NISTIR 5785

Summary and Results of the NIST Workshop on Proposed Guidelines for Testing and Evaluation of Seismic Isolation Systems

July 25, 1994
San Francisco, California

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U.S. Department of Commerce
Ronald H. Brown, *Secretary*
Technology Administration
Mary L. Good, *Under Secretary for Technology*
National Institute of Standards and Technology
Arati A. Prabhakar, *Director*

Abstract

In 1994, the Building and Fire Research Laboratory (BFRL) of the National Institute of Standards and Technology (NIST) published comprehensive draft guidelines for testing and evaluating seismic isolation systems. The procedures outlined in the guidelines include all the required tests of the isolation system, from the early stages of development (pre-qualification tests), to final production tests (quality control tests). The final guidelines for testing, which will be developed based on the draft guidelines and review comments from industry representatives, will benefit the seismic isolation industry and facilitate wider use of this technology. The guidelines will also serve as the basis for a national, consensus-based standard for testing and evaluating seismic isolation systems, that is being developed by the American Society of Civil Engineers.

A workshop was held on July 25, 1994 in San Francisco, California, to solicit feedback on the draft guidelines. The workshop provided a forum to review and discuss the draft guidelines. More than thirty representatives from the seismic isolation industry attended. The format of the one-day workshop included short presentations, open discussion and two working group sessions. The purpose of the report is to provide a written summary of the discussions that took place at the workshop. Furthermore, recommended revisions to the draft guidelines are outlined based on the working group discussions.

The workshop provided important and substantive feedback on the draft guidelines as described in this report. Several issues stimulated considerable debate among the groups including, scale model testing, performance criteria, quality control testing, factors of safety, aging of isolation systems, and the sustained compression test for elastomeric systems. New concerns were also raised that should be addressed in the final guidelines, such as, third party inspection of the test procedure, a test to evaluate the re-centering capability of the isolation system, and a direct shear test for elastomeric systems. Revisions have been formulated to address many of these issues. The suggested revisions should improve the final guidelines so that they are of most use to the seismic isolation industry.

Acknowledgements

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1. INTRODUCTION

The Building and Fire Research Laboratory (BFRL) of the National Institute of Standards and Technology (NIST) has recently published a comprehensive set of draft guidelines for testing and evaluating seismic isolation systems. The guidelines are contained in three reports (Shenton 1994a, Shenton 1994b, Shenton 1994c):

NISTIR 5359	**Draft Guidelines for Prequalification and Prototype Testing of Seismic Isolation Systems**
NISTIR 5345	**Draft Guidelines for Quality Control Testing of Elastomeric Seismic Isolation Systems**
NISTIR 5371	**Draft Guidelines for Quality Control Testing of Sliding Seismic Isolation Systems**

The procedures outlined in these guidelines include all the required tests of the isolation system, from the early stages of development (pre-qualification), through the design phase (prototype), and finally to production type tests (quality control (QC)). The final guidelines, which are being developed from the draft guidelines and comments on the draft guidelines from representatives from industry, will serve as a resource document for individuals and agencies involved in the design and construction of isolated structures. The final guidelines, when published, should benefit the seismic isolation industry and facilitate the wider use of this technology. The guidelines will also serve as a basis for a national, consensus-based standard for testing and evaluating seismic isolation systems that is being developed by the American Society of Civil Engineers.

The NIST draft guidelines were developed in close collaboration with industry. An Oversight Committee, consisting of five experts from the field, assisted in developing the draft guidelines. The committee helped define the test procedures and performance criteria, reviewed the draft guidelines, and generally provided guidance and feedback as the documents were developed.

Since they were published, an effort has been made to foster support for the guidelines and to solicit comments and feedback from the user community. The goal of this activity has been to develop a broader perspective of the needs and interests of the community, so the final guidelines will be of most use to the industry. As part of this effort, more than 200 copies of the guidelines have been distributed to researchers, practitioners, and agency representatives with a request for comments. Responses have been received from more than 40 individuals. In addition, presentations on the guidelines have been made at numerous professional meetings. The principal mechanism for soliciting feedback, however, was a workshop held on July 25, 1994 in San Francisco, California. The purpose of the workshop was to provide a forum for review and discussion of the draft guidelines. More than thirty representatives from industry, government and the research community attended. The format of the one-day workshop included short presentations, open discussion and two working group sessions. Participants were divided into three working groups. All three groups were given the same task, with only limited instruction and direction: to discuss the draft guidelines and debate issues related to testing. Discussion in the three working groups was recorded by BFRL engineers.

The purpose of this report is to provide a summary of the discussions that took place at the July, 25 workshop in San Francisco. Also, to formulate, based on these discussions, recommended revisions to the draft guidelines. The report is organized as follows. A summary of the working group discussions is presented in Chapter 2. The summaries are brief and include recommendations that arose from those discussions. Presented in Chapter 3 are the recommended revisions that have been formulated based on the working groups discussions. Conclusions are presented in Chapter 4. The Appendix includes the list of workshop participants, workshop agenda, a list of questions and suggested topics for group discussion, and working group assignments.

2. SUMMARY OF GROUP DISCUSSIONS

2.1 Working Group #1

A list of topics for discussion was developed by the working group; it includes issues raised in the Workshop document as well as others raised by the participants. Questions discussed are summarized below.

2.1.1. *Do the draft guidelines address the issues that are of greatest concern to engineers and owners? If a complete set of pre-qualification test results were available from the vendor, would the designer/user be satisfied?*

Discussion in the group varied from one topic to another. There was no final answer or resolution to the questions raised. Much of the discussion focused on how pre-qualification, prototype and quality control testing are related, when each is required, when certain tests can be excluded, and how many and what size units are tested in each case. There was generally some confusion as to how these issues relate to each other. Some of the more significant comments are listed below.

- How do you ensure the credibility of the pre-qualification? Who conducts the tests, the manufacturer or an independent testing laboratory? Pre-qualification is a mechanism where unqualified individuals and organizations are screened out from bidding on isolation projects. Manufacturers with a broad range of experience are attempting to infiltrate the field of base isolation, when in many instances they are not qualified.

- An "approved manufacturer program" is needed, and inspection of the pre-qualification tests should be conducted by a third party.

- If a comprehensive pre-qualification test program is in place, would the prototype tests still be needed? Prototype testing slows down project schedules considerably. In fact, the lack of popularity of seismic isolation is due, in part, to the fact that isolation hardware cannot be delivered in a timely fashion because of the time needed to conduct prototype tests.

- Does pre-qualification enable the user to circumvent prototype testing if it envelopes the project requirements, or is the purpose of pre-qualification to show that a manufacturer has the experience to provide products with accurate and reliable properties?

- If a manufacturer has conducted prototype and quality control (QC) tests of a large lot of production units (testing say 5% of the lot), and then the units are shelved for two years, is it necessary to conduct QC tests when some of these units are finally sold?

- In a recent project, 17 out of 70 units were rejected simply because the properties varied more than was specified for the project. If someone else wishes to purchase these units, which have been subjected to the complete set of prototype and QC tests, should these tests be required again?

- Is it possible under certain circumstances to eliminate prototype testing and increase production testing requirements? Certain owners/designers are more interested in production test results. The motivation for this strategy is that commercial projects are not going to utilize base isolation if the procurement process is too lengthy.

2.1.2. *Are these acceptance or testing guidelines? Should the Working Group focus on testing procedures or acceptance criteria? The latter will vary with application.*

One participant noted that there is a major difference between testing guidelines and acceptance criteria. There are several areas where the draft guidelines appear to do both. It was felt that the document should specify clearly how to conduct the tests and how to present the test results; however, the engineer of record should make the decision regarding the acceptance of the seismic isolation system, since this will vary depending upon the application. For example, the criteria for a hospital may be quite different from those for a two-story condominium. The document should refrain from including pass/fail acceptance criteria. It was felt that the document would be of most value for the longest period of time if it allows the engineering community the freedom to make decisions regarding the acceptance criteria of seismic isolation systems. Another participant felt that the document attempts to do both.

