CHAPTER 12

TRANSLATING EARTHQUAKE HAZARD MITIGATION MEASURES FROM ONE COUNTRY TO ANOTHER: A CASE STUDY

Christopher Rojahn
Applied Technology Council, United States
Abstract: This paper presents a collaborative programme by the Applied Technology Council in the United States and the Servizio Sismico Nazionale (National Seismic Service) in Italy to improve seismic safety in Italian hospitals. It describes how U.S. hazard mitigation measures and regulations were used in Italy. The paper also provides an overview of procedures for rapid visual screening of buildings for potential seismic hazards and for evaluating structural and non-structural components, including criteria for specifying the expected level of seismic shaking.

Applied Technology Council

Founded as a non-profit corporation in 1973 with the aid of the Structural Engineers Association of California, the Applied Technology Council (ATC) specialises in the development of engineering applications and resources for mitigating the effects of natural and man-made hazards on the built environment. Given its roots in seismically-active California, the vast majority of the organisation's efforts to date have focused on the means to reduce the potential impacts of earthquakes on buildings, bridges and other structures.

The ATC has essentially defined and developed the basis for the seismic design, evaluation and retrofit of buildings in the United States, as well as the assessment and repair of earthquake-damaged buildings. In addition, the organisation has served as the catalyst for introducing and implementing seismic protective systems for buildings and bridges (seismic isolation and energy dissipation devices), and has developed the current and pending specifications for the seismic design of federally-funded bridges. Key projects and publications over the last 25 years for improving seismic engineering practice in the United States are provided Text Box 12.1.

The collaborative United States–Italy programme initiated in the late 1990s to improve seismic safety in Italian hospitals has provided insight into the means by which seismic hazard mitigation measures

Text Box 12.1. Key ATC publications


ATC-6, Seismic Design Guidelines for Highway Bridges (1981), basis for current national standard specification.


ATC-33, NEHRP Guidelines for the Seismic Rehabilitation of Buildings (FEMA 273 Report), basis for current national pre-standard for seismic rehabilitation of buildings.

Keeping schools safe in earthquakes

and regulation are transferred from one country to another. While focused on improving seismic safety of hospitals, the programme defines a scope of collaborative activities that could serve as a model for an international programme to assess the seismic vulnerability and risks to schools and educational systems.

Collaborative United States-Italy programme to improve hospital seismic safety in Italy

The ATC-51 programme for improving seismic safety in hospitals in Italy, carried out jointly by the ATC and the Italian Servizio Sismico Nazionale (National Seismic Service), consisted of an initial project to develop overarching seismic hazard mitigation recommendations for adoption country-wide, followed by several focused projects under which key recommendations are being implemented. The initial project resulted in the development of a series of ten recommendations, six of which are focused on the short term, which will take place in the next few years, and four designated as long-term goals, which may require one or more decades to achieve (Table 12.1). The recommendations, published in 2000 in the ATC-51 Report, U.S.-Collaborative Recommendations for Improving the Seismic Safety of Hospitals in Italy, consider the seismic hazard in Italy, the characteristics of Italian hospital buildings and their performance in past earthquakes, and the existing regulations and standards applicable to the design and retrofitting of Italian hospitals. The recommendations draw on the experience in California of developing, implementing and enforcing hospital seismic risk-reduction programmes. Typical of ATC projects, the recommendations were developed by a "blue-ribbon" panel consisting of leading available specialists in the seismic design, evaluation, retrofit and regulation of hospitals from both countries. Since the development of the initial overarching recommendations for improving the seismic safety of Italian hospitals (Table 12.1), the National Seismic Service has funded two other ATC projects that provide the basis for implementing two of the recommendations (Recommendation 3, "Implement bracing and anchorage for new installations of non-structural systems"; and Recommendation 6, "Plan for emergency response and post-earthquake inspection"). The first of these follow-on projects, completed in 2002, resulted in the publication of the ATC-51-1 Report, Recommended U.S.-Italy Collaborative Procedures for Earthquake Emergency Response Planning for Hospitals in Italy; the second project, completed in 2003, resulted in the publication of the ATC-51-2 Report, Recommended U.S.-Italy Collaborative Guidelines for Bracing and Anchoring Non-Structural Components in Italian Hospitals. In both of these publications, and in the initial ATC-51 Report, the guidance includes recommendations pertaining to:

• Procedures.

