Feasibility Study on Base Mat Uplift of Nuclear Power Plants Using Large-Scale Blast Excitations (Part 2: Preliminary Uplift Test of Block Specimen)

Hideo Tanaka[1)], Haruo Tanda[1)], Tetsuo Suzuki [1)],
Atsushi Suzuki[2)], Koichi Yabuuchi[2)] and Tetsushi Watanabe[3)]

1) Safety Standard Division, Japan Nuclear Energy Safety Organization (JNES), Japan
2) Structural Engineering Nuclear Power Department, Kajima Corporation, Japan
3) Kobori Research Complex, Kajima Corporation, Japan

ABSTRACT

It is important to estimate the base mat uplift for the design of nuclear power plants against severe earthquakes in Japan. JNES (Japan Nuclear Energy Safety Organization) performs a test project focused on the base mat uplift behavior using blast-induced ground motions at a mining site. The investigation of the blast-induced ground motion is reported in part 1[1] in SMiRT-19.

In part 1, we selected Black Thunder Mine (BTM) in the U.S.A. as a test site and measured the blast-induced ground motion. As a result it was conformed that the blast-induced ground motions at BTM are enough acceleration level for the base mat uplift test and the observed motions have similar characteristics to the earthquakes.

Before the main tests, a preliminary test was executed at the test site in order to confirm that the method to measure the base mat uplift was working fine.

PRELIMINARY UPLIFT TEST

We built a concrete block specimen to measure the base mat uplift at the test site, as shown in Figure 1 and Figure 2. Six soil pressure cells were installed underneath the specimen to measure the contact between the base mat and the ground, as shown in Figure 3. Accelerometers are attached on the top of the specimen and at the ground to measure the 3-dimentional responses of the specimen and the ground motion, as shown in Figure 4 and Figure 5.