2.1.3. *Are the guidelines structured in such a way that they will be of use to the industry? Should they be combined into a single document?*

There was no general consensus among the group on whether the guidelines should be combined into one, or left as three separate documents. One participant recommended maintaining three separate documents, while another recommended combining them into one, noting that this would make for easier reference when a standard is finally prepared. Another participant felt that the first document (Pre-Qualification and Prototype Testing Guidelines) could be made sufficiently general to cover any kind of isolation system, with appendices provided to include specific information for each type of system.

2.1.4. *Dynamic testing: this issue is raised time and again when testing is debated. Facilities do not exist to test full scale isolation units at the actual period of isolation. Therefore, to establish the frequency or velocity dependence, scale model tests must be conducted. An attempt has been made to address this issue in test I.2 of NISTIR 5359; however, the issue is still not resolved. How can this be resolved in a rational and consistent manner? Should guidelines be provided to help resolve disputes between owners and manufacturers on this issue?*

Discussion initially focused on existing test facilities in the United States. The U.S. Department of Energy's (DOE), Energy Technology Engineering Center (ETEC) in southern California, is believed to be the most sophisticated facility for testing isolation bearings in the United States today. Units up to 1320 mm (52 in) in diameter can be tested, with horizontal design displacements as large as 760 mm (30 in). At a frequency of 2 Hz, up to 190 mm (7.5 in) of horizontal displacement can be developed.

Views varied in the group on the need for dynamic testing. One participant noted that in view of the fact that the largest testing facility in the U.S. cannot quite test large bearings dynamically in real time, does it make sense to require such tests in the guidelines? Another questioned the merit of testing individual full size bearings dynamically in real time: since the materials can be tested dynamically in real time, is there any other information that can be gained from a full size, real-time dynamic test of an isolation unit? Yet another participant suggested that this issue be considered in the broader context of other structural systems: steel moment frame connections, concrete beam-column joints, and other structural system components are all tested monotonically. What is the rationale for imposing a higher standard on base isolation systems? In response it was noted that other structural components do not rely on velocity dependent properties of the system for design, and, in most cases, strain rate effects are negligible. In base isolation, on the other hand, design properties may be affected by the load rate or frequency of loading. Furthermore, failure of a moment connection is usually not catastrophic, whereas the failure of an isolation unit could be catastrophic.

Others felt that some dynamic testing was necessary to determine if there is a dependency on rate of loading. In this case, testing smaller components at design capacity was felt to be acceptable: a few cycles at high velocity should suffice. Another participant noted that the number of cycles is immaterial, as the requirements and cost of the testing facility are the same.

2.1.5. *Scale model testing: this is another issue that continues to be raised whenever testing is debated. Because of limits of existing test facilities some tests must be conducted on scale model specimens. Full scale tests are recommended in the guidelines; however, scale model testing is permitted when the test capabilities would otherwise prohibit any such test. The guidelines recommend a scale factor of not less than 1/4. Is this too large or too small? Should it be limited based on the size of the prototype unit? Would this depend on the type of system or type of test being conducted?*

There was general consensus among the group that 1/4 scale should be the lower limit of acceptable scaling in any test. Also, it was felt that scaling is appropriate for determining the dependence on rate of load, temperature and other factors, but very inappropriate for determining the ultimate or failure capacity of the system. Failure characteristics are difficult to model and can only be obtained with confidence from full-scale tests.

It was noted that the Department of Energy has a program underway to assess scaling effects. Component tests and shake table tests are to be conducted. Full size isolation units are being used for all tests, except in the case of the largest size bearings, in which 1/2 scale specimens are to be used. For the shake table studies 1/4 scale model specimens are to be used.

One participant suggested that static and dynamic scale model tests be used to establish a correlation that can be extended to larger units. The issue was raised , if you cannot test the larger units dynamically, how can you extend the correlation established from the smaller units?

Another participant felt that for shake table tests, a scale of 1/4 was appropriate. However, for prototype and QC tests, scaling becomes more important for larger components because the limits of available testing equipment are approached. For these tests a limit of 1/2 scale was proposed.

2.1.6. *In characterizing the isolation system response some prefer to use velocity of loading, while others use the frequency of loading. For elastomeric systems, still others might prefer to use shear strain rate. Which is preferred and why? Is not the frequency (period) more natural from the designer's perspective?*

One participant felt that it didn't matter as long as rate of loading is taken into account properly. As long as you have velocity, frequency and displacement, the rate of loading can be expressed by any one of these three measures: use whatever is appropriate for the given type of isolation system. For elastomeric systems, shear strain rate is more appropriate. Another participant noted that for sliding systems, velocity is more relevant. From a designer's perspective it is more natural to use frequency.

2.1.7. *What factor of safety or reserve capacity is needed in the different displaced configurations (tests II.1 through II.5 of NISTIR 5359)? Should the factor of safety be the same, or different, for the different displaced positions?*

Discussion among the group covered a wide range of topics related to testing to determine the ultimate and reserve capacity. Most of the discussion centered on the particular factor of safety for the test, how the test is conducted, and what vertical loads are specified.

A poll was taken of the group to get suggestions on the α values in tests II.1 and II.2 of NISTIR 5359. For test II.1 values ranged from 1.5 to 3, with an average value of 2.3. For test II.2 values ranged from 1.1 to 2.0. There was some discussion as to whether the values for α should be the same in the displaced (II.2) and undisplayed positions (II.1). Most felt that a larger factor of safety was necessary in the undisplayed position. One participant commented that it does not make sense to place the same factor of safety on an event that will occur with 100% certainty (undisplaced) as one that will occur with much less certainty (displaced position). One participant, who favored equal factors of safety for both tests, noted that the vertical load specified in test II.2 does not include the effect of the structure overturning moment and therefore justified a larger factor of safety. A lower factor of safety could be used if the load included overturning forces.

There was confusion over the loads and displacements specified in these tests, i.e., these quantities are referred to as "design" values. It was suggested that the terminology be changed, since these are meant to refer to the rated capacity. There was general consensus that the loads should include the effect of overturning.

One participant suggested that the procedure in test II.2 of NISTIR 5359 is incorrect, because the system is restrained. An alternative procedure was proposed: apply the vertical load, displace the unit horizontally, switch to load control, maintain the horizontal load, observe the specimen to see if it continues to displace horizontally, i.e., is unstable. This alternative procedure is currently used in the European code.

Another participant noted that testing to failure is dangerous to both the operators and the testing equipment. Furthermore, due to the typically slow loading rates, ultimate strength tests may not be particularly meaningful: failure has more time to occur than in an actual isolated structure under earthquake motions. Therefore, even full scale tests may not be representative of actual behavior at ultimate conditions. Furthermore, one must differentiate between instability of an individual unit and instability of the entire system. At any given time, it may be shown theoretically that an individual isolator becomes unstable, but, unless the entire system becomes unstable, the individual isolator is constrained from developing excessive deflection. For a system with many isolation units, it is highly unlikely that more than a few units will approach instability.

2.1.8. *Specific values for the various performance criteria in the guidelines are needed. What are typical manufacturing tolerances for different systems on the market? How repeatable are the measures for stiffness and energy dissipation?*

The discussion turned to whether values for the performance criteria (α, ß) in the pre-qualification series should be specified or not. Also, whether systems should be designated as "dependent" or "independent" of some factor, depending on the results of a test and the performance criteria.

Some felt that α and ß should not be prescribed, rather it would be better to simply provide the pre-qualification data on the isolator performance. From this data the user would decide whether a system is dependent or independent of a particular factor, for their application. A hypothetical example was mentioned in which a system is defined to be temperature dependent based on the pre-qualification test, but in an actual project it is used over a much smaller temperature range, for which the properties are not that sensitive to temperature. Another participant felt that the performance criteria could be selected at the time the guidelines were adopted by the codes.

