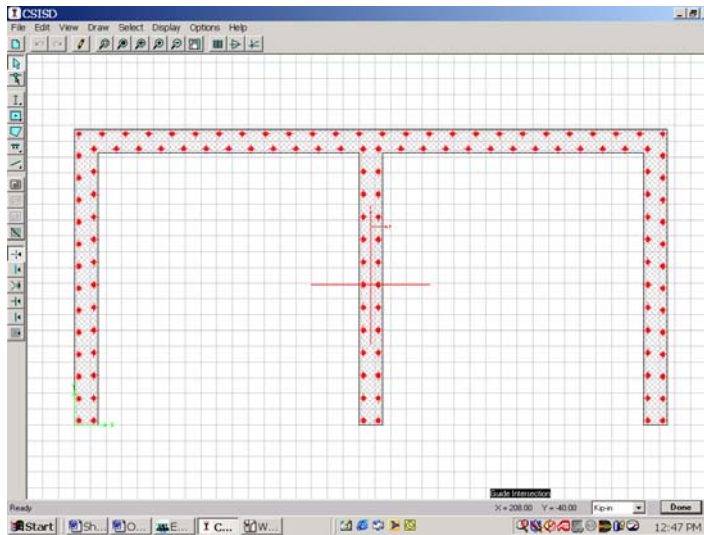
## OBJECT BASED SHEAR WALL DESIGN

With a pier being defined as an assemblage of wall elements, ETABS can design the wall by calculating the reinforcing that will be required to resist all the combinations of loads that the structure is to resist. The reinforcing distribution can easily be specified by the user as an assignment of typical reinforcing, or detailed on a bar-by-bar basis. See Figures 4 and 5. Three dimensional interaction diagrams are created and the reinforcing is calculated such that all load points, each represented by an axial force and biaxial moments, lie within the interaction volume.

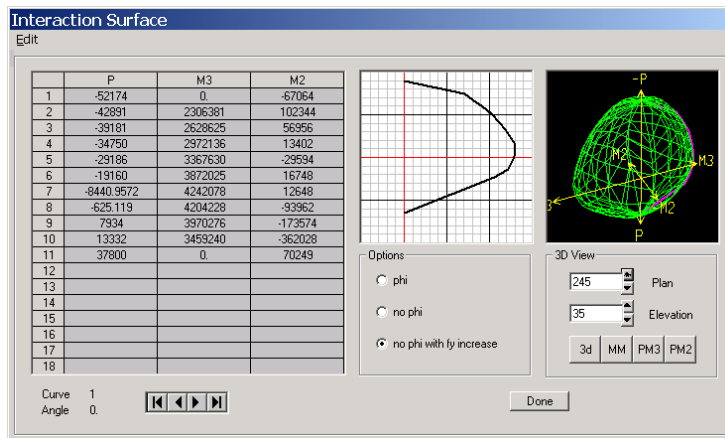
A simplified direct design method is also available where the wall overturning moment and axial force is resolved into edge C and T forces and edge trim reinforcing provided for any net uplift.

Design for shear forces is implemented by integrating forces across each linear leg individually. This procedure will automatically include the effects of torsion across non-planar sections.

See Reference 2 for details of the design procedures.



**Elevator Core Assemblage  
Reinforcing Layout – Using ETABS Section Designer  
Figure 4**



**Elevator Core Assemblage  
Inter-Action Diagram – Using ETABS Section Designer  
Figure 5**

## SUMMARY AND CONCLUSIONS

- The Physical Object based Finite Element Model makes the application of the Finite Element Method for the analysis and design of complex perforated shear walls and three dimensional core walls very practical for the Structural Engineer.
- In Physical Object based modeling the Structural Engineer creates the actual physical model of the using building large line and area objects. The Analytical Model is created automatically using the geometry of the physical model and mesh properties of the objects that are defined by the Engineer.
- Mesh compatibility between adjacent objects is enforced via automated line constraints that eliminate the need for the user to worry about mesh transitioning for mismatching meshes at interfaces of adjacent objects
- Grouping of the Area Objects into Piers is a very powerful mechanism to automatically obtain Design Moments and Shears across a wall section from a finite element analysis.

## REFERENCES

1. Computers & Structures, Inc., “*ETABS – Integrated Building Analysis & Design, User Interface Manual*,” January 2002
2. Computers & Structures, Inc., “*ETABS – Integrated Building Analysis & Design, Shear Wall Design Manual*,” January 2002
3. *Computers & Structures, Inc Website: [www.csiberkeley.com](http://www.csiberkeley.com)*