THE APPLICATION OF A US CORPORATE INDUSTRIAL SEISMIC PROGRAM IN JAPAN: A COOPERATIVE APPROACH

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SUMMARY

Over the past decade Hewlett-Packard Company has addressed seismic risk through a comprehensive program which addresses life safety and business interruption. Components of the program include the seismic evaluation of existing buildings in moderate and high seismic zones, the development and use of performance-based seismic standards for new and existing buildings, the seismic upgrade of buildings, and post-earthquake emergency response. The status of HP's inventory of over 1400 buildings worldwide is captured in a seismic database that provides quarterly reports to management. Until recently, more attention has been given to buildings in the US than abroad.

To address the challenges related to foreign buildings, a pilot program was set up in Japan where over 90 HP buildings are located. Japan was selected due to its high seismic hazard, the size and importance of the building stock, and the availability of a high level of earthquake engineering technology. The intent was to develop an approach that can later be utilised in other foreign countries.

INTRODUCTION

To address the HP seismic program within Japan a co-operative effort was put in place between HP's Corporate Seismic Program Manager, HP Japan's Country Facility Manager and Seismic Project Manager, and structural engineering consultants from both the US (Degenkolb Engineers) and Japan (Obayashi Corporation). This program represents the first attempt by HP to expand the boundary of its seismic program beyond the US without simply exporting US technology. Rather the program is based on integrating the earthquake engineering technologies of the two countries. This paper describes the development of the co-operative program, the similarities and differences in seismic standards and practices in the two countries, the implementation of the program in actual building evaluations and upgrades, and the post-earthquake response plan.

OVERVIEW OF HP SEISMIC PROGRAM

The development of the HP seismic program began on a comprehensive basis in 1988 when the company recognized that hundreds of its buildings worldwide were exposed to significant earthquake risk. Since that time the program has grown to encompass the following components: the construction of new buildings in accordance with specified performance levels, the evaluation of existing buildings to determine performance expectations, the seismic upgrade of buildings to improve performance, and post-earthquake response. Seismic standards for design of new buildings and for evaluation and upgrade of existing buildings are contained in the *HP Seismic Guidelines – Buildings and Contents*. The status of its existing building inventory is contained in a database that provides quarterly reports to HP management.

Corporate Seismic Guidelines

Through its document titled *Hewlett-Packard Seismic Guidelines – Buildings and Contents*, HP provides consistent standards to be applied to both new and existing buildings. The *Guidelines* are updated on a regular

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basis in order to take advantage of the most current consensus standards in the US, with the most recent update occurring in July 1998. At the core of the guidelines is a set of clearly defined seismic performance levels that are applied to new and existing buildings. Figure 1 defines the acceptable Seismic Performance Levels – A, B, and C for new and existing buildings. The figure is adopted from SEAOC Vision 2000 – *Performance-based Seismic Engineering of Buildings*.

For new construction, the 1997 Uniform Building Code (UBC) is used as the reference standard and defines Level C, the minimum, and default, seismic level. Levels A and B are intended to provide enhanced seismic performance for buildings having greater importance from a business risk standpoint. Buildings designed to these levels have restrictions on structural system and configuration, special lateral force requirements, story drift restrictions, and stricter nonstructural requirements. For areas of the US in which the UBC is not in use, the design may be based on the 1997 NEHRP Recommended Provisions. In all areas of the US the 1997 NEHRP maps are adopted to take advantage of more current seismic hazard information. For buildings constructed outside of the US the *Guidelines* provide a minimum standard against which local codes are applied. Peer review is used extensively in all areas to assure consistency.

The Guidelines address existing buildings through the adoption of two recently published US consensus standards: for building evaluation, FEMA 310 – *Handbook for the Seismic Evaluation of Buildings* is used; and for upgrade, FEMA 273 – *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* is used. Both sets of standards are performance-based and are well suited to incorporation into the HP performance standards. The Guidelines include the *HP Seismic Evaluation and Mitigation Policy*. This Policy is specifically intended to address life safety concerns. If desired by the business unit, business continuity can be addressed through the Guidelines based on risk management considerations. Procedures for two types of evaluation (Preliminary and Detailed) are specified based on FEMA-310. Preliminary Evaluations are required for all buildings located in areas equivalent in seismic hazard to UBC Zone 2a. The *Guidelines* provide seismic zonation maps to be used to establish zonation on a preliminary basis.

The *Guidelines* have been applied extensively over the last ten years to buildings in California and throughout the US. New HP buildings are most commonly constructed to seismic Level C, meaning that life safety protection is provided, but business continuity is of secondary concern. Construction to Levels A and B has been very limited due to the premium on costs associated with both structural and nonstructural systems. Buildings that have been candidates for higher performance levels are selected manufacturing buildings and data centres. A peer review process, which is described in the document, has been used to assure consistency.