Others preferred to have specific values for the performance criteria that can be included in specifications for a job, since engineers and designers may not know what is reasonable. Also, it was felt that without the performance criteria there would be a gap in the guidelines. The suggestion was made that a range of numbers could be provided in the guidelines, as the manufacturing tolerances are different for different systems. It was noted that the extent of prototype testing required by the guidelines depends on whether a system is dependent or independent of these various factors, which is similar to the requirements in the Uniform Building Code.

2.1.9. *Debate the different options for QC testing of completed units. Are there alternatives to those presented?*

The general consensus among the group was that Option 3 was preferred, which requires QC testing 20% of all isolation units in a given lot. There was, however, debate about specific details and issues regarding this option. For example, should the number of units tested be tied to the lot size? The suggestion was made that for smaller lots, all units be tested, and for larger lots, only 20% of all units be tested. The definition of "lot" was also not clear. One participant suggested testing 25% of all units in a lot, and for every unit that fails, test another 3. Another suggested testing 20% of the units, and for each one that fails, test an additional 4 units. The 15% variation in effective stiffness in the performance criteria was considered acceptable, since this translates into an 8% variation in fundamental period and an 8% variation in base shear. It was also noted that a user may specify more stringent requirements, on the number of units tested and the allowable variation, if they so desire. One participant noted that the time and cost of QC testing depends on the size of the units and number of units in the lot. For larger units, which can weigh over 1 ton, it can take 3 to 4 hours just to install and remove the units from the test rig. QC testing can amount to 5 to 10% of the total cost of the unit. The QC test program may exceed the manufacturing costs of the isolators when testing just a few units.

Option 2 of the draft guidelines was not favored by the group.

2.1.10. *The sustained compression test for elastomeric units is conducted primarily to detect debonding and delamination. The test is very time consuming and some question its ability to detect debonding. An alternative that has been proposed is a compression/shear test with minimal or zero vertical load.*

One participant questioned the purpose of this test. Another felt that this is one of the most misunderstood tests in base isolation and provided the following history of the test. It was motivated by observations made some years ago, during model tests of an isolated bridge at the University of California, Berkeley. Due to a very low budget, the bearings were manufactured very cheaply. These were installed on the model bridge on a Friday, and on the following Monday, the bridge model was skewed and one of the bearings had failed. The failure was presumed to be caused by sustained compression. Subsequent discussion with the manufacturer indicated that the adhesive used to fabricate the bearings was not fully cured at the time they were installed, so that the failure was really one of slow creeping movements of the adhesive. Elastomeric bearings are now bonded and fully vulcanized during manufacture. There has been no indication that the failure observed at Berkeley is representative of modern bearings.

Some participants felt that a percentage of the bearings manufactured should undergo some type of sustained compression test, one participant felt every unit should undergo the test. There were suggestions to reduce the sustained compression test to 30, 60 or 120 minutes. It was noted that it is important to observe the unit carefully during the test; it does not suffice to place the unit in the test rig, apply the load and walk away. One participant suggested a 60 minute test, but a vertical load equal to 1.5 times the design load: very large bearings may be stressed very lightly for sustained periods.

One participant noted that if the purpose is to observe delamination, then a shear test is needed. The Europeans apply a shear strain of 200% to check for delamination. Another participant preferred to keep the procedure of the sustained compression tests as it is currently stated in the draft guidelines, but the exception contained in Section 4.2.5 should read, (1) reduce the duration to 1 hour and (2) require a history of only 100 units for a manufacturer to qualify for the exception. It was noted by another participant that the problem with retaining the exception was with the precise meaning of the phrase "units of a similar design, material and construction" in the guidelines.

2.1.11. *Are the concepts of pre-qualification, prototype and QC testing clear? Are the different types of tests clearly defined and differentiable (i.e. when are pre-qualification tests required, when are prototype and when are QC tests required)? Is the extent of testing required obvious?*

One participant noted that there are legal ramifications to the issue of pre-qualification. When a project goes out to bid, pre-qualification can be used to screen unqualified vendors from bidding on a job. This may trigger legal challenges later in the bidding process. The question was raised of how this document will be used in an environment of public (open) bids?

2.1.12. *Who dictates the testing program or testing procedure: the manufacturer or the user? Which testing facilities should be listed in the Draft Guidelines?*

One participant noted that due to the limitations on testing equipment, the testing outfit sometimes dictates which tests are conducted and which are not. Yet, it is the user who is in the best position to decide which tests are more important, as the user knows best which properties are sought from the seismic isolation units.

It was noted that the ETEC facility in southern California was not listed in the draft guidelines. However, two Japanese testing facilities are listed, even though it is unlikely that a U.S. manufacturer will have seismic isolation units tested in Japan. The recorder noted that any omission of testing facilities was an oversight. Inclusion of the Japanese testing facilities was meant to provide the reader with a greater insight into the variety of facilities for testing seismic isolation equipment. Another participant suggested that U.S. customers may purchase bearings made in Japan, in which case they would be tested in Japanese test facilities.

2.1.13. *Definition of an isolation system. Does the system include the vertical load carrying system, or can they be decoupled? Some suggest that the vertical load carrying system can be* *considered separately from the isolation system. There doesn't seem to be consensus in the community on this issue, but there should be a clear definition in the guidelines.*

The discussion turned to a particular type of isolation system that is mentioned in the guidelines that uses vertical coil springs and dashpots as dampers. One participant (participant #1) questioned how this system isolates the structure from horizontal movements during an earthquake. Another participant (participant #2) noted that it works in a rocking mode. Participant #1 understood that the draft guidelines were intended for systems that provide seismic isolation in a horizontal plane. Furthermore, evidence from an instrumented building affected by the 1994 Northridge earthquake that utilized this isolation system indicated that horizontal and vertical accelerations were amplified. The question is whether or not the draft guidelines apply to rocking systems. What is the "design" displacement for a rocking system, when such a system does not allow relative horizontal movement between the substructure and the superstructure? Participant #2 suggested that the observed response during the Northridge earthquake may have to do with the low magnitudes of the motions experienced by the system. Another participant felt that there are legitimate rocking systems for seismic isolation, but they are not addressed by the draft guidelines.

2.1.14. *Research needs.*

Discussion varied from one topic to another. Some specific research topics mentioned are listed below.

- Effect of high vertical ground accelerations. One participant commented that the upper limit of load is intended to include the effect of vertical accelerations.

- Applicability of the 72 hour creep test. Is 72 hours long enough to gain the information needed. It may be preferable to establish a monitoring program for in-place isolation units.

- Ability of isolators to undergo displacements that greatly exceed the design displacements. The recent experience with the 1994 Northridge earthquake indicated ground displacements and accelerations that were much larger than expected.

- Stability: at what vertical load or lateral displacement, or combination of vertical load and lateral displacement, does an isolator become unstable? What constitutes instability for an isolator?

- Variation of isolator properties on system behavior. Engineers need to know what kind of variation in component properties they can expect, so that minimum requirements are met. Limitations on the variation of material properties have an impact on the cost of the isolation system, as different materials and manufacturing procedures may be used depending on the limitations.

2.1.15. *Additional tests/modification of existing tests.*

The group discussed additional tests or modifications to existing tests that might be important. A direct tension test was suggested. Clearly, not all components can be subjected to this test. Nevertheless, should the guidelines address it anyway? Another participant raised concern over the 4.4 °C (40°F) temperature range specified in test I.9 of NISTIR 5359. It was suggested that this may not be representative of actual conditions in many applications and geographic locations. For example, bridges in Illinois are designed for a temperature range of -34.4 °C (-30°F) to 54.4 °C (+130°F). Is the 4.4 °C (40°F) range specified in the guidelines applicable to such conditions? Another suggestion was a test for sliding systems. A time history analysis is carried out for the design, using a maximum credible earthquake, to determine the relative displacement history between the superstructure and the substructure. That output is augmented by a factor of 1.5 and used as input to the ram for the individual isolator test. Is this test feasible for elastomeric systems as well?

