THE ABC'S OF IBC SEISMIC COMPLIANCE

Earthquakes are a real problem and it is not just a California issue anymore. There have been a number of devastating earthquakes recently. January 12, 2010, a 7.0 earthquake hit Haiti, leveling much of Port-au-Prince. February 27, 2010, an 8.8 in Chile topples entire buildings. The city of Christchurch, New Zealand was rocked by a 7.0 in September 4, 2010 followed by a strong targeted 6.3 on February 22, 2011. The one-two punch destroyed hundreds of buildings. A 9.0 earthquake with tsunami shocked Japan on March 11th. Japans northern shore experienced total devastation and caused a state of emergency for four nuclear reactors. And most recently a 5.8 in Virginia surprised the mid-Atlantic region in September. In the wake of recent tragedies, it is natural to begin to wonder just how vulnerable we are here at home. Recent earthquakes revealed holes in the code regarding equipment, which resulted in changes to the code. Chapter 17 of the international Building Code (IBC) requires manufacturers of designated equipment to provide a "certificate of compliance". Despite being introduced a decade ago, questions and concerns still surround IBC-2009 requirements for cooling towers and similar equipment. In the wake of this requirement, registered design professionals (RDPs), authorities having jurisdiction (AHJ), manufactures have grasped for concrete direction on obtaining such a certification. This paper will show how to achieve IBC compliance, outline who is responsible with regards to doing so, and outline the process whereby project principals can secure IBC seismic certificate of compliance.

The Confusion

Over the years, third-party certification has been marginalized to the point that engineers, manufacturers, and building officials have lost the true meaning of certification. There is no good definition of IBC certification. The situation is clouded by language within the IBC that requires certification by "approved agencies." Considering the code does not well define an "approved agency," this leaves the door wide open. In the least credible path to product qualification, a manufacturer could designate itself as an "approved agency." This would be very cost effective for the manufacturer, but certainly not credible in the eyes of an RDP, AHJ, or building owner.

Many manufacturers have incorrectly claimed to be certified or have the ability to certify products through "self-certification." Certification is not when one sample piece of their equipment meets the requirements of an industry adopted standard/criteria or complies with a building code section. "Approval" of an agency does not give the agency the right to certify products. An AHJ giving approval is not the same as certification. And, there is no consistency in the AHJ requirements. Furthermore, there is a difference between qualification and certification. These situations have confused the entire manufacturing industry.

Understanding the difference between qualification and certification

Qualification is intended to ensure that a product design correctly and completely implements a specification and will meet the proper standards and requirements. Qualification may involve passing or successfully satisfying a test or analysis requirement. Qualification records include appropriate documentation and deem a product design officially "on record" as qualified to perform a special function.

Qualification involves a one-time sample product performance evaluation by test or analysis. However, this is just the first step toward certification. Certification includes third-party review of qualification for compliance to industry standards. Certification also ensures that the product manufacturer has a quality control program so that all future products manufactured will meet the original qualification or product performance. Table 1 describes the different qualification and certification processes and provides a relative level of credibility associated with each process. For example, a standard product that is "qualified" by shake-table test or engineering analysis is "Level 4 Qualification."

Certification is a confirmation of certain characteristics of an object, person, or organization. This confirmation shall be provided by an external review (third party) and includes an assessment. One of the most common types of certification is product certification. This refers to processes intended to determine if a product meets minimum standards and quality assurance. Organizational certification is provided by an *accredited* (not approved) agency, and the accreditation is given by a body that accredits certifying organizations. Product qualification determines if *one sample product* supplied by a manufacturer meets seismic and/or wind load requirements. In terms of credibility, refer to "Level 4" in Table 1.

Third-party product certification by an accredited listing agency reviews the product qualification records *and* inspects quality assurance procedures, which provide a higher level of confidence that the qualified product will consistently meet seismic and/or wind load requirements. This review is simplified if the manufacturer has an ISO registered quality plan. Third-party certification is critical for products. Qualifying one standard product is not enough. Inspection by an accredited listing agency substantiates the credibility of the manufacturer's ability to reproduce the qualified product. In terms of credibility, certification backed by an accredited third-party listing agency would result in "Level 6" in Table 1. One such listing agency is Seismic Source International (www.seismic-source.com)

Is the Certificate of Compliance worth the paper on which it is printed
Now that we know what is required to qualify equipment. How can the RDP, AHJ, and our competition know that the qualification is legit? If manufacturer A is doing it right and manufacturer B is getting his cousin Vinnie to rubber stamp a useless certificate, then which do you think will be cheaper, and which will a contractor purchase? Even NASA goes with the lowest bid. So a certificate is only as good as the quality assurance behind it. Table 1 shows how credibility increases with increased quality assurance requirements. It is essential, then, that the construction community pushes for Certification and verification by accredited third parties.