The most extensive application of the Guidelines has been in the evaluation and upgrade of existing US buildings. *Preliminary* seismic evaluations have been conducted for several hundred existing buildings. This has made it possible to rate all US buildings located in moderate and high seismic zones in terms of risk to life safety and expected loss of operation after a major earthquake. Buildings not rated as a *minimum* risk to life safety (see Figure 1) are required to have a *Detailed* seismic evaluation, which utilizes more advanced analytical procedures to assess seismic performance, and typically provides a seismic upgrade scheme and cost estimate. Depending on the intended long-term use of the building, upgrade schemes may be provided for one or more seismic performance levels.

Previous applications of the HP Guidelines to new buildings outside the US have involved projects in China, Japan, Italy, Mexico and Puerto Rico. Each of these projects involved one or more buildings that were designed to local standards and the Guidelines were used to achieve consistency, to the extent possible, with similar US projects. However, the application until now has not comprehensively addressed the seismic evaluation of all HP buildings within the particular country.

The Building Database

All critical information obtained from the seismic evaluations is collected in a database that is used to track the progress of the seismic program. The database contains substantial information on over 1400 buildings worldwide, including location, occupancy, general building information, building contacts and identification of HP business unit. For buildings requiring seismic assessment (UBC Zone 2a and higher) there is additional information covering the structural/seismic system, seismic hazard, and the results of each evaluation in terms of risk to life safety and business interruption. The database also has seismic upgrade cost estimating capabilities, utilizing HP-specific cost data obtained directly from the numerous detailed studies that have been completed. Reports from the database are produced for HP management on a quarterly basis.

Post Earthquake Response

The extensive building evaluation process has made it possible to implement a very effective post earthquake response program. From an engineering standpoint, the program is based on the pre-planned response by the seismic consultant, the HP Seismic Program Manager, and site facilities managers. The building seismic files that were developed from the preliminary seismic evaluations, and contain information on the critical elements of each building, are utilized. Copies of the files are kept at each site, at corporate headquarters in Palo Alto, and with the consultant, who is kept on annual retainer.

The program has been tested in two California earthquakes: the 1989 Loma Prieta Earthquake and the 1994 Northridge event. During the days following the Loma Prieta event, each of the 100-plus buildings in the Bay Area were assessed by a team consisting of the HP Seismic Program Manager, and structural engineers from Degenkolb. The team was dispatched to buildings based on priorities established at HP's emergency response center in Palo Alto. Priorities were based on the level of damage reported from the sites, the importance of the various facilities and knowledge of the buildings based on preliminary evaluations. In the Northridge earthquake a similar approach was used, but was simpler since only about 10 buildings required assessment. In both events there were buildings with substantial structural damage that required follow-up damage repair and upgrade.

Recent developments in the program have included the establishment of relationships with building officials in many of the Bay Area cities. This is intended to allow HP's response team to make the assessments of the buildings prior to the arrival of building officials or volunteers, so that the most appropriate appraisal is made, using all available information from previous evaluation reports.

HP ORGANIZATION AND FUNDING

The HP seismic program is managed within Corporate Real Estate through the efforts of the Seismic Program Manager, who reports to the Manager of Facility Operations. The Program Manager is responsible for establishment and coordination of the short and long-term efforts required to assure the program meets the goals set by the HP Real Estate Director. He is responsible for the establishment of the annual corporate program objectives and budget, coordination of site seismic activities worldwide, and coordination of consultant activities.

The Program Manager facilitates the efforts of HP project managers who report to the Manager of HP Corporate Design and Construction, and local site project managers who report to their business unit, by assisting in the interpretation of the HP *Seismic Guidelines*. This work involves new building construction projects occurring in all parts of the world and the enforcement of HP *Seismic Evaluation and Mitigation Policy* for evaluation and upgrade of existing buildings. In addition he provides guidance to HP's Geographic Real Estate Managers, who provide a connection between the Company's various business units and Corporate Real Estate in order to satisfy their space needs. HP business units include multiple sites and span across country boundaries.

The Program Manager's efforts are summarized in quarterly reports to management, generated through the building database, discussed above. Beyond this, the Manager is responsible for special activities that are undertaken each year as advancements to the program. Examples of such activities during the past year have included the database development, update of the *Seismic Guidelines*, and the establishment of the foreign buildings program.

Costs associated with the administration of the seismic program are divided between Corporate Real Estate and the various divisions that are affected. Program costs associated with the activities of the Program Manager, including consultant fees are covered through Corporate Real Estate, while building evaluations, preliminary and detailed, are covered by the business units affected. At HP, building construction costs, including professional fees, are paid by the business unit using the building. This includes seismic upgrade construction costs, as well as any premium on new building construction associated with higher seismic performance levels.