2.1.16. *Aging: this is another issue that continues to be raised when the performance of the isolation system is reviewed. Experts seriously doubt the usefulness of accelerated aging tests. Is there a simple solution to this problem, or are we resolved to waiting 50 or 75 years to test systems currently in use? Related to this, should the guidelines recommend and discuss future testing of stored units and units in service, and provide details on storage and a recommended future test schedule? If so, what is the recommended procedure?*

One participant commented that we do not know much about aging. Aging effects cannot be assessed by so-called accelerated aging tests, nor can we predict the life span of materials and components from such test data. For example, accelerated aging tests of rubber in elastomeric systems utilize elevated temperatures. However, aging is not a first-order chemical reaction, as it is assumed. It is difficult to accept data extrapolated from a 30 day test period to predict aging effects on stiffness for a 60 year period. The problem is not just how to establish an accelerated aging test, but also how to predict long term effects.

It was noted that material scientists and engineers have conducted accelerated aging tests for a variety of materials. In many cases they have the advantage of many years of observations for correlating and validating their test procedure. The question was raised, is there any such information that we can use for isolation systems? No one knew of anyone who had done such work with elastomers.

One participant questioned why isolation systems are being used if we do not know how long they will last? The response was that it is based on past experience. Another participant noted that there is evidence that natural rubber components can last long periods of time: a number of rubber bearings taken from a 100 year old bridge in Great Britain appeared to be in reasonably good condition. New antioxidants and antiozonants can presumably improve aging characteristics. Furthermore, several bearings left over from the Foothill Communities Law and Justice Center were recently tested at the University of California at Berkeley, Earthquake

Engineering Research Center. The tests were not quite conclusive. The initial assessment was that there was no change, or possibly just a slight increase of 3 to 5% in bearing stiffness over 10 years. Observations at Dynamic Isolation Systems, Inc. on units up to 5 years old were also not totally conclusive, due to factors such as changes in testing equipment; however, all indications are that, at least for periods of 5 to 10 years, aging is not seen to be a problem for the types of isolation systems that are currently being used.

One participant suggested that units be removed from a building after a predetermined period of time and tested to verify their properties. It is difficult, however, to convince building owners that this should be done. As an alternative it was proposed that extra bearings be bolted to a reaction block and stored next to the actual bearings in an isolated structure. It was noted, however, that the information obtained from these bearings may be misleading, because the stored bearings are not subject to the same load history as the bearings in service.

The question was then raised, should the aging test (I.11) remain in the guidelines? One participant commented that the test should not be eliminated: even if it does not provide the information needed, it may still provide an index with which to compare different materials (isolation systems). Another participant added that if we do not have an aging test, the owner will want to know how the aging issue is being addressed. Yet another participant noted that the problem is that the draft guidelines do not define a test procedure for aging. Rather, the guidelines simply state that facilities will be available for accelerated aging tests.

2.1.17. *Working Group 1 provided the following final recommendations:*

- Pre-qualification tests are of value, even though there was some initial confusion regarding these tests, prototype test and QC tests.

  -Testing and/or review by an independent third party is needed.
  -Can prototype tests be eliminated if sufficient pre-qualification tests are conducted?
  -Some terminology requires revision, for example, “design” criteria vs. rated capacity.

- There is no consensus on the format of the document, i.e. whether the three documents should remain as such, or if they should be combined into a single document.

- There is a lack of facilities for full scale dynamic tests of isolators. Therefore, small scale tests should be used to establish isolator performance under certain load conditions.

- Small scale model tests should be allowed for pre-qualification tests. However, for larger bearings, a scale of 1:4 may be too small.

- Ultimate capacity tests are dangerous. Total load (including seismic overturning effects) and total maximum displacement should be used, in conjunction with a factor of safety equal to unity, to define reserve capacity.

- Consensus was not achieved concerning specific values for performance criteria in the pre-qualification tests.

- Quality control tests should be conducted on 20% of all isolators, and for each failure, four more units should be tested.

- The duration of the sustained compression tests should be reduced to 1 hour.

- Rocking systems appear to be excluded from the Draft Guidelines because they do not operate in the horizontal plane.

- There is much uncertainty regarding the effects of aging on isolation systems, and accelerated aging tests do not appear to be applicable. Research is needed in this area.

2.2 Working Group #2

The Chairman asked the participants to suggest questions for discussion during the morning session. The questions printed in the workshop handout were discussed in the afternoon session. The group decided not to discuss all of the questions in detail. Questions discussed are summarized below.

2.2.1 *When is fire proofing of isolation units required, and how should fire resistance be rated?*

One participant thought that a three hour fire rating might typically be required, but wasn't sure how this rating should be achieved. The group generally agreed that fire rating is necessary, but that fire performance of isolators is beyond the scope of these guidelines. One suggestion for testing fire resistance was to initially load an isolation unit and determine its properties; unload the specimen and subject it to fire; then reload the unit and measure the changes in its properties. This would avoid the problem of trying to simultaneously load a specimen while subjecting it to fire. It was also suggested that if an isolation unit was subjected to a fire while in service, the unit should be removed and tested to determine the extent of fire damage.

2.2.2 *Full dynamic testing of isolators tends to damage some elements of certain isolators (e.g. the fuse elements which resist wind loads). This puts some types of isolation systems at a disadvantage, because proof testing prior to installation will use up some of the "life" of the system. How should this problem be addressed?*

It was suggested that only a sample of isolation units be subjected to quality control tests, so that every isolator is not damaged prior to installation. Presumably, those units damaged during QC testing could not be used in service, or the damaged elements of the isolators (such as steel elements subject to low cycle fatigue) would have to be replaced. The current state of practice, however, is to perform QC tests on every unit before installation. Perhaps as more confidence is gained with certain systems, QC testing would only be required for a small sample of units.

2.2.3 *Should the designer or the supplier be responsible for rating the capacity of isolation units?*

One participant felt that the designer should specify the shape of the hysteresis loops for an isolator, then the supplier should provide a unit with those hysteresis characteristics. Generally, however, the group felt that the designer should specify only effective stiffness and energy dissipation, and the supplier should provide units matching those parameters. Of course, the designer would know in advance the general hysteretic behavior of a type of isolator, and he could use that information, combined with the effective stiffness and energy dissipation, for design. In any case, the shape of the hysteresis loops for each isolator would eventually be reported to the designer as part of the QC testing.

2.2.4 *Understanding the vertical deformation characteristics of an isolation system is important to a designer, especially at large lateral displacements.*

One participant commented that vertical deformation characteristics are important because they affect the design of nonstructural building elements. It was generally agreed that the designer should be supplied with vertical deformation information gathered during the prototype and QC tests, but that performance criteria on vertical deformations are not necessary.

2.2.5 *Should re-testing of isolators be required after a major earthquake?*

In California, isolation units in hospitals must be inspected for damage after certain events, such as an earthquake above a threshold magnitude or a displacement that exceeds a threshold value. It was generally felt that the guidelines do not emphasize enough that isolators can have a limited life. Perhaps “life span” should be addressed in the prequalification tests. It was generally felt that something should be added to the guidelines to address the limited life of isolators.

2.2.6 *Is the 12 hour sustained compression test an adequate method for testing for delamination in elastomeric systems?*

Several participants felt that a better test for delamination of elastomeric bearings would be a direct tension test, or a pure shear test without axial load. It was generally agreed that these types of tests might be better indicators of debonding, but because they are more difficult to perform, they may not be practical. It was also felt that the criteria in the guidelines for what constitutes "debonding" needs to be clarified. Small delaminations may be acceptable in practice, therefore, there should be criteria defining what constitutes an acceptable delamination.

2.2.7 *What sampling methods should be used for materials tests?*

There was some confusion about the requirements for material tests stated in the guidelines. It appears that the requirements for material testing on page 7 of NISTIR 5345 are not clarified in the body of the document. How often do material tests need to be done? What sampling method should be used to select material specimens for testing? It was felt that some outside expertise on statistical sampling methods might be helpful.

2.2.8 *Has pulse loading been considered adequately in the guidelines?*

One participant felt there should be more specific prequalification tests aimed at determining the response to pulse loading (i.e., "spike" accelerations that are uncharacteristic of the rest of the earthquake). One suggestion was to require some type of drop test in the prequalification series. Generally, though, it was felt that pulse loading and rate dependency would be adequately addressed by the guidelines without modification.