The need for equipment to survive and earthquake is important to the building community. While the change has started slow, it has now come to fruition and Owners, RDPs and AHJs want the assurance of compliance with the IBC. It is time for equipment manufactures to gear up to meet the demand or be left behind.

	Qualification Certification Level	Basis of Evaluation	Explanation of Basis	Credibility
Qualified by test or analysis	1	None	Manufacture Provides Certificate of Compliance without any evidence, testing, or evaluations.	0%
	2	Testing or Analysis	Manufacturer qualifies products by non accredited agency or qualifies product by some other means such as analysis.	
	3	Testing at Accredited Laboratory	Testing is performed per a test program that meets ISO 17025 and is accredited.	
Approved Agency	4	(Certified) Qualification Agency Document Preparation	Provide assurance that the equipment testing and qualification meets adopted industry standards and has quality program that meets ISO 9001.	
Certified By Accredited IB	5	QA Record Verification (ICC-ES)	Material Certification Agency requires accredited testing and factory inspection by an accredited IB to criteria less than an ISO 9001.	
	6	Factory Inspection by Accredited Inspection Body (IB)	Listing service verifies qualification documentation to industry adopted standards and performs accredited IB factory inspection to ensure QA manual and records meet ISO 9001.	
	7	Product Certification Agency (PCA)	Performs all above per ISO Guide 65.	100%

Table 1

What Building Owners Want

An owner wants a building that will be safe and reliable. The building must be able to withstand human and environmental loads without failure. A good design is expected to protect the public, limit personal injury and protect property. Not only is it important to make a building that is structurally sound, but the non-structural components such as mechanical, electrical, plumbing, etc. (MEP equipment) must be designed to withstand seismic loads to protect an owners investment. Per Figure 1 the largest cost in a building is not in its' structure, but in the components that go into the building. Depending on the building usage, the cost of MEP systems and other non structural components can be from 48% to 70% of the cost of the building. In addition, economic considerations play a vital role in the building design. The cost of a building being down due to earthquake damage may exceed the cost of the building. Lost revenue, lost production, lost records and lost data can cause irrecoverable economic loss. In order for a building to perform its' intended function after an earthquake, the mechanical systems, including cooling towers, must survive and function post earthquake. Secondary damage is often a bigger culprit. If a pipe breaks off at its' connection to a cooling tower, pump, or even a small terminal unit, the floor or entire building can be flooded and knocked out of commission.

