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Benchmark study for the seismic analysis and testing of WWER type NPPs

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ABSTRACT: A Coordinated research program supported by the International Atomic Energy Agency on a "Benchmark study for the seismic analysis and testing of WWER type nuclear power plants is being performed with the participation of 22 institutes from 14 countries. This program involves a variety of applied research as well as a comparison of testing and analytical results for structures, equipment and distribution systems.

1 INTRODUCTION

A coordinated research program on the benchmark study for the seismic analysis and testing of WWER type nuclear power plants was initiated subsequent to the request from representatives of member states during the IAEA Technical Committee Meeting on the seismic safety of existing nuclear power plants held in Tokyo in August 1991. The conclusions of this meeting called for the harmonization of methods and criteria used in member states in issues related to seismic safety. In particular, seismic safety concerns related to WWER type nuclear power plants were expressed.

With this objective in mind, a consultants meeting was convened in Vienna to produce a working document for a coordinated research program. On the basis of the recommendations of this group it was decided that a benchmark study is the most effective way of achieving the principal objective. Two types of ex-USSR designed WWER reactors (WWER-1000 and WWER-440/213) were selected for the benchmark exercise.

Twenty two internationally recognized institutions (public or private companies) from fourteen countries take part in the seismic analysis and/or testing of the two prototypes which have been identified as Kozloduy NPP Unit 5/6 and Paks NPP, representing the WWER-1000 and WWER-440/213 respectively.

Two research coordination meetings were held so far, one in Paks and the other in Kozloduy. Reconnaissance plant walkdowns were performed during the meetings for the two selected prototypes. The next research coordination meeting is scheduled to be held in St. Petersburg, June 1995.

Seven volumes of research material has been prepared by the participating institutions. One of the major activities of the program has been the full scale dynamic testing of the Paks NPP using blasts.

2 INFORMATION ON PROTOTYPE PLANTS

Paks NPP

Paks NPP comprises four units of WWER-440/213 units. It is located about 100 kms south of Budapest on the Danube river. In the original design of the plant seismic loads had not been taken into consideration. The seismic input for the plant is still under investigation. Although preliminary values were in the vicinity of 0.35g, it is expected to have somewhat lower values as a result of the final assessment. An additional problem for Paks could be due to the potential for the liquefaction of sand layers under seismic loads. This aspect of the site is also under investigation. A major program of seismic evaluation and upgrading is underway at Paks NPP. The so called "easy fixes" have already been implemented. These mainly include equipment supports and anchorages, as well as strengthening of unreinforced masonry walls with the potential of collapsing on safety related items.

Structurally, the WWER-440/213 type NPPs lack a containment, i.e. protection from external loads. The reactor building structure is steel frame with infill walls and without proper bracing to resist lateral loads. The monolithic concrete part of the building is in the lower part of the structure and serves as an ultimate pressure boundary for extreme internal loads (Figure 1).

Kozloduy NPP Unit 5/6

Kozloduy NPP site has four units of WWER-440/230 and two units of WWER-1000. Units 5 and 6 refer to the 1000 Mwe units. The site is due north from Sofia and on the right bank of Danube. The soils can be classified as medium stiff with pockets of looser sands especially under parts of the water intake canals. Originally Units 5 and 6 were designed to 0.1g. The reassessed seismic design level is 0.2g associated with a wide band response spectrum rich in lower frequencies (mainly due to the Vrancea earthquake source). An additional near field earthquake needs to be defined for the site. This is expected to be finalized by September 1995. Although considerable work has been done in terms of re-evaluation and upgrading of the smaller units at Kozloduy (these units were not designed for seismic loads originally), so far only a seismic PSA was performed for Unit 5.

Structurally, WWER-1000 units are radically different from the WWER-440 units. The containment structure of the reactor building provides general protection from extreme external hazards (Figure 2). However the adequacy of this protection with respect to site seismicity still needs consideration.

3 PARTICIPATION AND TASKS

In the third year of its implementation, the number of participating institutions to the program has increased to twenty two, coming from fourteen member states. Each participating institution (generally a public or private company) has a well defined work plan and task. The distribution of tasks is generally made during the research coordination meetings.

The areas of interest are grouped in a matrix form and may be related to analysis, testing or experience data pertaining to structures, equipment or distribution systems. The application could be either for the Kozloduy NPP Unit 5/6 (i.e. WWER-1000) or the Paks NPP (i.e. WWER-440/213). Each participating institution identifies the area(s) of interest for the coming year during the research coordination meeting. A typical matrix showing the partition of tasks is given in Table 1.

After determining the area(s) of interest of the institutions, a workplan is prepared in terms of concrete tasks, identifying the scope of the task, participating institutions in the performance of the task, coordinator of the task and the date of completion of the task. The following is the summary workplan (titles only) which was prepared in June 1994.