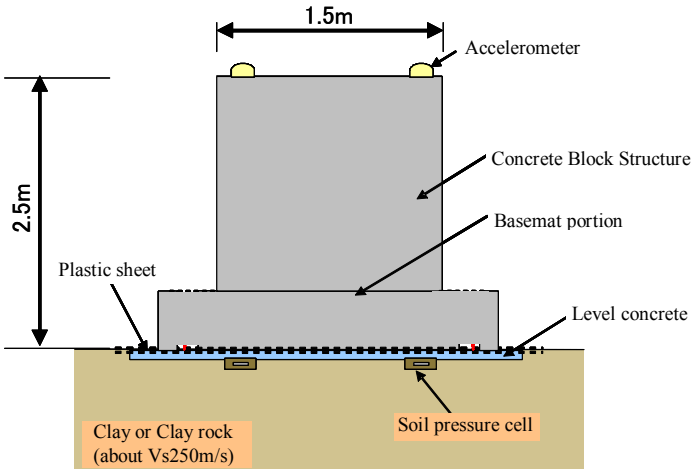


Fig. 1 Summary of preliminary test

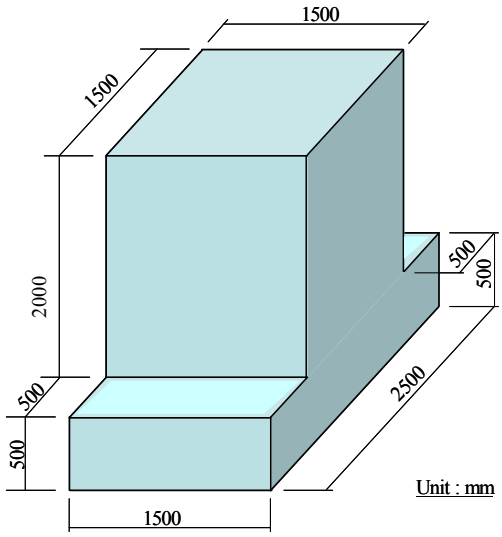


Fig. 2 Size of the concrete block specimen

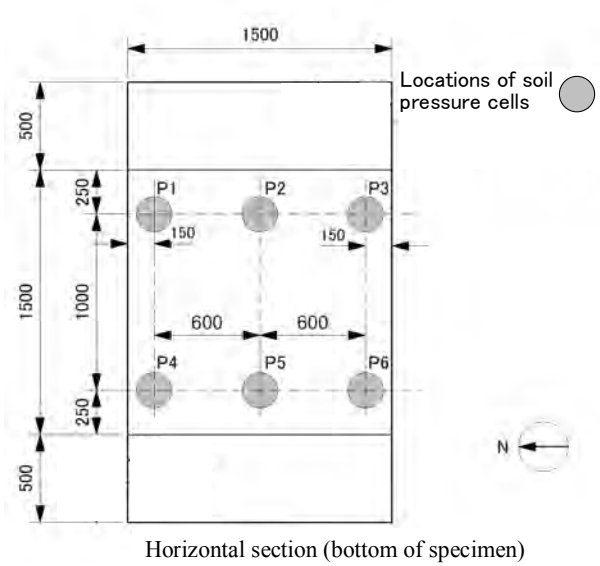


Fig. 3 Arrangement of soil pressure cells

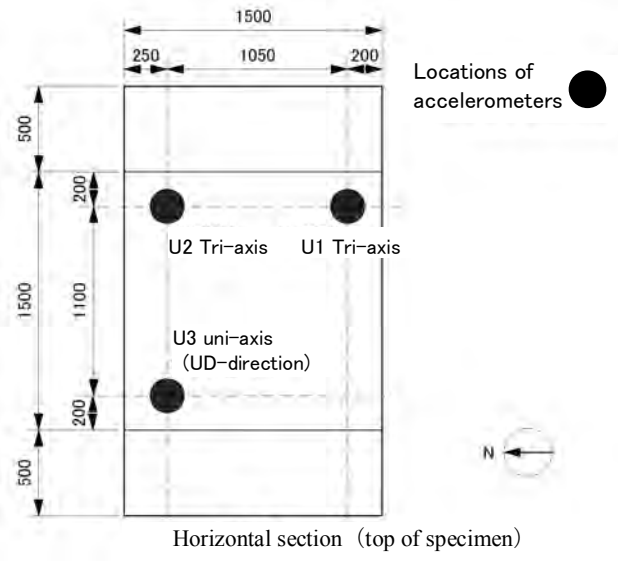


Fig. 4 Arrangement of accelerometers

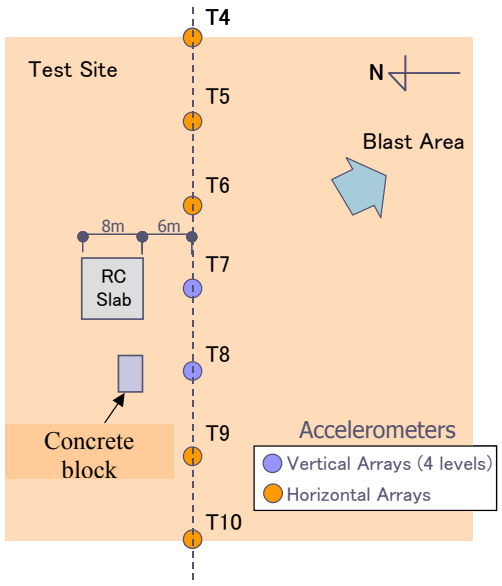


Fig. 5 Location of specimen and accelerometers

Fig. 6 Situation of the specimen

Results of Tests

Table 1 shows the maximum records of acceleration at the ground surface. The maximum horizontal acceleration recorded is approximately 12 m/s^2 in this observation. Figure 7 and Figure 8 shows the records of the soil pressure. In test 1, we can't see uplift behavior in the observation record. In Figure 8 of test 2, the flat line area in the minus pressure means that there is no contact between the base mat and the ground. We can also clearly see the base mat uplift motion in a video.

Figure 9 shows the comparison between soil pressures and response accelerations in test 2. We found a relationship for the occurrence time between soil pressures and response acceleration.

Table 1 Maximum acceleration

Date	Maximum acceleration at the top of the specimen *1 (cm/s^2)							Max. acc. at the soil surface T8 (cm/s^2)		
	EW		NS		UD			NS	EW	UD
	U1	U2	U1	U2	U1	U2	U3			
05/11/22 (Test-1)	325	317	503	507	180	103	–*2	234	252	104
05/11/27 (Test-2)	826	906	921	937	832	964	1046	1, 199	1, 004	492

*1 Low pass filter treatment with 30 Hz *2 data loss

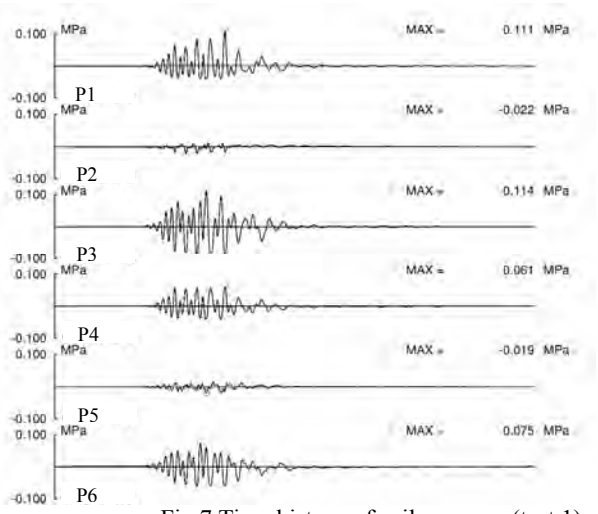


Fig.7 Time history of soil pressure (test 1)