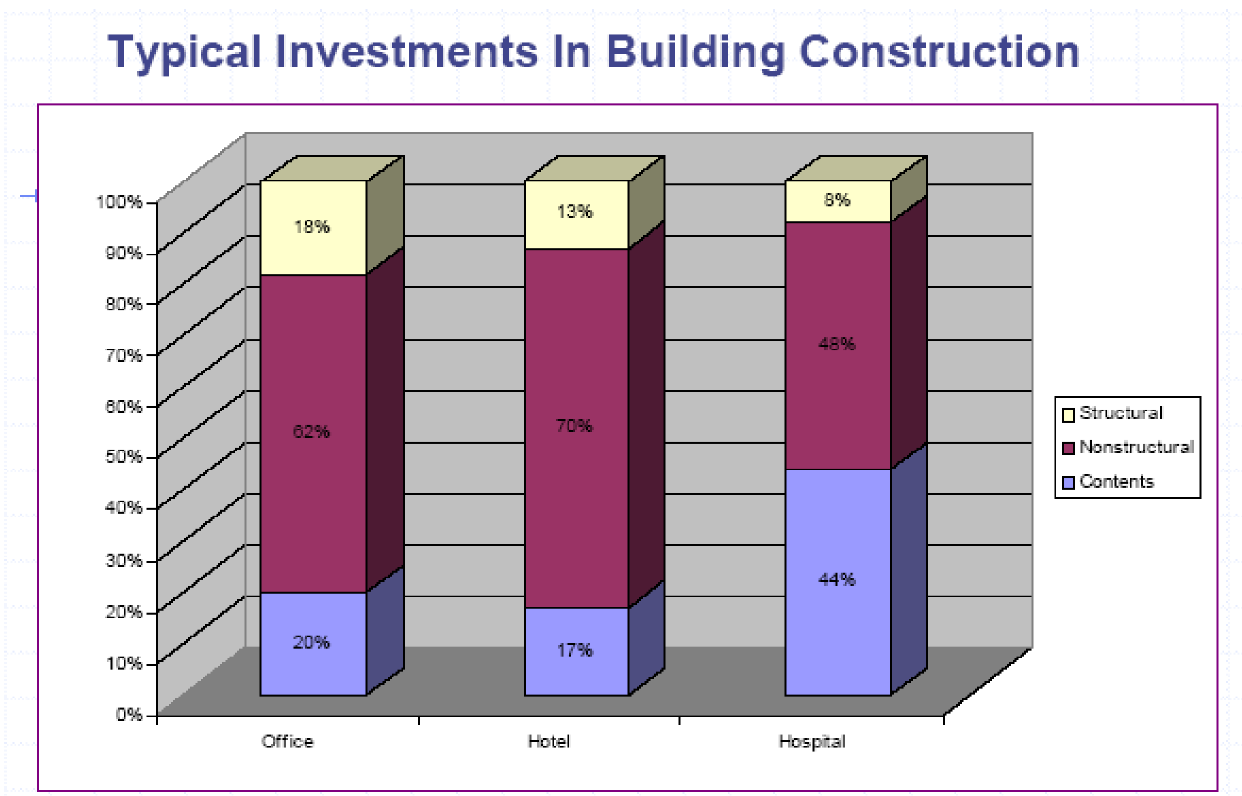

FIGURE 1

While big picture goals of better, safer, more efficient buildings are important goals in a project, it can be the mundane tasks and requirements that ultimately concern an owner the most. Permits, approvals, meeting local codes and the like can bog down any job and grind it to a halt. When Engineers were surveyed about what they are most concerned when constructing a new building, code compliance was one of the top four(CSE, August, 2010). The number one question asked of engineers by owners was about code compliance. Not green, not aesthetics, not even budget, but **code compliance**. Because one can have the most attractive, green and efficient building plan, but if the building does not meet codes, then there will be no approval of occupancy. So a lack of compliance can put a developer's capital and annual insurance costs at great risk. It is no wonder that code compliance was at the top of the list of concerns.

In short, building owners just want a building that will perform its intended function, and survive reasonably expected natural events without crippling the building or its operation.

Code Requirements

The implementation of the IBC had three significant impacts on seismic requirements for equipment:

1) Design for earthquakes is no longer just in California. Figure 3 is a map of Maximum Credible Earthquake acceleration for the United states base on the IBC maps. Any project located in a colored region has to consider earthquake loads. Figure 4 gives some fast facts for earthquake activity across the U.S.
2) More complicated and sophisticated formulas were developed to calculated the anticipated load on a piece of equipment, considering the location in the building and dynamic response of different types of equipment.
3) Equipment now had to provide some evidence that it was designed to withstand the anticipated seismic load. It was no longer acceptable to just anchor it down. Figure 5 is an excerpt from the IBC 2000 code that first required equipment qualification.

