PROPOSAL ON DATA COLLECTION FOR AN INTERNATIONAL EARTHQUAKE EXPERIENCE DATA

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Abstract

Earthquake experience data was recognized as an efficient basis for verification of seismic adequacy of equipment installed on NPPs. This paper is meant to initiate a database setup in order to use the seismic experience to establish the generic seismic resistance of NPP's equipment applicable namely to the Middle and East European countries. Such earthquake experience database should be then compared to the already existing and well-known SQUG-GIP database.

To setup such an operational earthquake database will require an important amount of efforts. It must be understood that this goal may be achieved only based on a long term permanent activities an coordinated cooperation of various institutions.

1. General Considerations

There are three types of experience data which can be used:

- data collected from real earthquakes,
- data collected from already performed seismic tests,
- data collected from already performed seismic analyses.

1.1. Data Collected from Real Earthquakes

The use of experience from strong motion seismic events has growing application. It has been only within the pass ten or fifteen years that data from strong motion earthquakes have generally and systematically been collected in detail and quality necessary to provide information required for direct application to individual equipment items.

The Post-Earthquake Investigation Team (PEIT) should be setup to conduct reconnaissance and detail research investigations by a special walkdown of power and industrial facilities affected by an earthquake. The objective is to gather field experience data on equipment and supporting structures similar to those in NPPs and to study on this basis the general seismic behavior of these affected power and industrial facilities. The PEIT investigations are only the way to evaluate seismic performance of equipment in its actual installed and operational conditions. They also provide insights into seismic behavior of building structures and their effects on equipment supported by these structures.

The main attributes of this approach are:

- real earthquake motion involved,
- field mounting and anchorage conditions are typical of actual installation,

- for NPPs equipment that is also found in non-nuclear facilities the information base is large,
- equipment is subjected to realistic operational conditions, natural aging effects and actual interfaces to connecting equipment or systems.

The following unresolved issues are the most important in relation to this activity:

- PEIT status and personnel (two or three international teams each of about five or more experts, organized and working under the direct IAEA guidance and administration?)
- financial support (NPPs, European Community?),
- working method (similar to that provided in the U.S. by EPRI or modified?),
- availability of the area and facilities affected by an earthquake (using IAEA reputation?),
- availability of earthquake and post-earthquake reports or other relevant documentation (using IAEA reputation?).

The Electric Power Research Institute (EPRI) in the U.S. established an expert team of about 30 investigators of several organizations from which the PEIT is formed. When an earthquake occurs, EPRI sends the PEIT to the earthquake area immediately for a period of about one weak to identify and investigate local power and industrial facilities. If a sufficient number of facilities is found in the affected area and ground motions are high (more than 0.2 g), the PEIT visits that area one or more times for detail investigations.

Earthquake data mainly may be found from the post-earthquake reports owned by utilities. In absence of an organized program regarding to post earthquake activities it should be very difficult and time consuming to collect such information at required quality.

The data which should be collected and evaluated in relation to an investigated equipment item are as follows:

- ID number of the investigated equipment item,
- generic class [1)],
- description of equipment type,
- description of the current seismic event (magnitude, epicentrum etc.)
- equipment location (place, distance from the epicentrum, type of the building structure, elevation, rank of building damage due to current seismic event),
- manufacturer the investigated equipment item,
- equipment size & weight,
- environment parameters (if available),
- post-earthquake report descriptors (number, revision, title, authors, date etc.),
- investigation date,
- description of equipment anchorage,
- description earthquake motion affected the investigated equipment item (PGA, spectra, accelerograms, whatever available from the post-earthquake report or estimated, etc.),
- description of damage (if any),
- description of functional failure (if any),
- description o observed seismic interactions,
- any other comments.

Note: 1) Proposed generic classes of equipment:

- motor control centers,
- low voltage svitchgears,
- medium voltage switchgears,
- transformers,
- horizontal pumps,
- vertical pumps,
- fluid operated valves,
- motor operated valves,
- ventilators,
- air handlers,
- chillers,
- air compressors,
- motor generators and associated equipment,
- distribution panels,
- batteries on racks,
- battery chargers and invertors,
- engine generators and associated equipment,
- instruments on racks,
- sensors on racks,
- I&C cabinets and panels,
- relays, switches, transmitters, sensors,
- instrument readouts (displays, indicators, recorders etc.)
- electrictrical penetrations,
- cable supporting structures,
- tanks,
- heat exchangers,
- filters,
- pipes (above ground),
- pipes (buried),
- HVAC ducts,
- other.

1.2. Data Collected from Already Performed Seismic Tests

The Seismic Test Investigation Team (STIT) should be setup to provide a collection of available seismic test data of NPP's equipment components. The objective is to gather seismic test data and to study on this basis the general seismic behavior of components during and after their seismic tests.

In comparison to the approach described in the previous section, the test data offer a different set of attributes:

- seismic tests involve relatively high levels of simulated input motions that are controlled, measured and documented,
- seismic test methods incorporate a number of conservative aspects,
- In-Structure Resonse Spectra (ISRS) are used as test input criteria and they must be properly enveloped by the broad-band Test Response Spectra (TRS),
- generally the Zero Period Acceleration (ZPA) of TRS is several times greater than that of ISRS,
- documented functional tests are normally included,
- failure mode information and fragility test data are available (from seismic test to failure),
- aging effects can be reproduced during some seismic test.

It is a common practice to use seismic testing for equipment whose functionality during and after an earthquake has to be assured. The most often form of seismic tests is testing on shaking tables. The equipment component to be tested is usually mounted on a programmable shaking table which provides its required base motions. When reduced scale testing is performed, similarity requirements of seismic testing must be considered.

