Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.VI)

10-5-13

EVALUATION OF EFFECTS OF THE MUEHLHAUSEN EARTHQUAKE OF 15.7.1980 ON THE NUCLEAR POWER PLANT BEZNAU, SWITZERLAND

S. TINIC[1] and V. LANGER[2]

[1]Project Engineer, Nordostschweiz. Kraftwerke AG (NOK), Baden, CH
[2]Project Manager, Nordostschweiz. Kraftwerke AG (NOK), Baden, CH

SUMMARY

The earthquake characteristics are briefly described, followed by its observation at the Beznau site. The instrumentation at the plant and the data processing are also described. Finally, the relevance of this event to the seismic requalification studies is discussed.

EVALUATION OF SEISMOGRAMS

Earthquake Characteristics North eastern Switzerland lies geographically in an area of low seismic activity. Since the Rhinau earthquake of Sept. 4th, 1959, the Mühlhausen area (in the region of Sierenz Southern Rhinegraben) is potentially the most active source of seismic activity for this part of Switzerland [1,2]. The Swiss Earthquake Service (SED) provides the following data for the more recent earthquake of July 15th, 1980, [1]:

- origin time (main shock): 12 17 21.84
- epicentre: latitude 47N37.63. longitude 7E30.51
- depth of focus: 15 km
- magnitude: 4.4

The earthquake was recorded at 15 seismographic stations. The data was evaluated and published in [3,4]. The earthquake was also recorded at the Beznau NPP, situated 55 km from the epicentre. It is the only one which has been registered instrumentally at the plant during its operational period (1969 to the present day). The peak accelerations of smaller magnitude earthquakes observed in the area were below the triggering level of the instruments. Fig. 1 shows the location of the Beznau NPP on the Macroseismic Map published by the SED.

Site an Structure The site of the nuclear power plant Beznau is located in the valley of the river Aare about 15 km south of the northern border of Switzerland. The soil profile consists of a layer of dense alluvial gravel about 16 m thick overlying weathered claystone. Fig. 2 shows a plan sketch of Beznau plants I and II. Both reactor buildings are 65.7 m high and founded on rock 15 m below the ground surface. The auxiliary buildings are founded at a depth of 2 m in the gravel layer. Their heights vary between 13 and 23 m.

Seismic Instrumentation Altogether the plant is instrumented with 5 three component accelerometers. Three of these are located in the reactor building. One is in the free field buried 5 m deep and the remaining one is installed in the fuel storage building. The instruments are oriented in the N-S and E-W directions. The exact locations are given in Table 1.