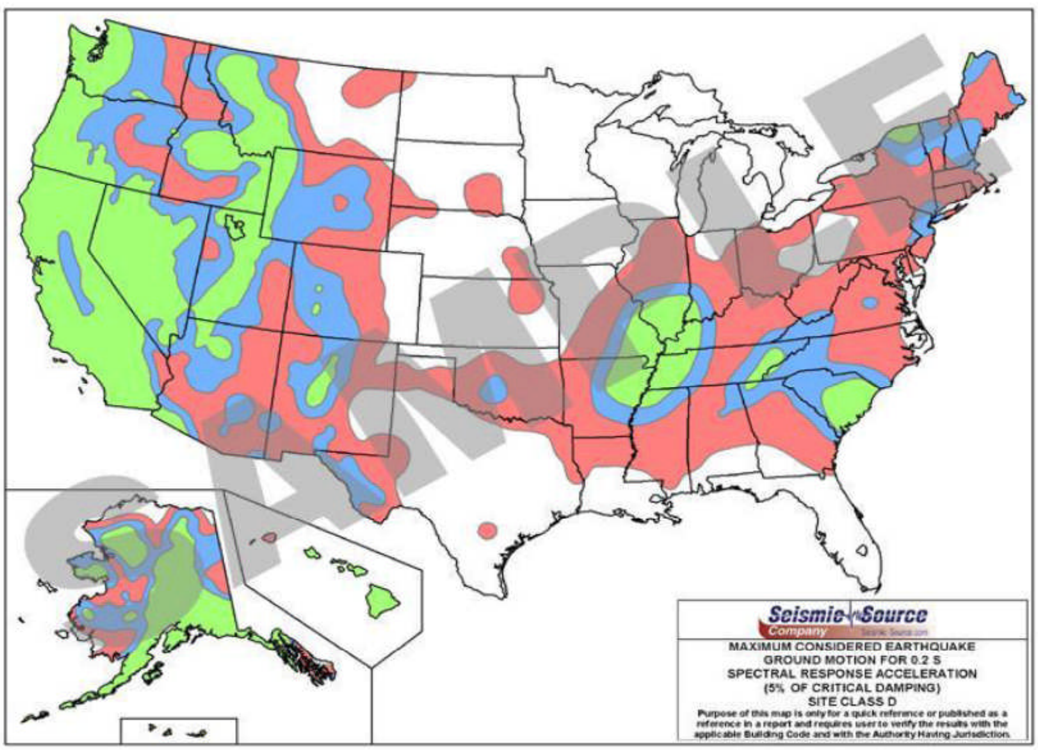

FIGURE 3

EARTHQUAKE STATS

- All 50 states have experienced an earthquake
- 39 are at risk of moderate to major earthquakes
- US has 10 moderate earthquakes per year
- 2 Earthquakes per week in the New Madrid region (Memphis to St. Louis)
  - M6+ Every 70 years….40-60% M6 Within 15 yr
- 5.5 -6.5 M in Utah about once every 7-10 years
- California experiences the most frequent damaging earthquakes; however, Alaska experiences the greatest number of large earthquakes.
- Earthquakes occur most frequently west of the Rocky Mountains, although historically the most violent earthquakes have occurred in the central United States.
- The largest earthquakes felt in the United States were along the New Madrid Fault in Missouri, where a 3-month-long series of quakes from 1811 to 1812 included three quakes larger than a magnitude of 8 on the Richter Scale. These earthquakes were felt over the entire eastern United States (over 2 million square miles), with Missouri, Tennessee, Kentucky, Indiana, Illinois, Ohio, Alabama, Arkansas, and Mississippi experiencing the strongest ground shaking.
- Worldwide (17) 7.0 to 7.9 earthquakes occurs each year. About 1 great earthquake (8.0+) per yr.

FIGURE 4

1708.5 Mechanical and electrical equipment.
Each manufacturer of designated seismic system components shall test or analyze the component and its mounting system or anchorage and shall submit a certificate of compliance for review and acceptance by the registered design professional in responsible charge of the design of the designated seismic system and for approval by the building official. The evidence of compliance shall be by actual test on a shake table, by three-dimensional shock tests, by an analytical method using dynamic characteristics and forces, by the use of experience data (i.e., historical data demonstrating acceptable seismic performance), or by more rigorous analysis providing for equivalent safety. The special inspector shall examine the designated seismic system and shall determine whether the anchorages and label conform with the evidence of compliance.

FIGURE 5

It has been a decade since this requirement was introduced, but the equipment manufacturers have had little direction on how to best meet the seismic qualification requirement. Since then, the code has gone through three updates (2003, 2006, and 2009). Some changes and additions have been made, but there are still misconceptions about seismic qualification. Most questions fall within two categories:

1) When is qualification required?
2) What is the minimum code requirement to obtain qualification?

When is Seismic Qualification Required?

There are three code criteria that dictate when equipment may be exempt from seismic qualification.

1. ***The Seismic Design Category (SDC)*** - A classification assigned to a structure based on its Occupancy or Risk Category (Emergency Facility, public assembly, warehouse, etc), the severity of the design earthquake ground motion at the site as defined by the IBC map similar to figure3, and the soil stiffness (rock solid, or shifting sand). The Seismic Design Category ranges from A to F. A is the least severe. F is the Most Severe. We won't go into all the details of how the SDC is determined as that could be an article unto itself, and we already need a strong cup of coffee to keep awake through the topic at hand. The good news is that the registered design professional for the project gives that to us. The general information page of the structural drawings is required by the IBC to list the SDC. It is typically on the first page of the structural drawings. In addition, most mechanical specifications will also give the SDC.