The following unresolved issues are the most important in relation to this activity:

- STIT status and personnel (one research team of about three experts, organized with one of the well-known testing laboratories as ISMES, EUROTEST-S&A, IEEES etc. working with the general IAEA commission?)
- financial support (NPPs, European Community?),
- working method (similar to that provided in the U.S. by EPRI or modified?),
- availability and exchange of seismic test reports or other relevant documentation (using IAEA reputation?).

The data which should be extracted from the seismic test reports (by STIT or by originators of test reports) and evaluated (by STIT) in relation to an investigated equipment item are as follows:

- ID number of the tested equipment item,
- generic class,
- description of equipment type,
- manufacturer of the tested equipment item,

- manufacturer standards used,
- equipment size & weight,
- environment parameters (if available),
- seismic test organization,
- organization for which the seismic test was performed,
- test report descriptors (number, revision, title, authors, date etc.),
- test date,
- description of equipment anchorage and test mounting,
- type of the performed seismic test (according to [5]),
- description of the applied seismic input (direction, type etc.),
- functions monitored,
- acceptance criteria,
- resonant search,
- description of damage (if any),
- verification of equipment functionality (if any),
- any other comments.

It is believed that there is a lot of already performed and interesting seismic tests which may be very useful for the proposed earthquake experience database. A number of such useful results from Romania (EUROTEST-S&A) has been already extracted from available documentation and investigated by Stevenson and Coman [4],

1.3. Data Collected from Already Performed Seismic Analyses

The Seismic Analysis Investigation Team (SAIT) should be setup to provide a collection of available seismic analysis data of NPP's equipment components. The objective is to gather seismic analysis data and to study on this basis the general seismic behavior of components during and after their seismic tests.

The following unresolved issues are the most important in relation to this activity:

- SAIT status and personnel (one research team of about three experts, organized with one of the well-known analysis offices as S&A, SIEMENS, WESTINGHOUSE, STUSSI etc. working with the general IAEA commission?),
- financial support (NPPs, European Community?),
- working method (similar to that provided in the U.S. or modified?),
- availability and exchange of seismic analysis reports or other relevant documentation (using IAEA reputation?).

The data which should be extracted from the seismic analysis reports (by SAIT or by originators of analysis reports) and evaluated (by SAIT) in relation to an investigated equipment item are as follows:

- ID number of the analyzed equipment item,
- generic class,
- description of equipment type,
- manufacturer of the tested equipment item,

- manufacturer standards used,
- equipment size & weight,
- environment parameters (if available),
- seismic analysis organization,
- organization for which the seismic analysis was performed,
- analysis report descriptors (number, revision, title, authors, date etc.),
- description of equipment anchorage,
- type of the performed seismic analysis,
- description of the used seismic input ,
- acceptance criteria,
- results of the analysis,
- any other comments.

Seismic qualification by analysis is generally applied to such items as heavy passive mechanical components, distribution systems, and civil structures. As stated in [4], due to well known uncertainty in analysis, this approach should be considered as only supporting information in earthquake experience data process, namely when the equipment is component is qualified by combined analysis and testing. It is believed that there is a lot of already performed and interesting seismic analyses which may be very useful for the proposed earthquake experience database.

From the other side, there is a good chance to receive some information also about seismic resistance of NPP's civil engineering structures which are usually analyzed, not tested.

1.4. Data Evaluation and Research Coordination

The data evaluation process generally should consist of the following main steps:

- obtain collected or extracted data,
- review data for suitability and completeness,
- enter data in the database and store on the disk,
- evaluate seismic capacity spectra related to an each equipment class, compare them to the SQUG bounding spectrum and available GERS spectra [2],
- determine caveats (inclusion and exclusion rules) related an each equipment class and compare them to the corresponding SQUG caveats [3],
- perform guidelines for evaluation of seismic interactions and anchorage of equipment typically occurred on European NPPs.

Research coordination of all three activities described above seems to be extremely important and should be, perhaps, performed by IAEA.

2. Conclusion

This paper presents the first proposal on data collection for an international earthquake experience data. Also data evaluation process is generally described. The paper is meant to initiate discussion and then a database setup in order to use the seismic experience to establish the generic seismic resistance of NPP's equipment applicable namely to the European countries. The future of this process will strongly depend on creation of the corresponding coordinated international program. Unresolved issues which are the most important in relation to these activities are also outlined in this paper.

Once the earthquake experience database will become operational, the first and most important benefit will be the reduction of efforts related to seismic evaluation and reevaluation of NPP's mechanical and electrical equipment, and namely that which is installed on VVER-type NPPs.

Abbreviations

GERS	Generic Equipment Ruggedness Spectra
GIP	Generic Implementation Procedure
EPRI	Electric Power Research Institute
IAEA	International Atomic Energy Agency
IEEES	Institute of Earthquake Engineering and Engineering Seismology
ISRS	In-Structure Response Spectrum
NPP	Nuclear Power Plant
PGA	Peak Ground Acceleration
PEIT	Post-Earthquake Investigation Team
SAIT	Seismic Analysis Investigation Team
SQUG	Seismic Qualification Utility Group
STIT	Seismic Testing Investigation Team
S&A	Stevenson and Associates
TRS	Test Response Spectrum
ZPA	Zero Period Acceleration

REFERENCES

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[5] CEI IEC 980 Recommended Practice for Seismic Qualification of Electrical Equipment of the Safety System for Nuclear Generating Stations. IEC, 1989.