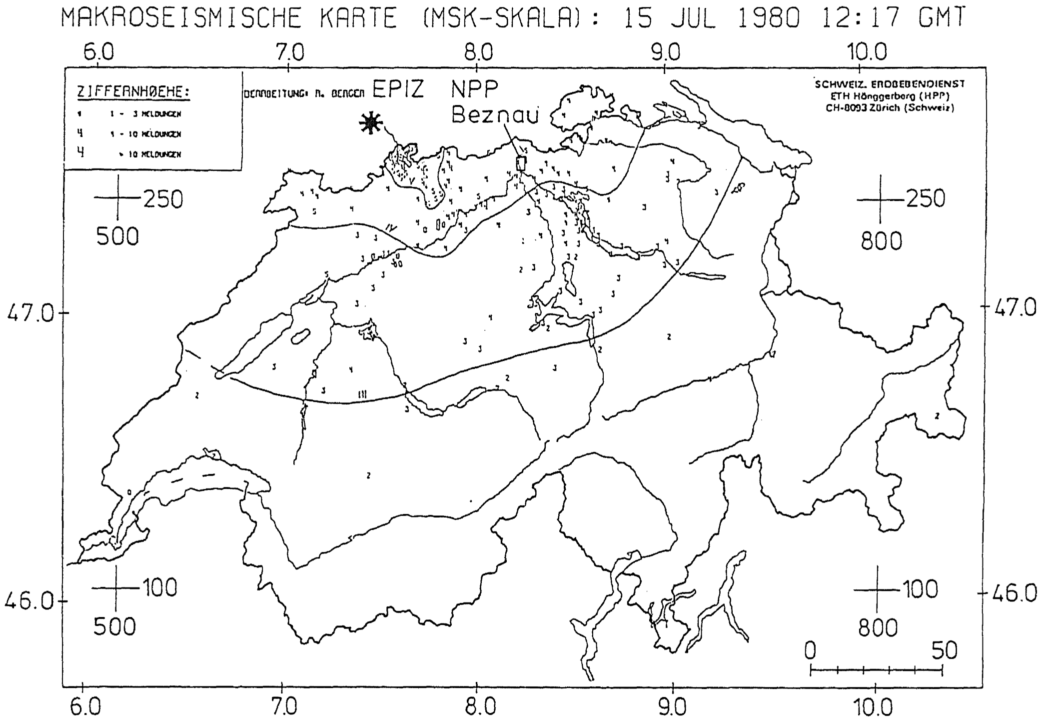

Fig. 1 Macroseismic Map of Switzerland (SED)

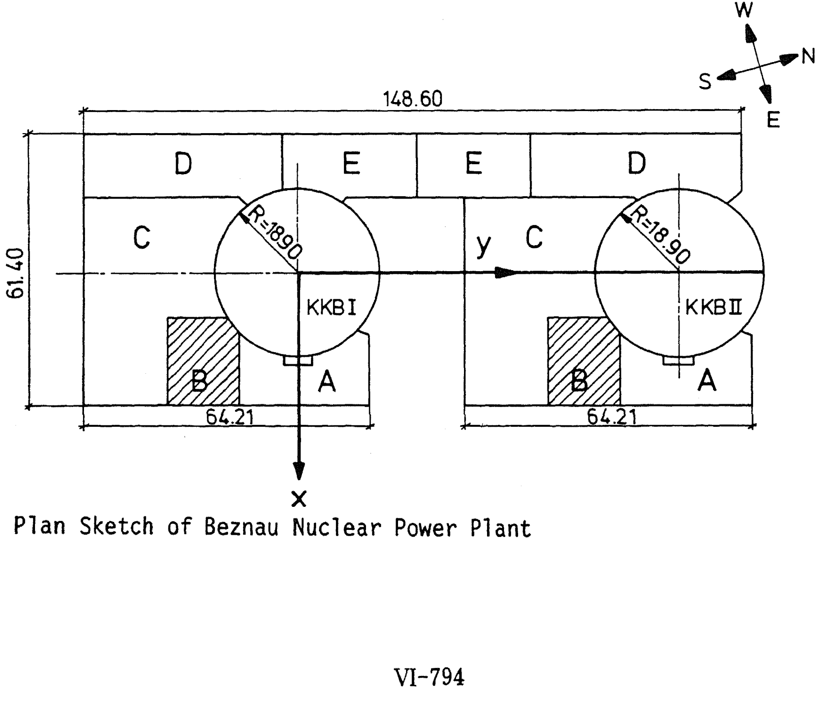

Fig. 2 Plan Sketch of Beznau Nuclear Power Plant

Table 1 Maximum recorded accelerations at the Beznau NPP for the Mühlhausen earthquake of 15.7.1980

Instrument	Location	Elevation	Max. Acceleration 10^{-3} g		
			E-W	N-S	Vertical
F2	Free field	- 5.0	1.70	3.21	0.55
G1	Reactor B. Foundation	- 13.0	2.39	2.66	0.47
G2	Reactor B. Int. Floor	+ 15.0	4.14	5.25	0.58
G3	Reactor B. Steam generator Accident support	+ 17.6	6.04	6.17	2.31
G4	Fuel Storage B.	+ 3.0	3.40	2.98	0.60

Recording and processing of seimographic data The earthquake was recorded in analogue form on all the instruments. Fig. 3 shows the signal recorded on instrument F2 located in the free field. The recorded seismograms were stored on a magnetic tape, which was subsequently sent to the SED, where for processing purposes the data was transformed to digital form. The direct current component was filtered out.