2. ***The Equipment Importance Factor (Ip)*** - The factor given to each piece of equipment indicating if it is important for the equipment to be operating after an earthquake. If the equipment is important or hazardous, then it is given an Importance factor Ip = 1.5. If it is not important or hazardous, then it is given an Importance factor Ip = 1.0. All components are assigned a component importance factor based on the following:

   > The component importance factor, *Ip*, shall be 1.5 if any of the following conditions apply:
   > 1)The component is required to function for life-safety purposes after an earthquake, including fire protection sprinkler systems and egress stairways.
   > 2)The component conveys, supports, or otherwise contains toxic, highly toxic, or explosive substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released.
   > 3)The component is in or attached to a Risk Category IV structure (emergency facility) and it is needed for continued operation of the facility or its failure could impair the continued operation of the facility.
   > 4)The component conveys, supports, or otherwise contains hazardous substances and is attached to a structure or portion thereof classified by the authority having jurisdiction as a hazardous occupancy.
   >
   > All other components shall be assigned a component importance factor, *Ip* equal to 1.0.

   While the code gives direction on minimum Importance factor requirements, the owner has the prerogative to require an Ip of 1.5 for any equipment based on risk of economic loss should the equipment fail. The importance factor decision must be made by the Registered Design Professional in conjunction with the building owner, based on the anticipated use of the equipment and its' need to operate post earthquake.

3. ***The Equipment Weight and mounting method*** - Smaller equipment may be exempt based on its' weight and whether it is floor mounted or hanging.

Armed with these 3 bits of information, (SDC, Ip, Weight & Mounting method) it can be determined if equipment is exempt from seismic requirements using Figure 6.

Equipment Exemptions

- Equipment in Seismic Design Category A or B
- Equipment in Seismic Design Category C where Ip = 1.0
- Rigidly Floor Mounted Equipment in Seismic Design Category D, E, and F where $I_p = 1.0$, equipment is mounted at 4 feet (1.22 m) or less above a floor level, and weighs 400 pounds (1780 N) or less. Suspended, wall mounted and flexibly mounted equipment are not included in this exclusion.
- Hanging, wall mounted, and flexibly supported components that weigh 20 pounds (89 N) or less and $I_p = 1.0$.
- Equipment items installed in-line with the duct system (e.g, fans, heat exchangers and humidifiers) with an operating weight less than 76 pounds (334 N). Equipment must be rigidly attached to duct at inlet and outlet, and duct must be restrained

Note: Flexible connections between the components and associated duct work, piping and conduit must be provided for all exemptions.

FIGURE 6

If the equipment is exempt, then there are no special seismic requirements. Simply install the equipment per manufacturer's instructions. If the equipment is not exempt and has an importance factor of 1.5, then the equipment shall be proven to be functional after an earthquake. If the importance factor is 1.0 or the equipment is not required to be functional after an earthquake, the equipment shall be designed not to structurally fail or fall over. Operational is not required, but a structural evaluation of the equipments substructure and attachment is required.

What is the minimum code requirement to obtain seismic qualification?

So you're not lucky enough to be exempt. Now what? Is it off to the shaker table to test? Not necessarily. Sometimes you can do analysis, sometimes shake table testing, or sometimes a combination of the two. But before we can determine what our requirements are, we need to go over some code definitions.

> **DESIGNATED SEISMIC SYSTEM.** Those architectural, electrical and mechanical systems and their components that require design in accordance with Chapter 13 of ASCE 7 and for which the component importance factor, *Ip*, is greater than 1 in accordance with Section 13.1.3 of ASCE 7.

ACTIVE EQUIPMENT. Equipment with dynamic moving or rotating parts or parts that are energized. Typical "Active Equipment" are fans, pumps, cooling towers and electrical switchgear. Equipment such as tanks, heat exchangers, enclosures, stands and pipe are examples of "Non-Active Equipment". Active designated seismic equipment constitutes a limited subset of designated seismic systems.

RUGGED EQUIPMENT. Past earthquake experience has shown that some active equipment is inherently rugged. Equipment such as pumps, compressors, valves, pneumatic controls and electric motors are examples listed in ASCE 7-C13. Analysis of the load path and anchorage is adequate to demonstrate compliance of active equipment such as these. For example, a base mounted pump would require analysis of the load pathbetween the pump and motor to the base and to the building structure attachment.