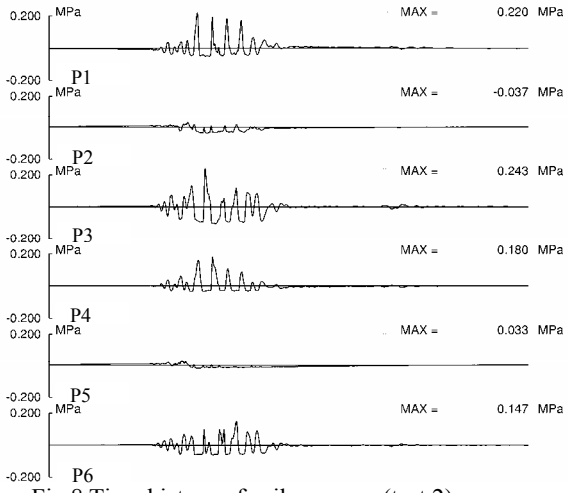
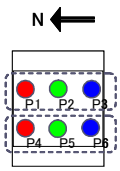


Fig.8 Time history of soil pressure (test 2)



Are. Acc. time history at the top of concrete block specimen (NS direction)

Are. Acc. time history at the top of concrete block specimen (UD direction)

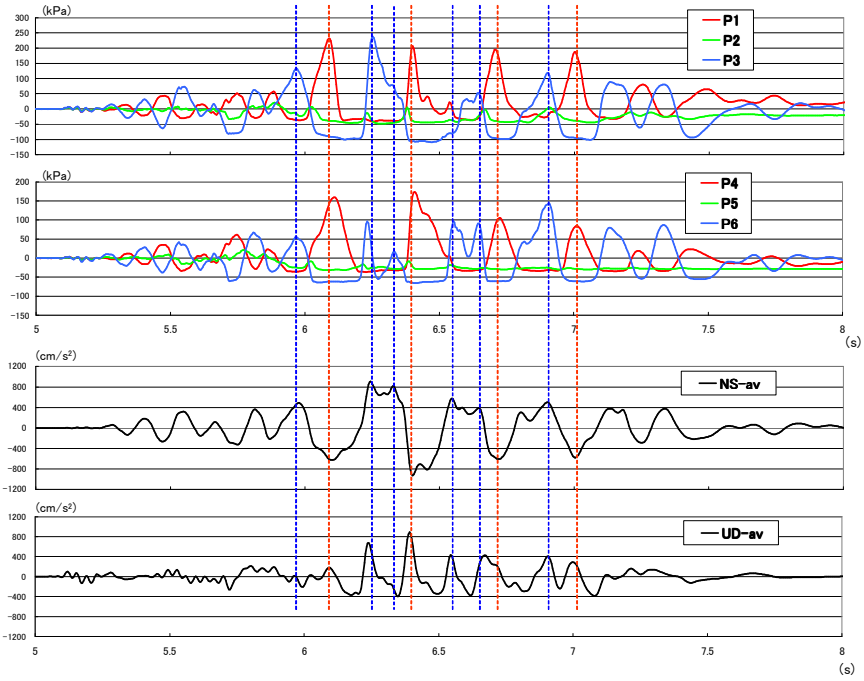


Fig. 9 Comparison between soil pressure and response acceleration（test 2）

SIMULATION ANALYSES

Simulation analyses using 3-dimensional FEM analysis were performed. Figure 10 shows FEM analysis model of the soil and the structure. We used the gap elements which were attached between the base mat and the ground to simulate the uplift phenomenon as shown in Figure 11. Table 2 shows the soil properties which were obtained from the simulation analysis of ground motion using a 3-dimentional multi-spring model [1].

Figure 12 show the acceleration time history on the top of the specimen. Because the specimen slipped in this test, the acceleration of observations recorded were later and smaller than simulation analysis after 6 seconds.

Figure 13 show the time history of the soil pressure. On the time history of the soil pressure, the observation and the analysis had good agreement.