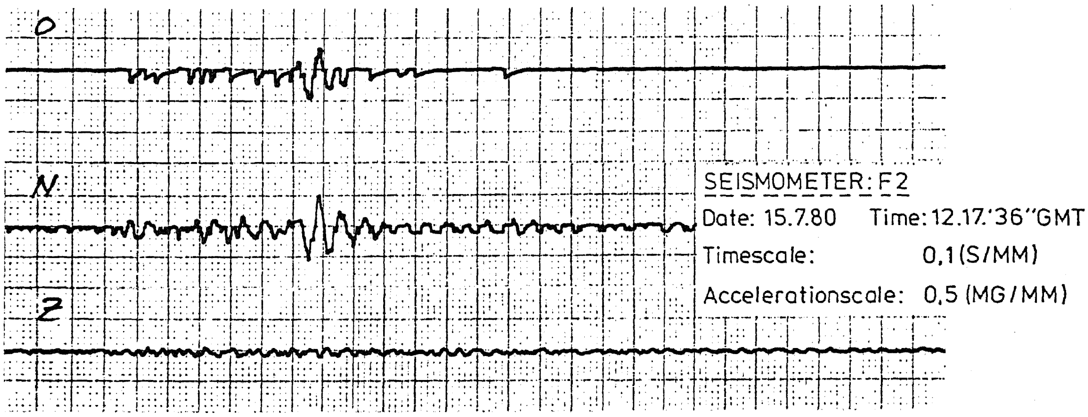

Fig. 3 Recorded Accelerograms

Evaluation of Data The processed data was evaluated by the engineers of the Nordostschweizerische Kraftwerke AG. The frequency content above 50 Hz was eliminated. The measured peak acceleration values are given in Table 1. The floor acceleration spectra for 4 % damping were then calculated. These results are shown in Fig. 4.

