Consulting engineer John F. Meeks, recently posed the question, "As long as wood truss design continues to be done in the shops of truss component and truss manufacturers, can their already three-dimensional computer program technology to be used to include 'system design' of the entire roof or floor system?"

Meeks is referring to U.S. Truss Plate Manufacturers (TPMs), who use their own computer programs to design trusses. Although these programs render complex architectural designs, they cannot design whole truss assemblies. Limited to designing assemblies on a truss-by-truss basis — as in conventional truss design — they analyze forces in individual trusses rather than the assembly as a whole.

Meeks suggests a solution to this problem, which has been discussed for several decades. No consensus exists on how to include system effects in assembly design. In the past, researchers tried to simplify the problem by developing system or load sharing factors similar to the repetitive member factor in bending, which can be used in conventional truss design. Much of the research to develop these factors has included analyzing unrealistic truss assemblies such as symmetrical ones that include few trusses. None of these factors — except bending — are part of state or national building codes.

Technological advances and high-speed computers can include system effects using three-dimensional structural analysis software by analyzing real truss assemblies that include actual geometry and construction conditions. Researchers at Oregon State University have used Extended Three-Dimensional Analysis of Building Systems (ETABS) software in recent studies to model several Fink and parallel chord single trusses and a simple pin-truss assembly.

"... perhaps it is time for the industry to add value to the structural system design . . ."

Model results matched experimental values and the study showed suitability of this software for investigating truss assembly system behavior.

To investigate system performance, researchers used SAP2000 software to analyze an actual roof truss assembly obtained from a TPM. The TPM also provided designs for 54 individual trusses plus two gable and trusses in the assembly. Analysis included the TPM's exact joint models and properties for single trusses and trusses in the assembly:

- Frame elements were used to model all wood truss members.
- Sheathing was modeled as beams on both sides of the ridge, spanning perpendicular to the top chord of the trusses.
- The sheathing beams, modeled as frame elements, were rigidly connected to the truss top chord.
- Sheathing beam elements were assigned the same thickness, width and stiffness as plywood.

To simulate and idealize connections between walls and trusses, the model used pin supports for both ends of trusses in the assembly. In practice, even though conventional single truss design is based on a pin support at one end and a roller support at the other, the same connection hardware is used at both ends in nearly all connections. Using pin supports at both ends represents...
This roof truss assembly was provided by a truss plate manufacturer and used to analyze system performance with SAP2000 software.

But researchers found that support reactions based on assembly analysis varied and were different from those derived from conventional truss design. The differences were primarily due to interactions between subassemblies and effects of boundary conditions such as gable end trusses.

The whole assembly analyzed for system performance comprised three subassemblies. Interaction between subassemblies depended on the connections between them. In one case, several trusses of one type in a subassembly were supported by the bottom chords of a truss in another subassembly. This situation is not modeled by conventional truss design and can impact the distribution of forces in the assembly.

Gable end trusses also affected the force distribution in an assembly, which is not modeled by conventional truss design. Researchers found that trusses next to gable end trusses had lower CSI values compared to values based on conventional truss design methodology. The stiff gable trusses tend to attract load away from adjacent trusses. Factors that are important in real assemblies can be either overlooked or are not present in the simple assemblies generally used to examine system factors. These studies demonstrate changes in individual truss behavior, due to system effects, when part of an assembly. A truss assembly model can be used to consider system effects directly. It can also provide a fuller description of truss behavior in the assembly compared to the conventional design method based on single trusses or single trusses plus a proposed system factor.

Commercially available software used by practicing engineers can enhance wood truss assembly design and analysis. As Mosk notes, "... perhaps it is time for the industry to add value to the structural system design ...

The benefits of using an assembly model instead of the conventional truss design method include:

• improved truss system design by including system behavior directly;
• increased safety through improved analysis and
• potential construction cost reductions.

ASAE member Rakesh Gupta is associate professor in the department of forest products, Oregon State University, Corvallis, OR 97331, USA; 541-737-8223, fax 541-737-3815, rakesh.gupta@orst.edu.

Tom Miller is associate professor in the department of civil, construction and environmental engineering, Oregon State University, Corvallis, OR 97331, USA; 541-737-3322, thomas.miller@orst.edu.