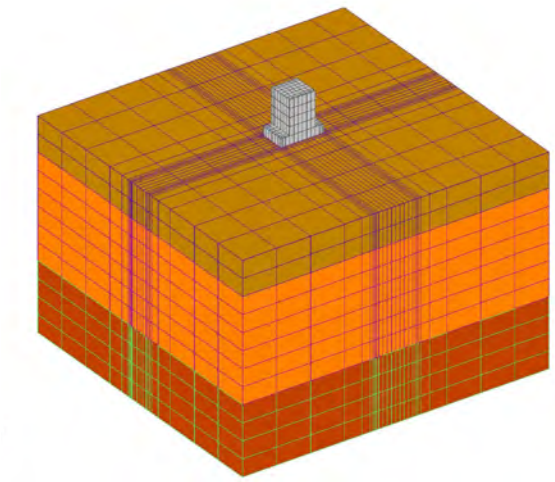


Fig 10 FEM analysis model

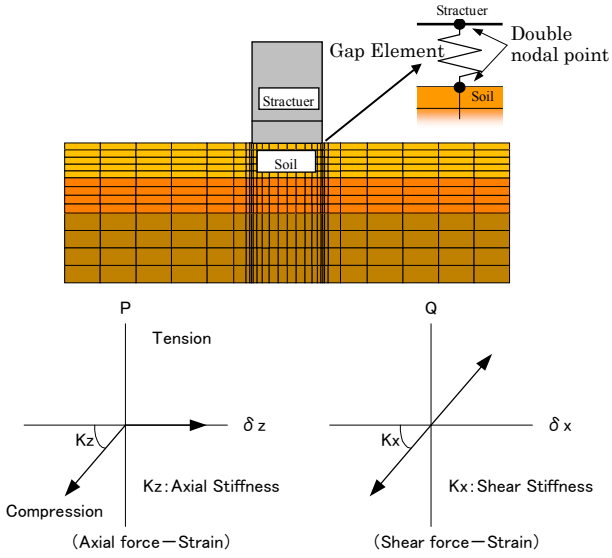


Fig. 11 Gap element

Table 2 Soil properties (Test 2)

Level GL (m)	Vs (m/s)	Vp (m/s)	ρ (Mg/m^3)	ν	G (MN/m^2)	h (%)
0.00						
-2.00	224	520	1.80	0.386	0.9	6.3
-8.00	140	980	1.80	0.490	0.3	11.4
-12.00	306	980	1.90	0.446	1.7	6.9