• Standards of practice.

• Risk exposure jointly perceived to be suitable for Italy.
Both countries have benefited from the collaborative ATC-51 programme: Italy has obtained fully documented and focused procedures for improving hospital seismic safety, and the United States has benefited from the development of new ideas and approaches.

Table 12.1. Summary of recommendations for improved seismic safety of Italian hospitals

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Applicable to</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short term</strong></td>
<td></td>
</tr>
<tr>
<td>Establish consistent review and enforcement of design and construction quality, beginning with the preparation of specific guidelines for this review and enforcement</td>
<td>New and existing buildings</td>
</tr>
<tr>
<td>Evaluate options for seismic risk-reduction programmes, including programme and performance objectives, long-term strategies, and possible passive and active seismic retrofit programmes</td>
<td>New and existing buildings</td>
</tr>
<tr>
<td>Implement bracing and anchorage for new installations of non-structural systems</td>
<td>New buildings and remodelling</td>
</tr>
<tr>
<td>Restrict the use of unreinforced masonry in new construction, depending on the seismic zone</td>
<td>New buildings and remodelling</td>
</tr>
<tr>
<td>Improve the inventory of structural data by collecting and documenting information on seismic vulnerability</td>
<td>Existing buildings</td>
</tr>
<tr>
<td>Plan for emergency response and post-earthquake inspection</td>
<td>New and existing buildings</td>
</tr>
<tr>
<td><strong>Long term</strong></td>
<td></td>
</tr>
<tr>
<td>Establish an active programme for non-structural bracing</td>
<td>Existing buildings</td>
</tr>
<tr>
<td>Improve seismic code provisions for new buildings</td>
<td>New buildings</td>
</tr>
<tr>
<td>Tie seismic design codes to performance-based design</td>
<td>New and existing buildings</td>
</tr>
<tr>
<td>Carry out a systematic seismic screening of existing hospitals, for an active seismic retrofit programme</td>
<td>Existing buildings</td>
</tr>
</tbody>
</table>

Source: ATC-51 Report.

Translating seismic vulnerability and risk assessment procedures from one country to another

Efforts to date on the collaborative United States-Italy programme for reducing seismic risks in Italian hospitals, in addition to those under consideration for future development, include establishing procedures for assessing the seismic vulnerability of buildings using rapid visual inspection; procedures for detailed seismic evaluation of buildings, including both structural and non-structural components; and criteria for specifying expected seismic shaking. This programme effort has also confirmed as workable the
procedures followed in adopting and adapting United States-developed procedures and criteria for hospital seismic safety in Italy. These approaches, including both the technical procedures and the translation and adoption approaches, provide constructive models for use in translating seismic vulnerability and risk assessment procedures for schools and educational systems to countries in need of such procedures.

**Translating seismic hazard mitigation measures from one country to another**

The approach for translating hospital seismic hazard mitigation procedures and regulations from the United States to Italy was based on a set of principles and actions identified at the outset of the project. These dictated that the seismic hazard reduction procedures and criteria recommended for Italian hospitals should:

- Be based on available procedures in the United States and on regulations known to be effective in reducing the seismic vulnerability of hospitals, in this case, those developed by the ATC, the Federal Emergency Management Agency (FEMA), the California Office of State-Wide Health Planning and Development, the Overseas Building Office (formerly the United States Foreign Building Office) and other agencies.

- Be based on the performance of Italian hospitals in previous earthquakes.

- Be consistent with existing laws in Italy.

- Consider the seismicity of Italy.

- Consider criteria for the seismic design of structural and non-structural components in hospital facilities in Italy, including new and existing structures.

- Consider the structural attributes of existing hospital facilities in Italy, including age, number of storeys, plan size and shape, and structural system materials; in this case, the extensive use of unreinforced-masonry walls.