Task 1. Safe shutdown systems identification/classification (task completed)

Task 2. Design regulations, acceptance criteria, loading combinations (task completed)

Task 3. Seismic input, soil conditions (task completed for Kozloduy NPP)

Task 4. Standards, criteria - comparative study (task completed)

Task 5. Plant walkdowns for reconnaissance (task completed)

Task 6. Dynamic analysis of Kozloduy reactor building (continuing)

Task 7. Dynamic analysis of Paks reactor building (continuing)

Task 8. Full scale blast testing of Paks NPP (task completed)

Task 9. Shaking table experiment for selected components (continuing)

Task 10. On site testing of equipment (task completed for Paks NPP)

Task 11. Distribution of previous test data (continuing)

Task 12. Experience data from Vrancea and Spitak earthquakes (continuing)

Task 13. Experience data from US earthquakes (continuing)

Task 14. Assessment of containment dome prestressing for Kozloduy NPP (task completed)

Task 15. Assessment of containment dome for different load combinations (continuing)

Task 16. Stress analysis of safety related piping for Kozloduy NPP (continuing)

Task 17. Dynamic analysis of selected structures such as stack, DG building (continuing)

Seven volumes of research material has been compiled reflecting the results of the completed tasks. These seven volumes are titled as follows:

Volume 1. Data related to sites and plants (Paks NPP and Kozloduy NPP)

Volume 2. Generic material: codes, standards, criteria

Volumes 3A, 3B, 3C. Kozloduy NPP, Units 5/6: Analysis/testing

Volumes 4A, 4B. Paks NPP: Analysis/testing

4 FULL SCALE DYNAMIC TEST OF PAKS NPP

One of the most significant tasks already completed is the full scale dynamic testing of the Paks NPP. The test was conducted by Ismes, an Italian consulting company and Paks NPP with assistance from local contractors especially for the realization of the blasts. The test was performed in December 1994 following a two week preparation period for placing the instruments and recording of smaller test blasts.

The blast location was about 2.5 kilometers from the reactor building. Two main blasts were performed with a total each of 300 kilograms of TNT charge. Three free field locations were selected for instrumentation. Two of these had two borehole (@40 meters and 15 meters depth) and one surface recording. About 40 meters corresponds to the depth of the firmer geological formation. An additional (fourth) instrument was located about 12 kilometers away in order to provide some information on attenuation characteristics. A large number of seismometers and accelerometers were mounted in the reactor building (some also in other buildings) to record the structural response. Instruments were also placed on certain heavy components and tanks.

Both blasts used a time delay to enhance the duration of the motion so that an adequate time series analysis was possible. In most locations a motion of about 20 seconds was recorded. The records are of very high quality. It should also be noted that all of the instruments functioned as intended. More detailed information on the full scale dynamic testing of Paks NPP can be obtained from the presentation of Ismes and Paks NPP in this session of SMiRT-13 (1).

During a meeting in Vienna in March 1995, between the IAEA, Ismes and Paks NPP, it was decided that one set of free field recordings will be made available for the benchmarking. Locations and directions of the in-structure instruments will be indicated and the participants will be asked to make a blind prediction of the response recorded at these locations. All the relevant dynamic soil parameters and structural properties will be provided to the participants. Preliminary results of the benchmarking are expected to be discussed during the upcoming research coordination meeting in St. Petersburg.

REFERENCES

Contri, P., Da Rin and Muzzi, F., 1995, "Full scale dynamic testing of Paks NPP", Proceedings of SMiRT-13

Table 1: Partition of tasks for participating institutions

	Structures		Components		Distribution Systems	
	Kozloduy NPP	Paks NPP	Kozloduy NPP	Paks NPP	Kozloduy NPP	Paks NPP
Analysis	SP (CH)-BRI (BG) AEP (RF)- Siemens (G) EQE (BG) MD (CR) CL (BG) CKTI (RF)	AEP (RF)- P-NPP (H)- Siemens (G) Ismes (I) MD (CR) EQE (BG) - EQE (USA) CL (BG)	AEP (RF)- CKTI (RF) VNIIAM (RF) WESI (B)	Siemens (G)- P-NPP (H) CKTI (RF)-SA (CR) VNIIAM (RF)	Siemens (G)- CKTI (RF) WESI (B) SP (CH)-BRI (BG) CL (BG)	P-NPP (H)- Siemens (G)- CKTI (RF)-SA (CR)
Testing		AEP (RF) Ismes (I) P-NPP (H) IZIIS (M)	AEP (RF) CKTI (RF) VNIIAM (RF) IZIIS (M) EQE (BG)	AEP (RF) Argonne (USA) CKTI (RF) P-NPP (H) VNIIAM (RF) IZIIS (M) EQE (BG)	AEP (RF) CKTI (RF) VNIIAM (RF)	AEP (RF) CKTI (RF) P-NPP (H) VNIIAM (RF)
Experience Data	AEP (RF)- Siemens (G) EA (Sp.)	AEP (RF)- Siemens (G) EA (Sp.)	AEP (RF)- Siemens (G) EA (Sp.) EQE (BG)-EQE (USA) VNIIAM (RF) WESI (B)	EQE (USA)-EQE (BG) AEP (RF)- Siemens (G) EA (Sp.) SA (CR) VNIIAM (RF) WESI (B)	EQE (USA)-EQE (BG) AEP (RF) EA (Sp.) EQE (BG) VNIIAM (RF) WESI (B) SA (CR) SA (US)	EQE (USA)-EQE (BG) AEP (RF) EA (Sp.) SA (CR) VNIIAM (RF) WESI (B) SA (US)