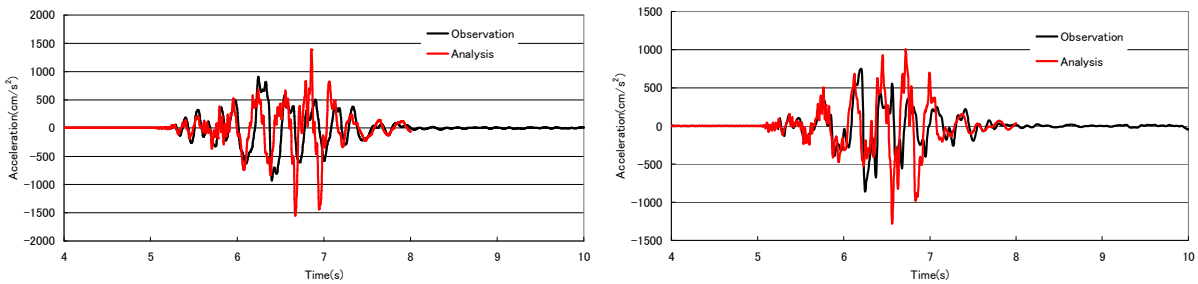


Fig. 12 Acceleration time history at the top of concrete block specimen

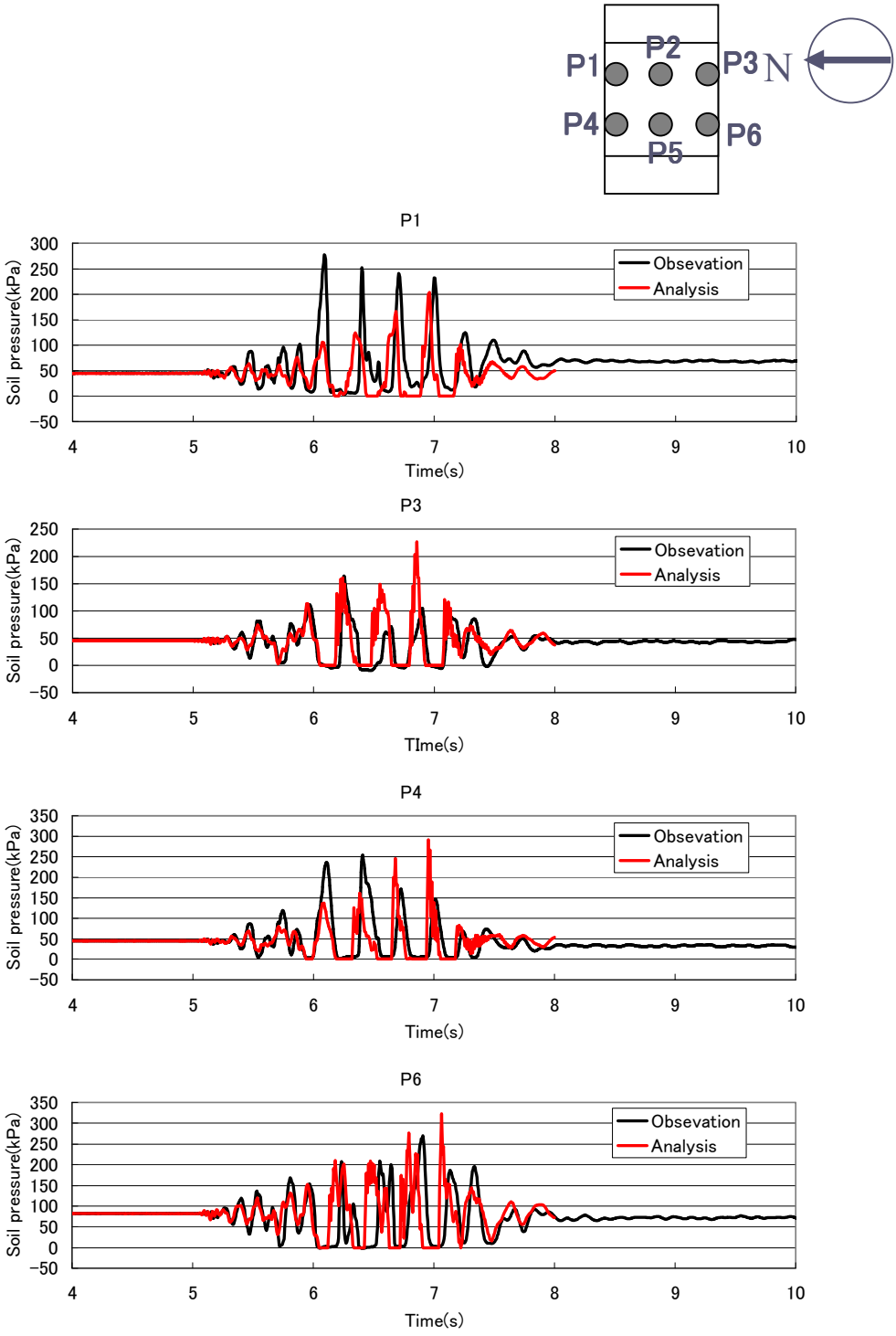


Fig. 13 Time history of soil pressure

CONCLUSIONS

(1) Strong ground motion, over 1G (=9.8m/s^2), was observed at the test site. We confirmed that strong ground motion is large enough for the base mat uplift phenomena to occur.
(2) We confirm that base mat uplift can be detected using soil pressure cells.
(3) We can simulate the uplift behavior with 3-dimensional FEM analysis using gap elements. As a result, it is difficult to simulate slipping behavior, but soil pressure could be roughly estimated.

ACKNOWLEDGEMENTS

This work was performed by JNES as a part of the Non-linear Soil-structure Interaction (SSI) test project commissioned by the Ministry of Economy, Trade and Industry (METI) of Japan. Technical issues have been discussed in the advisory committee on the project established by JNES (Chairperson: Professor Dr. T. Nishikawa).

The project staff from CE&MT are also acknowledged for their dedicated assistance with the field studies. Most importantly, we would like to thank the management and staff of Arch Coal's Black Thunder Mine for their assistance throughout the project. They were always very generous and provided us with support in many ways. Without their help, this work would not have been possible.

REFERENCES

1. Hideo Tanaka, Haruo Tanda, TetsuoSuzuki, Osamu Kontani, Koichi Yabuuchi, Shohei Sawada and Yuji Miyamoto (2007), “Experimental Study on Uplift of Nuclear Power Plants using Large Scale Blast Excitations (Part 1 Measurement and Investigation of Ground Motions),” SMiRT-19