- Consider the existing inventory of hospital facilities – that is, the number and regional distribution of facilities – relative to the regional seismicity.

The actions deemed necessary to carry out a successful project included:

- The selection of qualified consultants to develop the recommended procedures, in addition to a "blue ribbon" advisory panel consisting of leading available specialists in the seismic design, performance and regulation of hospital facilities from both countries, to overview and guide development of the recommendations.

- A field trip to Italy by members of the advisory panel and project consultants in the United States to observe the attributes and conditions of representative hospitals in Italy.

- A review by specialists in the United States of information and data provided by Italy on the historical seismicity of Italy, the performance of hospitals in previous earthquakes,
existing laws pertaining to seismic safety of hospitals, and available inventory information containing the number, age, size, height, plan-shape and structural system materials of hospitals.

- A field trip to the United States by Italian members of the advisory panel to observe the attributes and conditions of representative hospitals in California.

- A meeting of the bi-lateral advisory panel to develop the recommended procedures.

- A review of the final report by the bi-lateral advisory panel.

**Rapid visual inspection of buildings**

While a procedure for rapid visual screening of buildings for potential seismic hazards has not yet been developed for the ATC-51 programme for reducing seismic hazards in Italy, the existing procedure for this process in the United States could, with some effort, be adopted and adapted for assessing the seismic vulnerability of schools and educational facilities in other countries. The existing procedure in the United States for rapid visual inspection of buildings for potential seismic hazards was originally developed by the ATC in the late 1980s and published in 1989 in the first edition of the FEMA 154 Report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*. In 2002, the procedure was updated to include more recent seismic hazard information and a revised scoring system, based on more recently-developed building damage estimation curves; the updated version was published in 2002 as the second edition of the FEMA 154 Report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*.

**FEMA 154 rapid visual screening procedure**

The FEMA 154 rapid visual screening procedure (RVS) was developed for implementation by a government agency or corporate owner of a building, or the building department of a city or other community (known as the “RVS authority”) to identify, inventory and rank buildings that are potentially seismically hazardous. Although RVS is applicable to all buildings, its principal purpose is to identify:

- Older buildings designed and constructed before the adoption of adequate seismic design and detailing requirements.

- Buildings on soft or poor soils.

- Buildings with performance characteristics that negatively influence their seismic response.

Once identified as potentially hazardous, such buildings should be further evaluated by a design professional experienced in seismic design to determine if, in fact, they are seismically hazardous.

The RVS uses a methodology based on a “sidewalk survey” of a building and a Data Collection Form (Figure 12.1), which the person conducting the survey (known as the
“screener”) completes based on visual observation of the building from the exterior, and if possible, the interior. The Data Collection Form provides space for documenting building identification information, including building use and size, a photograph of the building, sketches and pertinent data related to seismic performance, including the development of a numeric and seismic hazard score.

Once the decision to conduct the RVS for a community or group of buildings has been made by the RVS authority, the screening effort can be expedited by pre-planning, involving the training of screeners and careful overall management of the process. Completion of the Data Collection Form in the field begins with the identification of the primary structural lateral-load-resisting system and materials of the building. Basic Structural Hazard Scores for various building types are provided on the form, and the screener circles the appropriate one. The screener modifies the Basic Structural Hazard Score by identifying and circling Score Modifiers, which are related to observed performance attributes, and which are then added (or subtracted) to the Basic Structural Hazard Score to arrive at a final Structural Score, $S$. The Basic Structural Hazard Score, Score Modifiers and final Structural Score, $S$, all relate to the probability of building collapse, should severe ground shaking occur; that is, a ground shaking level equivalent to that currently used in the seismic design of new buildings. Final $S$ scores typically range from 0 to 7, with higher $S$ scores corresponding to better seismic performance.

Use of the RVS on a community-wide basis enables the RVS authority to divide screened buildings into two categories: those that are expected to have acceptable seismic performance, and those that may be seismically hazardous and should be studied further. An $S$ score of 2 is suggested as a “cut-off”, based on present seismic design criteria. Using this cut-off level, buildings with an $S$ score of 2 or less should be investigated by a design professional experienced in seismic design.