2.2.9 *Is it practical to recommend all prequalification tests be conducted on the same units, since they are likely to be damaged during the testing?*

There was no general consensus on this question. Some participants felt that the test program had been designed in such a way that one or two units could survive the entire series and noted that it is desirable to use the same specimens for as many tests as possible to provide consistency between tests. Other participants felt that some systems may be put at a disadvantage by expecting one or two units to survive a series of 23 tests: units might be damaged during some of the early tests, biasing the results in the later tests. Also, the amount of damage suffered would depend on the type of isolation system. It was proposed that one be allowed to substitute an undamaged unit for a damaged one when necessary, provided the substitution was reported in the test results.

2.2.10 *Do the draft guidelines address the issues that are of greatest concern to engineers and owners? If a complete set of pre-qualification test results were available from the vendor, would the designer/user be satisfied?*

One participant expressed concern that shake table tests are not part of the pre-qualification tests. Several participants concurred, but there was no general agreement on what the goal of the shake table tests should be. Practically speaking, only one or two structural frames types could be tested with a given type of isolation system. It was eventually concluded that some shake table testing is desirable, and that the goal of the testing should be to establish confidence in the isolation system, rather than to test the system rigorously with a range of structure types and configurations. Analytical studies should accompany the shake table tests, with the objective of testing the system theoretically in a wide variety of circumstances.

2.2.11 *Are the guidelines structured in such a way that they will be of use to industry? Should they be combined into a single document?*

There was no general consensus on whether the three reports should be combined into one, or left as separate documents.

2.2.12 *Definition of an isolation system: does the system include the vertical load carrying system, or can they be decoupled?*

It was generally agreed that the vertical and horizontal load carrying systems cannot be decoupled, and that they should be treated together in the guidelines.

2.2.13 *Scale model testing.*

It was generally agreed that 1/4 scale is a good lower bound for scale model testing. This conclusion was based more on practical considerations than on rigorous modeling.

2.2.14 *When a simple compression or tension test is conducted to determine ultimate or reserve capacity, should the specimen be free to deform laterally, or restrained from deforming?*

It was generally agreed that while it is desirable to allow free lateral translation, in actual laboratory test situations it is not practical or safe to do so.

2.2.15 *Aging of isolators - how should this be addressed in the guidelines?*

The consensus of the group was that not enough is known about aging of isolation systems, and that further research needs to be done in this area. A limited number of tests on aged elastomeric bearings seem to indicate that their properties change very little over time, but this needs to be confirmed by more extensive studies. One participant suggested that surplus units be donated to a university for the purpose of setting up a long term evaluation program.

2.2.16 *How should pre-qualification testing be handled for systems that already have a history of use and prior testing?*

The group felt that the user should determine whether or not pre-qualification tests are required for a system that has a long history of prior use. The guidelines should not address this issue.

2.2.17 *Quality control testing of elastomer: direct shear test?*

The group favored the idea of using a direct shear test for quality control of elastomers.

2.2.18 *Should the acceptance or rejection of a completed unit be based on comparison of the QC test results against the supplier's stated rated capacity, the prototype test results, or neither?*

It was agreed that all acceptance criteria should be referenced back to the original design values.

2.2.19 *Should α and β values be specified in the guidelines?*

There was a division of opinion on this question. Some participants felt that owners should be given discretion to choose α and β values, while others felt that owners need at least recommended values of α and β to make informed decisions. It was suggested out that even recommended values of α and β would become *de facto* standards.

It was generally agreed, however, that the correct approach for selecting appropriate values of α and β is to back calculate values from the effects that α and β have on overall structure performance. A change in α or β would be considered significant if that change altered overall structure performance (e.g. base shear; period) by more than about 10 or 15 percent.

2.2.20 *What should the temperature ranges be for testing?*

One participant felt that the guidelines should list specific temperatures at which tests should be conducted, and that there should be more temperature points than the three currently required in test I.9 of NISTIR 5359. This would give the designer more information and flexibility.

2.2.21 What research topics should be pursued?

The group suggested the following potential research areas:

- Effects of aging on the performance of isolators (including exploring the validity of accelerated test methods for material specimens).

- Investigate the scaleability of elastomeric systems.

- Ultimate capacity of isolation units at varying levels of lateral displacement.

2.2.22 *Draft Options: The group reviewed most of the sections of the three documents which contained "Draft Options" and made recommendations about which option was better.*

<u>NISTIR 5359:</u>

- Page 13: Information related to earthquake return period should be in the commentary. The guidelines are not an appropriate place to specify seismic risk parameters.
- Page 30: This example appears to be out of place. It should appear before page 13.
- Page 33: There was no consensus within the group over whether or not α and β values should be specified in the guidelines. It was agreed, however, that α and β values should be determined based on their effects on the overall structural performance.
- Page 42: The first option was recommended.

- Page 51 (top of page): Even thought the first option is more desirable, the second option is the only realistic one.
- Page 51 (bottom of page): Whatever range of values is used, the option needs more explanation and justification in the commentary.
- Page 52: As with the above item, give more guidance in the commentary.
- Page 53 (top of page): The first option is desirable, but only the second is practical.
- Page 53 (bottom of page): Needs further discussion in the commentary.
- Page 54: Needs further discussion in the commentary.
- Page 55: Some value has to be determined, but the group could not determine how it should be done.
- Page 69: Did not discuss this item.
- Page 72: The second option is desirable, but only the first is realistic. Mounting of specimens in the test needs to be addressed.
- Page 73: No consensus.
- Page 76: No consensus.

<u>NISTIR 5345:</u>

- Page 5: Move this to the commentary.
- Page 15: More expertise in sampling methods may be required to resolve this option.

(The remaining options in the NISTIR's 5345 and 5371 were not discussed because of a lack of time).

2.3 Working Group #3

A list of topics for discussion was developed by the group that includes those in the Workshop document, as well as others raised by the participants. Questions discussed are summarized below.

2.3.1 *The role of an independent observer or inspector in the testing process.*

Most testing is done by the manufacturers of the isolation units, using their equipment and facilities. Questions will often be raised as to whether the tests were performed correctly and in accordance with the specification or standard. It was suggested that an independent observer or inspector should be present during testing and that the guidelines should include language to define the role and responsibility of such an inspector. One participant noted that this was particularly important for QC testing.

2.3.2 *Test to evaluate the re-centering capability of the isolation unit/system.*

It was suggested that a test be included in the guidelines to evaluate the re-centering capability of the isolation unit or system. This would presumably be a pre-qualification test. Another noted that when evaluating re-centering, one must look at the response of the entire system and not just one unit.

2.3.3 *Do the proposed tests realistically represent the actual field conditions?*

One participant commented that the tests for wind degradation and temperature variation do not accurately simulate the field conditions. It was suggested that the AASHTO requirements be reviewed.

2.3.4 *Test to establish the dependence on aging.*

The group agreed that this is an important issue that is not well understood. There is a need for a dedicated research program on aging and the work should begin immediately. Aging effects are particularly important for highly-filled rubbers. One participant commented that there are plans to remove and test units from the Foothill Communities Law and Justice Center (the first building to be isolated in the United States, completed in 1986). It was noted that there is some aging data from applications in New Zealand and England, but the materials tested are different from those being used today. Work is currently being conducted through the National Center for Earthquake Engineering Research (NCEER) and funded by the Federal Highway Administration to study aging in sliding systems. NCEER is also exploring the possibility of working with the Earthquake Engineering Research Center (EERC) and the California Department of Transportation (Caltrans) to conduct a similar study on elastomeric units. One participant suggested that the manufacturers have a responsibility to the owners to address this issue. The participants agreed that the guideline documents begin to address the aging issue, but also agreed that considerable work remains to be done before an acceptable standard test for aging can be developed.

