STATIC vs DYNAMIC MODELING

The basic format for tests and/or analyses of seismic resistant systems follow one of the following two primary paths, static or dynamic modeling. Within these major categories there are a myriad of detailed approaches that will not be addressed here. Instead, this document will focus on the significant differences between the static and dynamic models, what can be gained from each and when one might be preferred over another.

The static analysis involves applying a force either mathematically to a mathematically modeled system or to apply an actual force to a physical model. This force must be applied in the direction that will generate the largest possible static forces in the equipment, the equipment anchorage and the restraint. The force at that restraint is then measured or computed for comparison to the statically rated capacity of the restraint, the equipment, the anchorage device or the local load conditions on the structure. In order to use this analysis to address the forces that occur in a dynamic situation, like an earthquake, a factor (or series of factors) is then applied to the computed forces. These factors have been "fine tuned" with experience and currently offer a high degree of confidence. Unfortunately, these amplified factors can only be directly related to the structural performance of the system.

In a dynamic analysis, a time varying input force is used. The force is generated from historical ground acceleration data from an earthquake that has properties that are expected to be similar to those that would be experienced at the proposed project site. The amplitude of this profile is adjusted upward or downward to provide peaks that coincide with the seismic design values for the project.

In the case of equipment, if the study is done analytically, a model that not only addresses the basic geometry of the system, but also models the dynamic cushioning in the restraint device itself is needed. If an actual sample is tested, samples of the equipment, restraints and anchorage systems as well as a shake table large enough to mimic the appropriate seismic accelerations are necessary. In addition, the dynamic input forces must accurately portray not only the expected earthquake, but must also accurately account for the direction of the wave front and the impact of dynamic factors in the structure.

On the surface, it is obvious that a dynamic test will be considerably more expensive than would be a static one. In order for it to be justified in the practical world, there is a requirement that if offers a fair trade-off in value to the end user.

Dynamic modeling has been most commonly used with regard to building structures and with systems were failure can result in serious danger or loss of life (Nuclear facilities for example). With regard to the building structures themselves, there are several factors that allow dynamic models to offer easily justified benefits. First, the cost of the analysis, compared to the cost of the structure, is relatively low. In addition, since buildings are generally "one-offs", they normally include extensive individualized design work specific to

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the application anyway and as such, frequently are already "modeled". An additional factor specific to a structure is that the consequences of failure, from a life-safety standpoint, are significant. Finally, from a cost/benefit side, the use of a dynamic model can open the potential to reduce or simplify the structure and can actually reduce its cost.

With regard to those applications involving the potential for extremely hazardous material release, cost is not even an issue. It is critical to all concerned that the system is analyzed in absolutely the best way possible. Both static and dynamic modeling methods should be used and conservative factors applied to the result.

Hospitals and other facilities that must remain operational after a seismic event pose more of a dilemma. The dynamic analysis of the structure can often be justified as noted above, however the mechanical equipment inside can be a problem. Of primary concern is the current requirement identified in the IBC and TI-809-04 codes for critical equipment to remain operational. This means that not only must the equipment be structurally substantial enough to ride out an event, but also that its internals must be tough enough that the tremor will not generate internal mechanical failures. There is no practical way to model this statically. Instead, the individual equipment component parts must be designed to accept significant forces within allowable fatigue limits. This type of analysis is common for vehicles or other devices that are subject to dynamic loads, but is not commonly used in the design of static equipment. The only other option would be to perform substantial dynamic testing over a wide input spectrum (both in frequency and direction) on existing equipment. This would likely cost considerably more than the value of the equipment itself.

Note that the above also holds true for those pieces of equipment in non-critical structures, but who's continued operation after a seismic event would be needed to ensure life-safety.

Benefits of a static analysis become clear in non-critical applications. Here, the use of static techniques and appropriate factors offer conservative, easily documented and repeatable results that can confirm the structural durability of the equipment and anchorage for minimal cost. In these cases (where continued operation of the equipment is not required), life safety can be addressed simply by applying a conservative static analysis.

In these applications, if the potential cost or downtime that might result from internal damage to this equipment is a significant issue, features could be added internally by the manufacturers for minimal cost that could increase the confidence level of continued operation greatly. The key here is that the cost to offer a 90% chance of success would only be a fraction of the cost that would be required to guarantee success.

Over the long term, it is likely that equipment designed to be installed in seismically active areas, will become more robust and will be designed to meet some reasonable fatigue

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criteria. Once this becomes common practice, much of the need to perform detailed dynamic analyses or testing of this equipment will likely disappear.

Currently, the best “value” is to perform static analyses with the inclusion of appropriate factors on all equipment installations. The resulting forces can be used to validate the capability of the equipment to remain in place during an appropriate seismic event.

Where it is necessary to certify the continued operation of the equipment as well, current practice is that it be dynamically tested or analyzed. At best, this is not comprehensive and requires that all factors are appropriately accounted for, that the actual ground forces experienced are similar to those assumed in type, frequency and magnitude and that the unit in the field behaves at least as well as the unit in the lab.

Better than the dynamic qualification test however, is that the equipment should be “designed” to withstand all anticipated and factored forces expected on its internal components within the fatigue limits of the materials that make it up and with some reasonable additional safety factor.

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