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- Indiana Repertory Theatre; Stage Floor & Trap System Indianapolis, IN

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## New Loads for Old Structures

*Is the building strong enough and how can I find out for sure?*

*The following is an excerpt of the original article.*

Entertainment venues are perhaps among the most varied types of buildings — ranging from new multi-million dollar facilities designed specifically for touring shows to converted old churches, theatres or schools. While the new performing arts centers get all the attention, it's much more common for a performance venue to be an older or converted facility. One of the greatest unknowns in converting or re-fitting an older building is the load carrying capacity of the structure. The loads imposed by large flying units, heavy wagons, and modern lighting and sound equipment are not trivial.

### DETERMINATION OF CAPACITY -- WHERE TO BEGIN

Evaluating a new load case and its impact on an existing structure requires two general sets of information; what are the new and existing load cases and what is the capacity of the structure?

#### Load Cases

Structural engineers use load cases (the sum of all the loads acting on a structural element or system at one time), as defined by building codes, to determine how to design a structure.

For a preliminary evaluation, you will need to know the magnitude of the proposed loads and the possible combinations of those loads. Getting some feel for the relative magnitude of new and existing loads will go a long way towards understanding if your new load case is small or large relative to the existing loads.

#### Current Capacity of the Structure

The need to determine the capacity of an existing structural element is directly related to the consideration of risk — the magnitude of the new loads relative to the existing loads, or the risk of property damage or injury related to failure.

Structures are generally designed to meet two broad sets of criteria; strength and serviceability. Strength is the ability of the structure to safely support the load without overstressing any part of the structural system.

Serviceability addresses the fitness-for-use of a particular structural component for a specific load case and is sometimes defined in terms of deflection. For example, a floor system with excessive deflection can feel bouncy or unsafe. Excess deflection can also cause cracks and deterioration of finishes. Most building codes place a limit on allowable deflection for structural members — one of the more common applies to live load deflection.

There are many other forces and combinations of forces that act on a structure, including earth pressure, stress due to changes in temperature, residual stresses from fabrication, etc.

When analyzing a large portion of a structure such as a roof, be careful to consider the impact of non-intuitive forces acting on the system — gravity loads are fairly apparent, wind loads and other lateral loads are not so obvious.

*Article continues on back page.*

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The full version of this article originally ran in the Winter 2002 issue of Protocol, the quarterly journal of the Entertainment Services and Technology Association. For more information visit [www.esta.org](http://www.esta.org)

AFFILIATE MEMBER  
**ESTA**  
ENTERTAINMENT SERVICES & TECHNOLOGY ASSOCIATION

ESG was formed to address the growing need for structural engineering in the entertainment industry.

As the entertainment industry grows there is an increasing need to address building code requirements, to ensure that structures are adequately strong & safe, and to address the realities of liability issues in today's society.

### GLOSSARY

**Live load** Loads imposed on a structure by people or items that are not permanently attached to the structure.

**Dead load** Loads imposed on a structure that are part of the permanent structure.

**Load case** A combination of various loads acting simultaneously.

**Deflection** A change in the shape of a structural element due to an applied load.

**Stress** Force divided by area (e.g. pounds per square foot).

**Allowable Stress** Stress applied to an element that does not result in a permanent change in the shape of the element.

**Load path** The series of elements in a structure that resist a specific load.

### 3 STEPS TOWARDS EVALUATING EXISTING STRUCTURES

#### Initial Evaluation

Determine the age of the structure. Buildings built after about 1940 in the U.S. were generally designed to support minimum loads as defined by building code. The older the building, the less likely it is that the concept of design loads were used. If you cannot find, or reasonably assume minimum design loads, you must do some analysis.

For example, you may be able to show that the actual loads are less than the design loads, the structure is stronger than the design load requirements, or that a slightly larger amount of deflection is acceptable. A roof structure designed for a 20 psf dead load may actually only be supporting 10 psf, leaving room for some additional load onto the structure.

#### Structural Evaluation

If you do not feel comfortable with an approximate analysis you should locate or develop an accurate set of plans, which allow you to define complete load paths. In addition, you will need to make a reasonable determination as to the material strength. With this information, you can proceed with a more formal analysis. Remember, if you have *not* defined a complete load path for your loads, down to the foundation, you have not adequately modeled the structural system.

#### In-Place Load Tests

If the structural evaluation is not conclusive, this method can be very valuable in proving the capacity of an existing structure. Many structures have redundancies in their designs that allow them to carry more load than they may have been designed for. Full-scale tests using large amounts of bulk material are frequently cumbersome to perform, but they can be very simple and effective.

#### SUMMARY

The structural evaluation of an existing building can be done in a wide variety of ways with a range of accuracy, but will provide a general gauge of the risk of imposing new load onto an existing structure. In some cases, if the new loads are small relative to the existing loads, you can do your own evaluation and feel quite comfortable that the structure is safe. However, if after an initial assessment you are not fully confident with your own analysis, you may want to contact a structural engineer.

Don't take a chance with life safety; keep evaluating until you are sure that you have a comfortable and conservative answer.

#### Disclaimer and References

This article is not intended to be a thorough treatment of the topic of structural evaluation of existing buildings. Local, state and national building codes need to be consulted prior to the renovation or use of existing structures. The author cannot be responsible for any evaluation based solely upon this article.

Readers interested in more information may find the following basic structural analysis texts to be of interest: *Simplified Engineering for Architects and Builders*, 9th Edition by James E. Ambrose and *Structural Design for the Stage* by Holden, Sammler & Sammler.