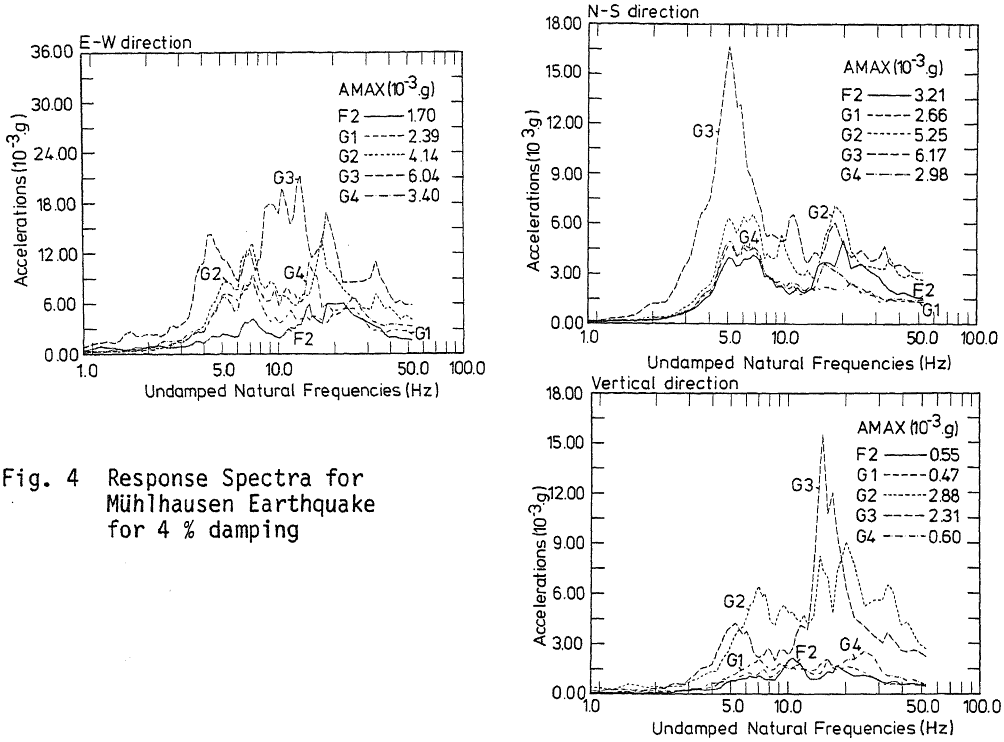

Fig. 4 Response Spectra for Mühlhausen Earthquake for 4 % damping

The response spectra in the E-W and N-S directions for the recordings on instruments G1 and G2 in the reactor building clearly show the amplification of frequencies of the structure's eigenfrequencies at 5 and 8 Hz, whereas the higher frequencies at 18 Hz were damped out. The spectra from instrument G3 exhibit higher values than the others. This is because the instrument is located on the steam generator accident support. The dynamic response of the latter differs from that of the reactor building. The measurements of the instrument G4, which is installed in the fuel storage building, shows clearly that this building and the reactor building differ in their dynamic behaviours. The lowest eigenfrequencies of the soil-structure system of this building in the horizontal direction are identificable at 6.0 and 7.2 Hz.

SEISMIC REQUALIFICATION STUDIES

Dynamic Models The reactor building and coolant loops were modelled with a 3-D lumped mass beam-element system, while the ground was modelled by spring and viscous damper elements, their parameters are related to the properties of a layered soil system. The dependence of the soil parameters on shear strain was determined by means of field and laboratory testing.

Seismic Input Artificially generated acceleration time histories, based on the US-NRC spectra, were used as seismic input. From the risk standpoint (SSE) the annual probability of occurrence was 10^{-6}, yielding a site intensity on the MSK scale of VII.6 and a corresponding maximum horizontal acceleration of 0.15 g, with the maximum vertical acceleration equal to 2/3 of this, i.e. 0.10 g. For the OBE loading level the corresponding values are half of these, i.e. 0.075 g and 0.05 g respectively.

Dynamic Analysis In the analysis the seismic input was applied at the base of the foundation in all 3 directions simultaneously. The method adopted was that of modal analysis. At the selected positions response spectra were generated from the resulting acceleration time histories. The smoothed and broadened spectra represent the definitive results.

COMPARISON OF SPECTRA OBTAINED FOR MUEHLHAUSEN EARTHQUAKE AND THE SEISMIC REQUALIFICATION STUDIES

For the following reasons the spectra could not be compared directly:

1. Orientation The seimograms corresponded to geographic E-W orientation, whereas in the dynamic analysis the seismic input was applied in the axes of the structure (see Fig. 2), a difference of 19.5° azimuth.

2. Level of Excitation In terms of maximum amplitude the acceleration levels for OBE are 44 times higher in the X direction, 23 times in the Y direction, comparing the X direction to the E-W direction, and 90 times in the vertical direction. For this low excitation level the strains will be proportionately smaller, thus influencing the strain dependent soil properties of stiffness and damping. Due to the higher stiffness at a low strain level the frequencies of the coupled soil-structure system will be higher than the calculated design values.

3. Frequency Content Fig. 5 shows a comparison of the frequencies of the design spectrum (after US NRC) and that of the actual earthquake in the N-S direction, with the US NRC spectrum scaled down to have the same maximum amplitude. The measured spectrum has pronounced frequencies above about 4 Hz and especially around 25 Hz, there being a trough at 10 Hz. Below 15 Hz the amplitude lie below those of the design spectrum