2.3.5 *Virgin versus scragged behavior of elastomeric systems.*

This is an important issue that is relevant only to elastomeric systems. One participant noted that under high temperature and pressure the movement of rubber molecules is an age-hardening process. New rubber materials, with high carbon content, are particularly sensitive to it. In this participant's practice each elastomeric unit is "scragged", by subjecting it to three cycles at 100% shear strain. It was suggested that a procedure for scragging be included in the guidelines, and that scragging be conducted by either the manufacturer, or as part of the QC test procedure. Another participant suggested that scragging be defined as part of the manufacturing process.

2.3.6 *Scale model testing.*

The group discussed tests to failure, and in particular, the use of scale model specimens in this kind of test. The group questioned whether the failure of the scale model specimen would be representative of the behavior of the full scale unit. It was noted that from Caltrans' perspective, testing to failure is important. Therefore, scaling becomes an important issue because of the limitations of existing test facilities. One participant questioned whether scale model tests can provide confidence in the performance of the full-scale unit. It was suggested that for elastomeric units scale model testing to failure would not give results that are representative of the full scale unit, because the curing process is different.

2.3.7 *Number of specimens required for pre-qualification testing.*

The group discussed the number of specimens required for pre-qualification testing. Two specimens, as currently required, seemed to be too few. Since pre-qualification tests are required only once (a one-time investment), to test perhaps 8 to 10 specimens is justified. It was also suggested that the number required might depend on the type of system, i.e., elastomeric or sliding.

2.3.8 *Number of units that are QC tested.*

The group noted that the current practice is to test every single unit that is manufactured before it is installed. Suppliers of sliding devices, however, believe that since the sliding units have higher reliability in production, there is no need for such extensive testing. The group generally agreed that since testing is actually a very small part of the total cost, and a reasonable way to ensure the performance, that all units should be QC tested.

2.3.9 *Test for creep dependence.*

Some participants commented that the 72 hours specified in test I.10 of NISTIR 5359, to establish a dependence on creep, is not long enough. Some questioned where the 72-hours came from.

2.3.10 *Bridge versus building isolation systems: size and capacity differences.*

The group discussed the differences in size between bridge and building isolation units/systems. One participant noted that the DOE/ETEC facility in southern California may have the capability to test full scale units at dynamic rates. Caltrans may be using the ETEC facility for testing isolation units. Another participant commented that the ETEC facility may not be adequate for testing systems for buildings because of their larger size.

2.3.11 *Draft option parameters α and β.*

It was noted that α and β may vary depending on a particular project or application. One participant suggested that instead of specifying particular values for α and β in the guidelines, that they be determined as part of the test and reported to the owner/designer. The user can then decide, based on the reported data, if the unit/system is appropriate for their particular application. Another proposal was to provide a range of values for each test as a guide or benchmark that the designer can use in evaluating the system. One participant suggested that an "Index of Dependence" be used to define the level of dependency an isolation unit exhibits on the various load and environmental factors (similar to the first option proposed).

2.3.12 *Rate of loading used in the tests.*

One participant commented that the frequency or rate of loading specified in most of the tests is too slow. Page 35, Section 1.2, of NISTIR 5359 states that the purpose of the test (I.2) is to establish the dependence of system response on frequency of loading. Yet, in all tests, the guidelines require the loading not to exceed 0.004 cycle per second. This number needs clarification or justification.

2.3.13 *Range of specimen sizes that should be tested.*

One participant suggested that only 2 or 3 different sizes would be required for pre-qualification testing. Another suggested that the number of sizes depends on what you are looking for: for material characteristics perhaps 2 or 3 sizes is enough; for dynamic properties, many more sizes may be needed. This will also depend on the confidence level that is required. A database needs to be developed to define such levels. For elastomeric systems, one participant suggested that rather than dealing with size, one should pre-qualify the elastomer in terms of its physical characteristics. In response it was suggested that this is a quality control issue: that is, it is much more difficult to maintain the quality in larger units than it is in smaller units.

2.3.14 *Draft Options: The group discussed many of the "Draft Options" in the guidelines for pre-qualification and prototype testing. The group made the following recommendations for specific changes in NISTIR 5359:*

- Page 13: Top Draft Option -- use design displacement.
- Page 13: Bottom Draft Option -- make $D_{TM} = 1.5D$.
- Page 30: α and ß values are unresolved.
- Page 33: α and ß values are unresolved.
- Page 51: Top Draft Option - select (b).
- Page 51: Bottom Draft Option - select 3.0.
- Page 52: Line 2 under "sequence" - change D to D_{TM}.
- Page 52: Line 2 under "procedure" - change P_D to P_U.
- Page 52: Draft Option - select 1.1.
- Page 53: Top Draft Option - select (b).
- Page 54: Line 3 under "sequence" - change D to D_{TM}.
- Page 54: Draft Option - select (d), use α - 1.1.
- Page 55: Delete "Lateral Load and" from heading 5.4.5.
- Page 55: Draft Option -- use D > or = α D_{TM}, where $\alpha = 1.1$.
- Page 72: Draft Option -- choose the bottom set.

3. RECOMMENDED REVISIONS TO THE DRAFT GUIDELINES

Based on a review of the working group discussions, recommended revisions to the draft guidelines have been formulated and are outlined below. The revisions have been formulated by the author, taking into consideration the majority opinion or "quasi-consensus" agreement reached within the groups, with consideration given to evolving state of the technology. The recommended revisions were developed from common topics of discussion in the three groups, or from issues that appear to be particularly important to the final guidelines for testing. For each topic a brief summary of comments is presented, followed by the recommended revision.

3.1 *Scale model testing.*

Summary of comments: There was general consensus among the groups that scale model testing is acceptable in some, but not all cases. Scale model testing is appropriate for tests to determine such things as dependence on rate of load, temperature and other factors, but inappropriate for tests to determine the ultimate and reserve capacity of a specimen. The groups generally agreed that an acceptable lower limit of scaling, for any type of test is 1/4 the full scale.

Recommendation: The guidelines should stress that full size specimens shall be tested whenever possible; however, in those cases where scale model specimens must be tested (due to limitations of the test facility) they shall be not less than 1/4 the full scale. Furthermore, ultimate and reserve capacity tests shall, in all cases, be conducted on full size specimens.

3.2 *Quality control testing of completed units: number of units tested.*

Summary of comments: There was no general consensus among the groups regarding the draft options that pertain to the number of completed units tested as part of the QC program (p. 15 of NISTIR 5345 and p.14 of NISTIR 5371). One group recommended that all units be tested, another recommended that 20% of a lot be tested, with various "triggers" to require further testing if units failed the test, and the last group suggested that the problem needed further study.

Recommendation: Without a formal and rigorous quality control program of parts and materials, the QC test of the completed unit is the only way to guarantee the quality of the finished product. Although the guidelines outline production tests of parts and materials, it does not, nor was it ever intended to serve as a comprehensive quality control program for the production of seismic isolation systems. Such a program would vary greatly from one type of system to the next. Therefore, given the new and evolving state of this technology, it is prudent to recommend that all isolation units manufactured be tested. Commentary will be added to suggest an alternate, less demanding program as suggested by the one group. Appropriate cautionary remarks regarding the use of a less demanding program will be noted. Finally, an effort should be undertaken to review the theory behind sampling and testing, as it is used in quality control programs, to support the issue at hand.

3.3 *Performance criteria - draft option parameters* α *and* β.

Summary of comments: There was much discussion among the groups regarding the performance criteria, i.e., draft option parameters α and β found in many of the test procedures. Some questioned whether performance criteria should be included in the guidelines at all, i.e., the guidelines should simply outline the test procedures. In this regard it was argued that a decision of whether a system is "acceptable" or "unacceptable" for a particular application should be left to the designer. Others felt that without performance criteria the guidelines would be of limited use to the industry and users. It was further noted that designers and users need, and want a benchmark with which to evaluate the performance of isolation units. More than one group suggested that results of the tests should be reported and that systems should not be "branded" as "dependent" or "independent" of some factor. Based on the results of the pre-qualification series a user can determine if the system is dependent on some factor for their particular application. More than one group suggested that performance criteria be specified in terms of a range of values, with perhaps a recommended value that is based on the overall performance of the isolated structure.