The procedure presented in the FEMA 154 Handbook represents the preliminary screening phase of a multi-phase procedure for identifying hazardous buildings. Buildings identified by this procedure as potentially hazardous must be analysed in more detail by an experienced seismic design professional. As RVS is designed to be performed from the street, with interior inspection not always possible, hazardous details will not always be visible, and seismically hazardous buildings may not be identified as such. Conversely, buildings identified as potentially hazardous may prove to be adequate.
### Figure 12.1. FEMA 154 (2nd edition) Data Collection Form (high seismicity region) for use in rapid visual screening of buildings for potential seismic hazards

Rapid Visual Screening of Buildings for Potential Seismic Hazards

**FEMA-154 Data Collection Form**

<table>
<thead>
<tr>
<th>Address:</th>
<th>Zip:</th>
</tr>
</thead>
</table>

**Other Identifiers**

- No. Stories: __________________ Year Built: __________________
- Screener: __________________ Date: __________________
- Total Floor Area (sq. ft.): __________________
- Building Name: __________________
- Use: __________________

![PHOTOGRAPH](image)

**OCCUPANCY**

<table>
<thead>
<tr>
<th>Assembly</th>
<th>Commercial</th>
<th>Govt.</th>
<th>Residential</th>
<th>Historic</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>11-100</td>
<td>101-1000</td>
<td>1000+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SOIL TYPE**

- A: Hard Rock
- B: Avg. Rock
- C: Dense Soil
- D: Soft Soil
- E: Very Soft Soil
- F: Post-1980 Soils

**FALLING HAZARDS**

- Unreinforced Chimneys
- Parapets
- Cladding
- Other

**BASIC SCORE, MODIFIERS, AND FINAL SCORE, S**

<table>
<thead>
<tr>
<th>BUILDING TYPE</th>
<th>W1</th>
<th>W2</th>
<th>S1 (BR)</th>
<th>S2 (MR)</th>
<th>S3 (LM)</th>
<th>S4 (GC CRM)</th>
<th>S5 (URM INF)</th>
<th>C1 (WFR)</th>
<th>C2 (WFR)</th>
<th>C3 (URM INF)</th>
<th>PC1 (TD)</th>
<th>PC2 (TD)</th>
<th>RM1 (HD)</th>
<th>RM2 (HD)</th>
<th>URM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Score</td>
<td>4.4</td>
<td>3.8</td>
<td>2.8</td>
<td>3.0</td>
<td>3.2</td>
<td>2.8</td>
<td>2.0</td>
<td>2.5</td>
<td>2.8</td>
<td>1.6</td>
<td>2.6</td>
<td>2.4</td>
<td>2.8</td>
<td>2.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Mid Rise (4 to 7 stories)</td>
<td>N/A</td>
<td>N/A</td>
<td>+0.2</td>
<td>+0.4</td>
<td>N/A</td>
<td>+0.4</td>
<td>+0.4</td>
<td>+0.4</td>
<td>+0.2</td>
<td>N/A</td>
<td>+0.2</td>
<td>+0.4</td>
<td>+0.4</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>High Rise (&gt; 7 stories)</td>
<td>N/A</td>
<td>N/A</td>
<td>+0.6</td>
<td>+0.8</td>
<td>N/A</td>
<td>+0.8</td>
<td>+0.8</td>
<td>+0.6</td>
<td>+0.8</td>
<td>+0.3</td>
<td>N/A</td>
<td>+0.4</td>
<td>N/A</td>
<td>+0.6</td>
<td>N/A</td>
</tr>
<tr>
<td>Vertical Irregularity</td>
<td>-2.5</td>
<td>-2.0</td>
<td>-1.0</td>
<td>+1.0</td>
<td>N/A</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>N/A</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
</tr>
<tr>
<td>Plan Irregularity</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.5</td>
<td>N/A</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.5</td>
</tr>
<tr>
<td>Pre-Code</td>
<td>0.0</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-0.8</td>
<td>-0.8</td>
<td>-0.8</td>
<td>-0.2</td>
<td>-1.2</td>
<td>-1.0</td>
<td>-0.2</td>
<td>-0.8</td>
<td>-0.6</td>
<td>-1.0</td>
<td>-0.8</td>
<td>-0.2</td>
</tr>
<tr>
<td>Post-Benchmark</td>
<td>+2.4</td>
<td>+2.4</td>
<td>+1.4</td>
<td>+1.4</td>
<td>N/A</td>
<td>+1.6</td>
<td>N/A</td>
<td>+1.4</td>
<td>+2.4</td>
<td>N/A</td>
<td>+2.4</td>
<td>N/A</td>
<td>+2.8</td>
<td>+2.6</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**SOIL TYPE**