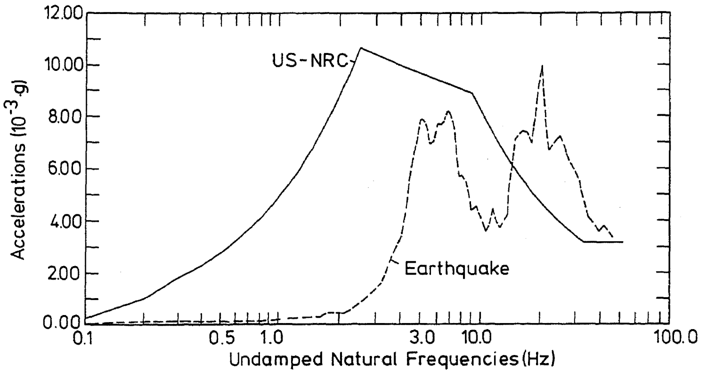

Fig. 5 Comparison of frequency content of US-NRC spectrum with Mülhausen spectrum for 4 % damping

4. Location of the Instruments The spectra for the requalification studies were only generated for the selected positions. Only in 2 positions are the locations near to those of the instruments, i.e. for the intermediate floor of the reactor building (G2) and the fuel storage building (G4).

Despite the stated reasons the frequencies of the soil-structure system could be distinguished in the measured spectra. Leaving aside the question of differing orientations, for both reactor and fuel storage building the frequencies are higher than those obtained in the requalification studies, as would be expected with increased soil stiffness at low strains.

Fig. 6 shows a comparison of the spectra at the intermediate floor of the reactor building in the N-S direction for instrument G2 (scaled up by a factor of 23) with that of the requalification study in the Y direction. It is evident from the figure that the rigid body motions (i.e. above about 30 Hz) are practically the same. Up to 18 Hz the measured values are lower, corresponding to the frequency content of the input motion. The higher value for the Mühlhausen earthquake at 20 Hz is also to be explained by the input frequency content. For OBE, with a much greater excitation level, the high frequency components would be damped out.

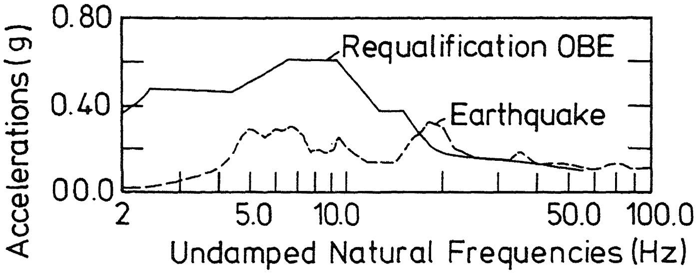

Fig. 6 Comparison of the recorded (instrument G2) spectra in N-S direction with that of the design study for the intermediate floor (elevation +15.0 m) for 4 % Damping.

CONCLUSIONS

Although the Mühlhausen earthquake represents only a very low excitation level, the response spectra permit some extrapolation to be made regarding the dynamic behaviour of the facility at design levels. This was borne out by the comparisons made for the independent seismic requalification studies. Allowing for the free field frequency content of the measured spectra, the comparative study confirmed the reliability of the method of analysis employed. The experience gained in the study helped in defining the new concept for seismic instrumentation.

ACKNOWLEDGEMENTS

The authors wish to thank the Nordostschweizerische Kraftwerke AG and the Swiss Earthquake Service for the support given in this study.

REFERENCES

[1] Mayer-Rosa, Benz, Kradolfer & Renggli, Inventar der Erdbeben 1910-1982, SED, ETH-Zürich, Nagra Technical Report 83-08.

[2] Deichmann & Renggli, Mikrobeben-Untersuchung Nordostschweiz, Teil 2: Seismizität, Jan. 1983 - 1984, SED, ETH-Zürich, Nagra Technical Report 84-12

[3] Rouland, Hässler, Bonjer, Gilg & Mayer-Rosa, The Sierenz Southern Rhinegraben Earthquake of July 15, 1980 - Preliminary Results, Proc. 17th Assembly of ESC, Budapest, 1980

[4] Pavoni, Seismotektonik Nordostschweiz, Nagra Technical Report 84-45