Recommendation: The final guidelines should be structured in such a way that the performance criteria are specified in terms of a range and a recommended value. The commentary to the guidelines should include discussion of the basis for selection of the performance criteria. Furthermore, the notion of classifying a system as "dependent" or "independent" be dropped in the final guidelines; instead, appropriate triggers be incorporated into the prototype test series to govern the extent of testing required in that phase (in the draft guidelines the extent of prototype testing depends on whether a system is "dependent" on some factor).

3.4 *Aging of isolators.*

Summary of comments: There was general consensus among the groups that (1) the effects of aging on the performance of the isolation system is an extremely important issue, (2) little is known or understood about the effects of aging on the isolation units now being used, (3) more research needs to be conducted in this area, (4) the guidelines do not address in detail how an aging test should be conducted, and so in that sense they are of limited use, but the guidelines do confront the issue and provide a basis on which testing could be conducted, (5) not enough information is available at this time to develop a useful aging test of isolation systems. In the absence of an acceptable accelerated aging procedure, more than one group suggested that a procedure for storing and testing isolation units at a later date be included in the final guidelines.

Recommendation: The pre-qualification test for aging be included in the final guidelines. Commentary be added regarding the state of knowledge of the effects of aging and the lack of an accepted accelerated aging procedure. Guidelines should be added for testing extra isolation units that are stored near the structure. The guidelines should describe how the units are stored, how many are stored, at what time interval they be tested and how the results are reported.

3.5 *Number and sizes of specimens tested as part of the pre-qualification program.*

Summary of comments: More than one group discussed the quantity and sizes of specimens that are tested during pre-qualification. Some questioned whether it is reasonable to expect one specimen to survive the entire pre-qualification series (more than 20 independent tests). It was suggested that one be allowed to substitute new specimens for a damaged one during the pre-qualification series. Others noted that it is important to maintain consistency during testing and therefore, testing the same unit is important. Finally, given that it is a one-time investment, it was also suggested that many more units and sizes be tested as part of the pre-qualification program.

Recommendation: The guidelines be reworded to state that "a minimum of two specimens shall be tested" in the pre-qualification series. Commentary will be added to note that users would benefit from tests of more than two units and from units of different size. Furthermore, the guidelines be reworded to state that a new specimen may be substituted for a damaged one, in the pre-qualification series, provided it is clearly noted in the report; however, whenever possible the same unit should be used in the entire pre-qualification series. The term "damaged" would have to be clearly defined.

3.6 *Are the guidelines structured in such a way that they will be of use to the industry? Should they be combined into a single document?*

Summary of comments: There was no general consensus within or between the groups regarding this issue. There were suggestions to keep the documents separated as well as suggestions for merging them into one document.

Recommendation: No firm recommendation reached at this time.

3.7 *What factor of safety or reserve capacity is needed in the different displaced configurations? Should the factor of safety be the same, or different, for the different displaced positions?*

Summary of comments: Group one discussed this issue at length, but reached no consensus. Some suggested that there should be a larger factor of safety in the undisplayed position, an event that will occur with 100% certainty, than in the extreme displaced position, an event that has a much lower probability of occurrence. There was confusion over the load applied in the displaced position, in particular, whether it included the additional load due to the structure overturning moment. There was consensus that the load applied in the displaced position should include the effect of overturning.

Recommendation: The guidelines be reworded to clearly state that the axial load in the displaced position is to include the effect of the structure overturning moment. Provide appropriate ranges and a recommended factor of safety for the displaced and undisplayed positions, per Section 3.3 above.

3.8 *Twelve hour sustained compression test for detecting delamination in elastomeric units.*

Summary of comments: Two groups discussed this test in some detail. One participant commented that it is the most misunderstood test in base isolation and provided the history of the procedure. Some felt that the duration of the test should be reduced, to between 30 and 120 minutes, and the axial load increased. Others felt that a more appropriate test for detecting debonding would be a direct tension test or a shear test with no axial load. It was suggested that the criteria for establishing debonding be clarified.

Recommendation: Available data and information from the results of 12 hour sustained compression tests should be compiled and analyzed, from which an acceptable duration for the test can be established based on past experience. An effort should be undertaken to study the viability of using a direct tension test, or a shear test without axial load, for establishing debonding. Commentary will be added which describe these types of tests and notes that further research is needed before a standard test, using either of these methods, can be developed.

3.9 *Do the draft guidelines address the issues that are of greatest concern to engineers and owners? If a complete set of pre-qualification test results were available from the vendor, would the designer/user be satisfied? What additional tests, is any, are recommended?*

Summary of comments: Each of the three groups discussed this issue, either directly or indirectly. There was considerable discussion among the groups on a variety of topics related to this question. A summary of some of the more significant points is presented below:

a. There was some confusion over how the pre-qualification, prototype and quality control tests are related. In particular, when each type of test is required, when or if certain tests can be excluded, and how the three relate to each other. Some questioned whether prototype testing would be required if a comprehensive pre-qualification program had been conducted, i.e., could pre-qualification testing circumvent the need for prototype testing? Could prototype testing ever be eliminated or scaled-back, in favor of more quality control tests?

b. More than one group recommended that an independent, third party observer be present during all testing. In the absence of an independent observer some may question the credibility of the test results. There is currently no mention of an independent observer in the draft guidelines.

c. One group suggested that a test to evaluate the re-centering capability of the isolation unit/system be included in the guidelines. This would presumably be a pre-qualification test.

d. One group alluded to the need for a fire rating test, i.e., to evaluate the performance of the isolation unit after it has been subjected to several hours of fire. The discussion turned to methods for fire proofing, and that fire proofing is generally handled separately from the design of the isolation unit. The group then suggested that this test was outside the scope of the guidelines.

e. One group expressed concern that shake table tests were not part of the pre-qualification series. The group suggested that a limited number of shake table studies, as part of the pre-qualification series, would be beneficial for establishing confidence in the isolation system.

f. One group suggested that a direct shear test of the elastomer be included in the production tests for elastomeric systems.

g. The vertical deformation characteristics of the isolation unit/system are important because they affect the design of nonstructural building elements. One group emphasized that the designer should be supplied with vertical deformation characteristics of the system from the pre-qualification and prototype tests, but that there not be performance criteria on vertical deformations.

h. One group questioned the need for guidelines or requirements for re-testing isolation units after a major earthquake. There are currently no guidelines for re-testing units after an earthquake.

i. One group suggested that the test to evaluate dependence on temperature be modified: the test should be conducted at more than three temperatures.

Recommendations:

a. Portions of the guidelines will be edited to clarify the distinction between the three types of tests and the conditions under which each governs.

b. A section will be added under "General Requirements" to state that an independent observer shall be present during all testing.

c. A pre-qualification test will be modified, or a new test added, to evaluate the re-centering capability of the isolation unit.

d. Because fire proofing is usually handled separately from the design of the isolation unit, i.e., fire proofing may involve sprinklers, secondary cover, etc, a test to evaluate the performance under fire is considered to be beyond the scope of the guidelines.

e. Shake table tests, although they are extremely important, are beyond the scope of the guidelines. Commentary will be added that suggests augmenting the tests of the isolation unit with shake table studies.

f. A direct shear test of the elastomer be included in chapter 3 of NISTIR 5345.

g. No changes required. Sections 4.3 through 4.6 of "General Requirements" (NISTIR 5359) stipulate that vertical deformations shall be measured at two points on the load plane and that hysteresis loops of the vertical deformation shall be included in the Report of Results.

h. This is beyond the scope of the guidelines; however, commentary will be added to suggest that units may need to be tested following a major earthquake.

i. No change required. All tests outlined in the guidelines should be considered minimum requirements. Testing at three temperatures is a reasonable minimum requirement.

4. CONCLUSIONS

A national workshop was held on July 25, 1994, in San Francisco, California, to solicit feedback on the draft guidelines for testing and evaluating seismic isolation system, recently published by the National Institute of Standards and technology. The workshop provided an open forum for review and discussion of the draft guidelines and was attended by representatives from the user, manufacturer and research communities.