- D: Soil Type C

| Soil Type C | 0.0 | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 |

**SOIL TYPE**

- E: Soil Type D

| Soil Type D | 0.0 | -0.8 | -0.8 | -0.6 | -0.6 | -0.6 | -0.4 | -0.6 | -0.6 | -0.4 | -0.6 | -0.6 | -0.6 | -0.6 | -0.6 |

**SOIL TYPE**

- F: Soil Type E

| Soil Type E | 0.0 | -0.8 | -1.2 | -1.2 | -1.0 | -1.2 | -0.8 | -1.2 | -0.8 | -0.8 | -0.4 | -1.2 | -0.4 | -0.6 | -0.8 |

**FINAL SCORE, S**

**COMMENTS**

- Detailed Evaluation Required

* = Estimated, subjective, or unreliable data

- BR = Braced frame
- MRF = Moment-resisting frame
- SW = Shear wall
- TD = Tilt-up
- RC = Reinforced concrete
- LM = Light metal
- RD = Rigid diaphragm
- URM INF = Unreinforced masonry infill

© OECD 2004
Adaptation and adoption for use in other countries

The FEMA 154 RVS procedure could be adopted and adapted to other countries. This would require a process similar to that used in the ATC-51 programme for hospital seismic safety in Italy, namely:

• The identification of representative building types in the region to be assessed.

• The development of structural hazard scores and modifiers reflecting the building’s seismic-resisting attributes, and the seismicity and soil conditions in the region to be assessed.

• The use of specialists from both the United States and the region to be assessed to develop and review the adapted procedure, including revised Data Collection Forms.

Detailed seismic evaluation of structural and non-structural components

Existing procedures in the United States for detailed seismic evaluation of buildings have been developed over the last 15 years using a comprehensive research and development process involving numerous design professionals and researchers, with substantial funding from the Federal Emergency Management Agency. The evaluation procedures are based on the seismic performance of buildings in previous earthquakes and focus on evaluations intended to determine if life-safety hazards exist. The procedures involve the use of a checklist approach intended to uncover weak links in both structural and non-structural components. Checklists, formatted as evaluation statements requiring a true or false response, are provided for building features common to all building types, for foundation and geologic site hazards, for non-structural components, and for the special features of 15-model, or common, building types. If the response by the evaluating engineer to any evaluation statement is false, the structural or non-structural component addressed by that evaluation statement is deemed to be potentially hazardous, and a process of simple calculation is used to determine if that component is in fact hazardous.

As is the case for the FEMA 154 procedure for rapid visual screening of buildings for potential seismic hazards, existing procedures in the United States for detailed seismic evaluation of buildings, including both structural and non-structural components, could, with some effort, be adapted for assessing the seismic vulnerability of schools and educational facilities in other countries. The process would require an approach similar to that proposed for the adoption and adaptation of the FEMA 154 RVS procedure, namely:

• The identification of common building types, in addition to seismic-resisting attributes, in the region to be assessed.

• The adaptation of FEMA 310 checklists or evaluation statements to reflect the building’s seismic-resisting attributes, the seismicity and soil conditions in the region to be assessed.