SEISMIC INTERACTION. Per IBC, Chapter 23 and ASCE, Chapter 13, the effects of seismic relative displacements shall be considered in combination with displacements caused by other loads as appropriate, including the dynamic effects of the equipment, its contents, and its supports. The interaction between the equipment and the supporting structures, including other mechanical and electrical equipment, shall also be included. Each nonstructural component's seismic interactions with all other connected components and with the supporting structure shall be accounted for in the design.

CERTIFICATE OF COMPLIANCE. (IBC, 1702, 1708): A certificate stating that materials and products meet seismic force requirements and specified standards or that work was done in compliance with approved construction documents. Each manufacturer of designated seismic system components shall test or analyze the component and its mounting system or anchorage and submit a certificate of compliance for review and acceptance by the registered design professional in responsible charge of the design of the designated seismic system and for approval by the building official. Qualification shall be by an actual test on a shake table or by an analytical method using dynamic characteristics.

APPROVED AGENCY. (IBC, 1702): An established and recognized agency regularly engaged in conducting tests, analysis, qualification, or furnishing inspection services, when such agency has been approved.

SPECIAL SEISMIC CERTIFICATION (ASCE 13.2): Designated, Active mechanical and electrical equipment that must remain operable shall be certified by the supplier based on approved shake table testing or experience data.

LABEL. (IBC 1702, ASCE 13.2): An identification applied on a product by the manufacturer with mfg. name, function performance, name of an approved agency that indicates that a representative sample of product has been tested and(/or) evaluated by the approved agency.

CERTIFIED/REGISTERED(LISTED): Written assurance (certificate) by an independent, accredited external body that audits the manufacturer's management system, verifies conformance to a standard, and records certification in client register.

ACCREDITED IB: formal recognition by an accreditation body (IAS-International Accreditation Service) that a certification body is competent to carry out certification in specified business sectors. Accreditation is like certification of the certification body, providing increased credibility.

Now we can determine what is required for seismic qualification. See figure7 for a flow chart.

Step 1) Determine if equipment is exempt (Figure 6). If not move to the next step.

Step 2) Determine if the equipment has been deemed a "Designated Seismic System" by the engineer of record. This would mean the equipment has an Ip=1.5 and that the equipment must operate as intended post earthquake. If not, then stop - Special Seismic Certification is not required. All that is required is anchorage calculations to insure the equipment will remain in place, and the manufacturer certifies that the equipment has been designed to withstand seismic without consequential damage. The equipment is simply designed not to structurally fail or fall over. Operational is not required, but an evaluation of the equipments substructure and attachment is required. This prevents the unit from causing damage to other essential equipment. This type of certification can be based on pertinent industry reference standards for manufacturing the equipment (ASME, MSS, AHRI, etc.). The method of certification is up to the manufacturer. If it is a designated system then proceed to step 3.

Step 3) Is the system rugged? This is ultimately up to the registered design professional (RDP) and the authority having jurisdiction (AHJ) to approve. There are some such as that have made lists of approved rugged equipment. Table 1 lists some typical industry accepted rugged equipment. Ask the RDP and AHJ. If approved, then stop - all that is required is a Certificate of Compliance verifying that the equipment is approved as rugged and that anchorage calculations have been performed. If it is not rugged then proceed to step 4.

TABLE 1

Typical rugged
Pump
Valve
Electric motor
Pneumatic controls
Compressors
Tanks

Step 4) Is the equipment "Active Equipment"? If not, then the analysis may be used to qualify the equipment and create the Certificate of Compliance. If it is "Active, then proceed to Step 5.

Step 5) Determine if the equipment is a candidate for a combined analysis plus shake table testing or if the unit as a whole must be shake table tested. This decision is different for every type of equipment. It must be determined by coordination between a manufacturer and the qualifying engineer or agency that is performing the qualification work for the equipment manufacturer. It must also be acceptable to the RDP and approved by the AHJ. If the equipment will be by combined analysis plus shake table testing, then static portions such as the base and enclosure of the equipment are qualified by analytical methods using Finite Element Analysis and traditional engineering calculations and practices, considering dynamic characteristics and maximum considered earthquake forces as required by the code. Analysis verifies the unit is designed to withstand applied seismic loads by analyzing all load paths from top of the enclosure, through the base and to the attachment to the building. Active components in the equipment supplied by others and mounted on or within the enclosure would have independent seismic certificates of compliance based on shake table tests supplied by the component manufacturer. All load paths from the connection of the active and static components through the equipment and to the building attachment would be verified analytically. On the other hand, some equipment that contains fragile components, contains complex seismic interaction, and is not inherently rugged cannot be analyzed with enough accuracy to be useful. For complex or fragile components, shaker table testing may therefore be the only practical way to ensure that the equipment will be operable following a design earthquake. In general, custom and field built up equipment are good candidates for a combined method. "Off the shelf" items are good candidates for shake table testing. It is vitally important to communicate with the Qualifying Agency, RDP and AHJ to verify which method is acceptable.