In small working groups the workshop participants debated important and unresolved issues related to testing and evaluating seismic isolation systems. A number of issues stimulated considerable debate, including, scale model testing, performance criteria, factors of safety, aging of isolation systems, quality control testing and the sustained compression test for elastomeric systems. Appropriate revisions will be made to address many of these issues in the final guidelines for testing. Several new issues were also raised by the working groups that are not addressed in the draft guidelines. These include, a third party inspection of the testing procedure, a test to evaluate the re-centering capability of the isolation system, and a direct shear test for elastomeric materials. These are important issues that should be addressed in the final guidelines.

Recommendations for specific revisions of the draft guidelines have been formulated based on the working group discussions and were presented in Chapter 3. The recommended revisions, in addition to the feedback received from the mail review, will be used in developing the final guidelines for testing.

REFERENCES

Shenton III, H.W. (1994a), "Draft Guidelines for Quality Control Testing of Elastomeric Seismic Isolation Systems," NISTIR 5345, February 1994, National Institute of Standards and Technology, Gaithersburg, Maryland.

Shenton III, H.W. (1994b), "Draft Guidelines for Prequalification and Prototype Testing of Seismic Isolation Systems," NISTIR 5359, March 1994, National Institute of Standards and Technology, Gaithersburg, Maryland.

Shenton III, H.W. (1994c), "Draft Guidelines for Quality Control Testing of Sliding Seismic Isolation Systems," NISTIR 5371, March 1994, National Institute of Standards and Technology, Gaithersburg, Maryland.

APPENDIX

On the following pages are the List of Participants, Workshop Agenda, a list of possible topics for group discussion, and the Working Group assignments.

NIST Workshop on Proposed Guidelines for Testing and Evaluation of Seismic Isolation Systems

San Francisco International Airport Hilton Hotel
July 25, 1994

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Agenda

8:00 am Registration

8:30 am Welcome - Tripp Shenton (NIST)

8:35 am Opening Remarks - Riley Chung (NIST)

8:40 am Overview of the Draft Guidelines/Objectives of the workshop- Tripp Shenton

9:00 am Comments:

Ian Buckle, NCEER and a member of the Oversight Committee
General
Saif Hussain, Chair, SEAOSC Base Isolation Subcommittee
SEAOSC review
Ian Aiken, SEAONC Base Isolation Subcommittee
SEAONC review (canceled)
Tripp Shenton, NIST
Summary of comments received to date

9:30 am General question and answer period; charge to working groups

9:45 am BREAK

10:00 am Morning session working groups

12:15 pm Lunch

1:15 pm Reconvene - open discussion, specific question and answer period

1:45 pm Afternoon session[1] working groups

4:00 pm Reconvene - summary comments and recommendations from working groups

4:30 pm Open discussion, question and answer period

5:00 pm Adjournment

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[1]Refreshments served in individual break-out rooms.

Possible Topics for Working Group Discussion

General

- Do the draft guidelines address the issues that are of greatest concern to engineers and owners? If a complete set of pre-qualification test results were available from the vendor, would the designer/user be satisfied?

- Are the concepts of pre-qualification, prototype and QC testing clear? Are the different types of tests clearly defined and differentiable (i.e., when are pre-qualification tests required, when are prototype and when are QC tests required)? Is the extent of testing required obvious?

- The concept of rated capacity is fundamental to the guidelines; is the concept obvious to the reader? Is the list and description of parameters complete (chapter 2 or 3)?

- Are the guidelines structured in such a way that they will be of use to the industry? Should they be combined into a single document?

- Are there critical issues that remain to be resolved in testing of isolation systems that require further research and testing? Chapter 7 of NISTIR 5359 discusses some areas for further research.

- How do the participants see these guidelines being used? How can they be of most benefit to the industry? How would the guidelines be used in conjunction with the current codes for seismic isolation (UBC, AASHTO, SEAOC)?

- Definition of an isolation system. Does the system include the vertical load carrying system, or can they be decoupled? Some suggest that the vertical load carrying system can be considered separately from the isolation system. There doesn't seem to be consensus in the community on this issue, but there should be a clear definition in the guidelines.

- Are there other issues that should be addressed in the guidelines? An example is, guidelines for independent inspection and verification of test facilities, since most testing is done by the manufacturers themselves.

Prequalification and Prototype Testing

- Dynamic testing: this issue is raised time and time again when testing is debated. Facilities do not exist to test full scale isolation units at the actual period of isolation (for example, a unit with a design displacement of 10" at a period of 1.0 second, with a full vertical load). Therefore, to establish the frequency or velocity dependence, scale model tests must be conducted. An attempt has been made to address this issue in test I.2; however, the issue is still not resolved. How can this be resolved in a rational and consistent manner? Should guidelines be provided to help resolve disputes between owners and manufacturers on this issue?

- Scale model testing: this is another issue that continues to be raised whenever testing is debated. Because of the limits of existing test facilities some tests must be conducted on scale model specimens. Full scale tests are recommended in the guidelines; however, scale model testing is permitted when the test capabilities would otherwise prohibit any such test. The guidelines recommend a scale factor of not less than 1/4. Is this too large or too small? Should it be limited based on the size of the prototype unit? Would this depend on the type of system or the type of test being conducted?

- In reviewing the list of pre-qualification tests, in particular, Table 5.1, is the list complete, are there additional tests needed? Can some of these tests be eliminated?

- Is it practical to recommend all prequalification tests be conducted on the same units?

- In characterizing the isolation system response some prefer to use velocity of loading, while others use the frequency of loading (as in guidelines, e.g., test I.2). For elastomeric systems, still others might prefer to use a shear strain rate. Which is preferred and why? Is not the frequency (period) more natural from a designer's perspective?

- What factor of safety or reserve capacity is needed in the different displaced configurations (see performance criteria in test II.1 through II.5 in the prequalification and prototype document, NISTIR 5359)? Should the factor of safety be the same, or different, for different displaced positions?

- When a simple compression or tension test is conducted to determine ultimate or reserve capacity, should the specimen be free to deform laterally, or restrained from deforming?

- Aging: this is another issue that continues to be raised when the performance of the isolation system is debated. Experts seriously doubt the usefulness of accelerated aging tests. Is there a simple solution to this problem, or are we resolved to waiting 50 or 75 years to test systems currently in use? Related to this, should the guidelines recommend and discuss future testing of stored units and units in service, and provide details on storage and a recommended future test schedule. If so, what is the recommended procedure?

- Consider the performance criteria that are now in the draft guidelines - are they appropriate?

- Specific values for the various performance criteria in the guidelines are needed. What are typical manufacturing tolerances for different systems on the market? How repeatable are the measures for stiffness and energy dissipation?

- How should pre-qualification testing be handled for systems that already have a history of use and prior testing? Should the guidelines propose a method for handling this issue, or leave it up to the user?

Quality Control

- Debate the different options for QC testing of completed units in 4.4.1. Are there alternatives to those presented?

- Quality control testing of elastomer. The usefulness of some of the tests in section 3.3 of NISTIR 5345 have been questioned. In particular, the test for hardness (durometer), high temperature aging and ozone resistance. Some suggest placing more significance on a direct shear test to assess the quality of the material.

- Should the acceptance or rejection of a completed unit be based on comparison of the QC test results against the suppliers stated rated capacity, the prototype test results, or neither?

- The sustained compression test for elastomeric units is conducted primarily to detect debonding and delamination. The test is very time consuming, and some question its ability to detect debonding. An alternative that has been proposed is a compression/shear test with minimal or zero vertical load.

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Working Group Assignments

Working Group #1 Room: Vintage 4&5 Chair: Saif Hussain Recorder: Arturo Schultz	Working Group #2 Room: Vintage 6 Chair: Robin Shepherd Recorder: Andy Taylor	Working Group #3 Room: Vintage 7 Chair: Masson Walters Recorder: Riley Chung
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M. Karshenas	Tod Sutton	
Victor Zayas		