EVALUATION AND UPGRADE OF HP JAPAN BUILDINGS

Pre-screening

In Japan as in the US, the building code edition used for the original design of a building has a significant influence on the results of the seismic evaluation. However, since building codes are changed much less frequently in Japan, the effect is much more pronounced. For example, while the three model building codes used in the US are revised on a three-year cycle, the Japan Building Standard was last updated in 1981. That edition of the code is a widely accepted benchmark used to separate seismically adequate from inadequate construction in Japan and has been adopted to serve this purpose in the HP Japan seismic program.

Although FEMA-310 permits pre-screening through the use of benchmark codes, this step has not been adopted in the *Guidelines* for use in the HP program in the US. In other words, buildings are not eliminated from further study simply by meeting a specific code. This is due to the simplicity of conducting the Preliminary Evaluation using FEMA-310 Tier 1, the volume of useful data produced, and the occasional seismic deficiencies uncovered in the process. However, after studying a sampling of HP buildings in Japan, and based in Obayashi's first-hand knowledge of the design and plan review process in Japan, it was concluded that the use of a pre-screening process based on the 1981 benchmark would be consistent with the intent of the HP Guidelines. Therefore buildings designed to meet the requirements of the 1981 code have been rated as life safe.

Preliminary and Detailed Evaluation

HP Japan has made a major effort over the past decade to eliminate from its inventory buildings that were constructed to codes before 1981. This has resulted in a relatively modern building stock compared to Japanese buildings in general and to HP buildings outside of Japan. In fact, after the pre-screening exercise, involving confirmation of the date of construction and code used, all but six buildings were eliminated from further seismic study based on the 1981 benchmark year. These included two steel frame buildings, two reinforced concrete buildings, and two SRC buildings (composite structural and reinforced concrete frames).

The process adopted for evaluation and upgrade of HP Japan buildings incorporates both US and Japanese standards. FEMA-310 Tier 1 is used in the preliminary evaluation, as it is in the US. For buildings judged inadequate in the preliminary evaluation, a detailed evaluation is conducted using the Japanese standard for evaluation of existing buildings, Sokushin-hou. This standard provides a very detailed computational method in which a Seismic Index I_S is calculated to represent the seismic performance expectation for the structure. The index includes a consideration of strength, ductility, configuration and deterioration. The index is calculated for each story in each principal direction. Then each of those values is compared to previously established Seismic Judgement Indices I_{S0} relating to actual building damage levels observed in past earthquakes. For example, an index value of $I_{S0} = 0.6$ was established by Obayashi as the minimum level for life safety protection, so that any portion of the building failing to comply with that value requires upgrade in some form.

Seismic Upgrade

The Takaido Headquarters building was found to be deficient based on the Japanese Standard and was seismically upgraded. The building is a five-story SRC system, constructed in 1978. It has a building area of 8600 square meters. The SRC system is not in common usage in the US and is not specifically addressed in FEMA-310. However it was evaluated based on consideration of the relative contributions of the concrete and steel systems. Concerns resulting from both the preliminary and detailed evaluations included inadequate column strength in the first story and upper story weaknesses resulting from the eccentric location of concrete walls in the transverse direction.

The goal of the seismic upgrade was minimum life safety protection. The upgrade included the addition of three steel braced frames in the transverse direction, one full-height and two in the first story, as well as two first story concrete shear walls and two first story steel braced frames in the longitudinal direction.

POST EARTHQUAKE RESPONSE IN JAPAN

HP Japan and Obayashi have developed a post earthquake response plan intended to address the life safety evaluation of buildings throughout the country. In the past, arrangements of this type have not been commonly used in Japan. However, the Kobe Earthquake in 1995 demonstrated the value of this pre-planning process.

Although HP's major facility in Kobe performed extremely well in that event due to its design, it was clear that a more comprehensive program would be of great value in preparing for future events.

In the program, the inventory of buildings has been divided into nine geographic areas covering the country and maps have been developed showing each building location in the area. Geographic areas include Tokyo (37 buildings), Hokaidou (1 building), Touhoku (6 buildings), Tyubu (13 buildings), Kantou (17 buildings), Kinki (6 buildings), Chugoku (2 buildings), Sikoku (1 building), and Kyusyu (3 buildings). The building plans for buildings in each area are kept by an Obayashi office in that area and engineers located within the area are designated to respond to those buildings.

The trigger level for response by Obayashi engineers is set a Shindokai 5 or greater. Reporting forms have been developed based on standard forms used by the Tokyo Municipal Government. Semi-annual meetings are scheduled to be held between the two organizations to assure information is current and to consider advancements in the program.