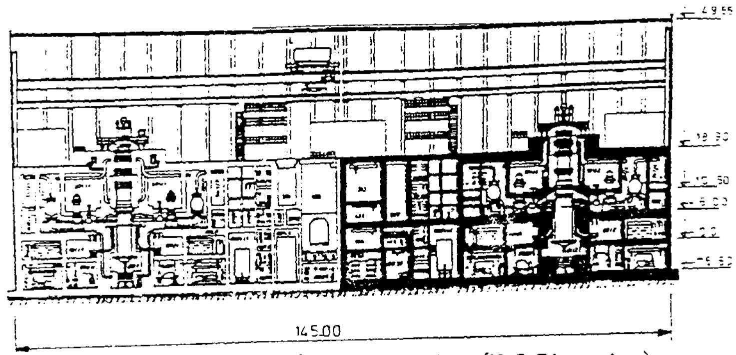
Legend: List of Participating Institutions

AEP	:	Atomenergoprojekt- Moscow, Russian Federation
BRI	:	Building Research Institute, Bulgaria
CKTI	:	Central Steam Generator and Turbine Institute, Russian Federation
CL	:	Central Laboratory of Seismic Mechanics, Bulgaria
EQE(BG)	:	EQE, Bulgaria
EQE(US)	:	EQE International, USA
EP	:	Energoproekt, Bulgaria
ISMES	:	ISMES Spa, Italy
IZIIS	:	Skopje Earthquake Engineering Laboratory, Macedonia
KNPP	:	Kozloduy NPP, Bulgaria
MD	:	David Engineering, Czech Republic
PNPP	:	Paks NPP, Hungary
SA(CR)	:	Stevenson and Associates, Czech Republic
SA(R)	:	Stevenson and Associates, Romania
SAGE	:	SAGE Engineering, Belgium/UK
Siemens	:	Siemens, Germany
SAS	:	Slovak Academy of Sciences, Slovakia
SP	:	Stuessi and Partner, Switzerland
VNIIAM	:	All Russia Nuclear Power Engineering Research and Development Institute
WE	:	Woelfel Engineering, Germany
WESE	:	Westinghouse Energy Systems Europe, Belgium

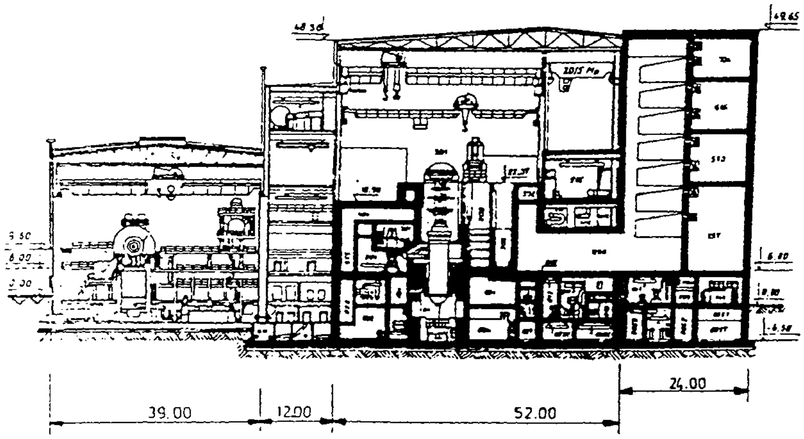
Associated Institutions:

Argonne National Laboratory, USA
Stevenson and Associates, USA
National Earthquake Engineering Laboratory, Tsukuba, Japan

Figure 1: Paks NPP cross sections



Longitudinal Cross Section (N-S Direction)



Perpendicular Cross Section (E-W Direction)

Figure 2: Kozloduy NPP Unit 5 - Reactor Building Cross Section