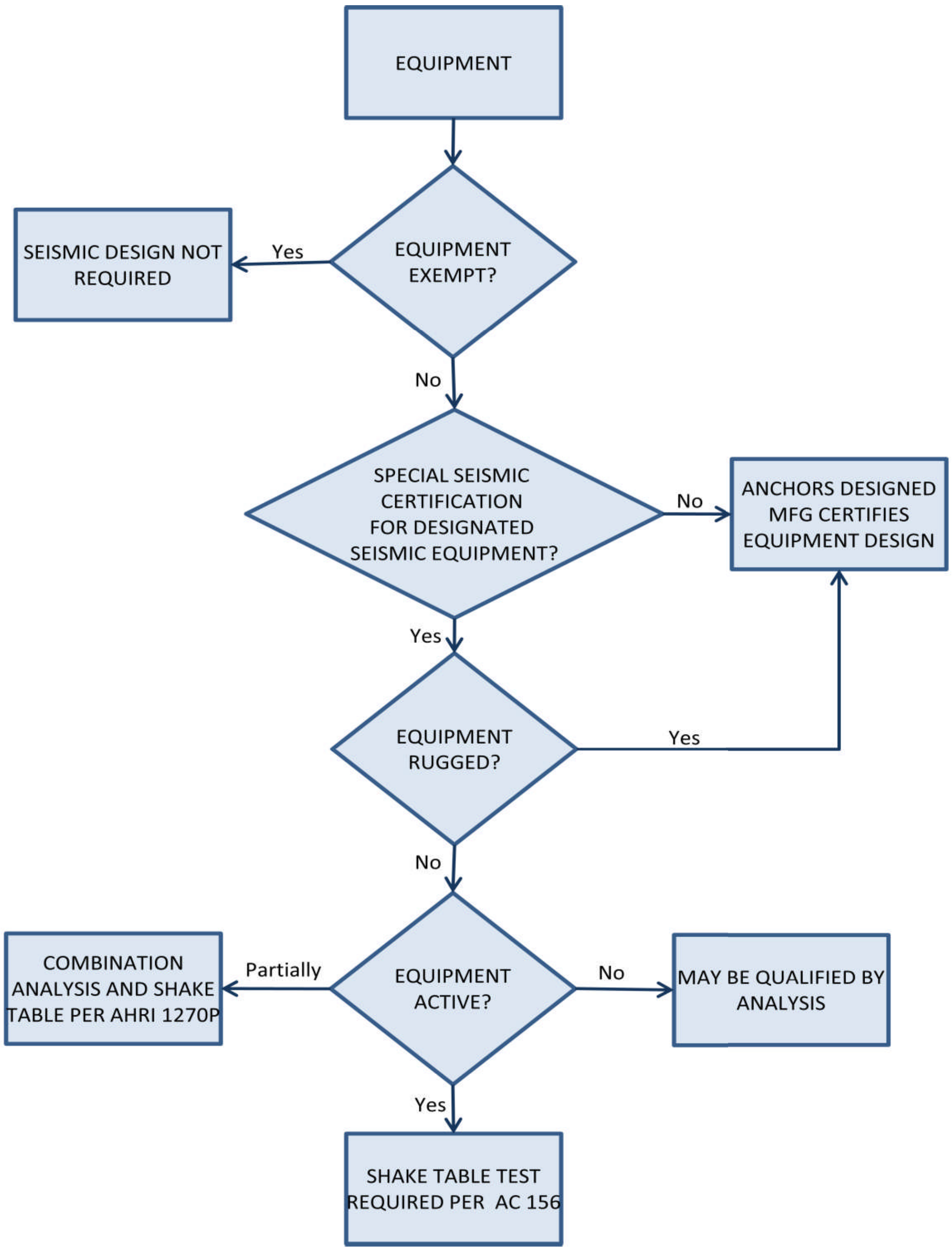

FIGURE 7