CONCLUSIONS

Through a pilot program in Japan, HP has taken the first steps to bringing consistency to its seismic program worldwide. The HP Japan program integrates US and Japanese technologies, resulting in the successful evaluation and upgrade of existing buildings and pre-planning for post-earthquake response. In addition, the application of HP's performance based seismic standards has been successfully expanded beyond the US. The Japan program provides a valuable experience that can be applied to HP buildings in other countries.

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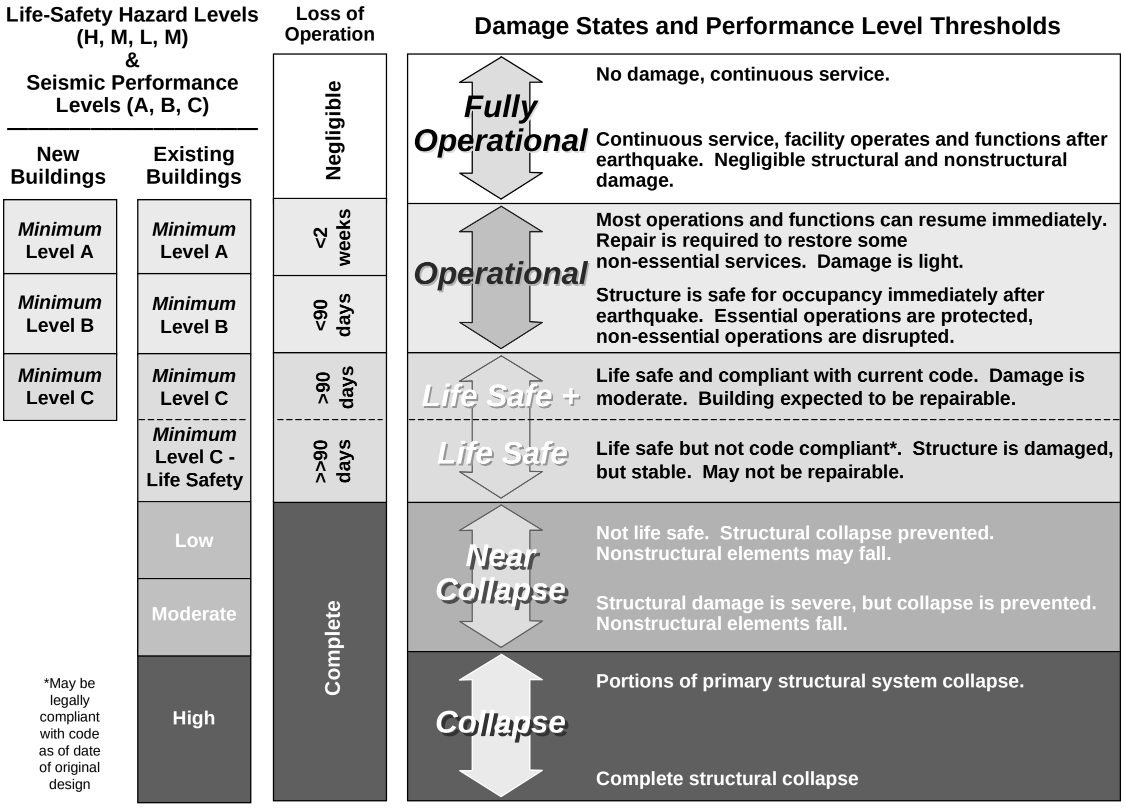

Life-Safety Hazard Levels (H, M, L, M) & Seismic Performance Levels (A, B, C)
New Buildings
Existing Buildings
Loss of Operation
Damage States and Performance Level Thresholds
Minimum Level A
Minimum Level B
Minimum Level C
Minimum Level A
Minimum Level B
Minimum Level C
Minimum Level C - Life Safety
Low
Moderate
High
*May be legally compliant with code as of date of original design
Negligible
<2 weeks
<90 days
>90 days
>>90 days
Complete
Fully Operational
Operational
Life Safe +
Life Safe
Near Collapse
Collapse
No damage, continuous service.
Continuous service, facility operates and functions after earthquake. Negligible structural and nonstructural damage.
Most operations and functions can resume immediately. Repair is required to restore some non-essential services. Damage is light.
Structure is safe for occupancy immediately after earthquake. Essential operations are protected, non-essential operations are disrupted.
Life safe and compliant with current code. Damage is moderate. Building expected to be repairable.
Life safe but not code compliant*. Structure is damaged, but stable. May not be repairable.
Not life safe. Structural collapse prevented. Nonstructural elements may fall.
Structural damage is severe, but collapse is prevented. Nonstructural elements fall.
Portions of primary structural system collapse.
Complete structural collapse

Figure 1