• The use of specialists from both the United States and the region to be assessed to develop and review the adapted procedures and checklists or evaluation statements.
Evaluation of non-structural components, as developed under the ATC-51 programme

The recommended procedures for bracing and anchoring non-structural components in hospitals in Italy, as documented in the ATC-51-2 Report, *Recommended U.S.-Italy Collaborative Guidelines for Bracing and Anchoring Non-Structural Components in Italian Hospitals*, comprise assessment guidelines advising that specific non-structural components be identified as requiring seismic evaluation or anchoring. These guidelines are based on four considerations:

- Seismicity, expressed as the Seismic Zone from the Italian building code.
- The seismic vulnerability of the component to earthquake damage, for a given seismicity.
- The importance of the component to hospital post-earthquake operation.
- The cost and disruption to retrofit or anchor the component.

The goal is to focus design and construction resources on the most critical and cost-effective non-structural seismic improvements. All four of the above considerations must be taken into account in any policy on non-structural seismic evaluation and design.

Specific examples are provided in the ATC-51-2 Report, which indicates when seismic evaluation and anchoring are required, considering both new and existing installations. Twenty-seven example components are presented, and each non-structural component is assessed in terms of its vulnerability, importance, and cost and disruption to retrofit. Based on these attributes, a recommendation indicates in which zones the component should be retrofitted, and in which zones seismic anchoring should be part of new installations. Each example component is summarised using photographs, a summary assessment of the component attributes, and recommendations for evaluation and anchoring (Figure 12.2).

While the non-structural component evaluation guidelines and criteria specified in the ATC-51-2 Report refer to hospitals in Italy, these simplified procedures offer a model approach for developing specifications for evaluating non-structural components in schools. The process for developing the component example guidance (Figure 12.2) was based in part on a field trip by U.S. specialists to hospitals in Italy to observe and document existing procedures for anchoring and bracing non-structural components. A similar process would be required to develop guidance for non-structural component anchoring and bracing in schools and educational systems.

**Seismic loading criteria**

Criteria used in the United States to specify the level of seismic shaking in seismic design of new buildings and in the seismic rehabilitation of existing buildings have evolved over the last decade from a specification of ground motions with a 10% probability of being exceeded in 50 years – which corresponds to an earthquake return period of 475 years – to a specification of ground motions with a 2% probability of being exceeded in 50 years.
which corresponds to an earthquake return period of 2 475 years. This change has come about largely to account for ground shaking due to large infrequent earthquakes, which are not captured by the shorter earthquake return period. Consideration of large infrequent events is only necessary, however, if the region under consideration has long fault lengths that are capable of generating such earthquakes. In the United States, such regions include California, the Pacific Northwest, Alaska and the New Madrid, Missouri region.
It appears that seismic loading criteria for the vast majority of seismically active regions outside the United States specify ground motions roughly equivalent to those with a 10% probability of being exceeded in 50 years. The prevalence of these criteria suggest that, for the time being, the norm for quantifying the seismic shaking hazard is a specification equivalent to ground motions with a 10% probability of being exceeded in 50 years. Consideration must also be given, however, to the factors used to reduce ground motions to the level used in seismic design (called R-factors in codes in the United States). In addition, as time-dependent seismic hazard analysis capabilities improve, it may be advisable to consider time-dependent analysis results, particularly in regions where the period of time from the last large infrequent event equals or exceeds the return period for that event.

**Programme costs**

The cost of the ATC-51 programme for improving seismic safety of hospitals in Italy covers the development of recommendations and guidelines, as well as design and construction costs related to implementing the recommendations and guidelines. The cost of recommendation and guideline development ranged from approximately USD 80 000 to slightly more than USD 100 000, averaging approximately USD 100 000 for each of the three projects completed to date. The costs for design and construction have not yet been determined.

**Notes**

1. Applied Technology Council has also been involved in several international projects, including a series of ten United States-Japan Workshops on the Improvement of Structural Design and Construction Practices (ATC-15 series, held every other year since 1984), a series of United States-New Zealand workshops on seismic design of highway bridges (ATC-12 series), and in the development of a United States-Italy collaborative programme for the improvement of seismic safety of hospitals in Italy (ATC-51 series).