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EARTHQUAKE RESISTANT CELLULAR NETWORK BASE TRANSFER STATION PROVED UNDER THE SEVERE EARTHQUAKE EVENTS AT NIIGATA

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Abstract

The network equipments are now essential tools for communication among individuals as well as societies, especially at the hazard situation such as earthquake strike. In 2004, an earthquake of magnitude 6.8 was occurred at Niigata, Japan. In spite that the magnitude was one of common great earthquakes in Japan, many mountains and roads were collapsed, and many lifelines were destructed. The Slim base transfer station (BTS) model made by Samsung Electronics had been operating around Niigata more than a hundred. It was reported that less than 15 set among them showed blackout after the earthquake by interruption of electricity, not by the malfunction. The Slim BTS weighing about 200 kg was subjected to the Zone 3 earthquake loading of GR-63-CORE by finite element analysis and shaking table test. The functional operability and structural safety were confirmed by test for Zone 3 earthquake requirements. The objective of this paper is to describe how the Slim BTS could work during the Niigata earthquake without structural or operational failures. The results of FEM analysis by NASTRAN could explain the earthquake response relations between test and real situation.

INTRODUCTION

The network equipments are now essential tools for communication among individuals as well as societies, especially at the hazard situation such as earthquake strikes. In 2004, an earthquake of magnitude 6.8 with following less earthquakes was occurred at Niigata, Japan, October 23, 17:56 JST. In spite that the magnitude was one of common great earthquakes in Japan, many mountains and roads were collapsed, and many lifelines were destructed as shown in Photo 1 and Figure 1.[1]

The Slim base transfer station (BTS) model manufactured by Samsung Electronics had been operating around Niigata region more than a hundred as shown in Photo 2. It was reported that less than 15 set among them showed blackout after the earthquake by interruption of electricity, not by the malfunction or failure. Moreover the structural deformations were not observed.[2]

The Slim BTS weighing about 200 kg have been subjected to the Zone 3 earthquake loading of GR-63-CORE[3] by the shaking table test conducted by Korea Institute of Machinery & Materials (KIMM) as shown in Photo 3[4]. The functional operability and structural safety were confirmed by the test for Zone 3 earthquake requirements.

Since the rigidity of the Slim BTS was relatively smaller in side-to-side direction, the Slim BTS could not satisfy the required displacement responses specified for Zone 4 earthquake loading of GR-63-CORE by test. The objective of this paper is to describe how the Slim BTS could work during the Niigata earthquake without structural or operational failures.

Photo 1 – Example of destruction of roads by the Niigata earthquake

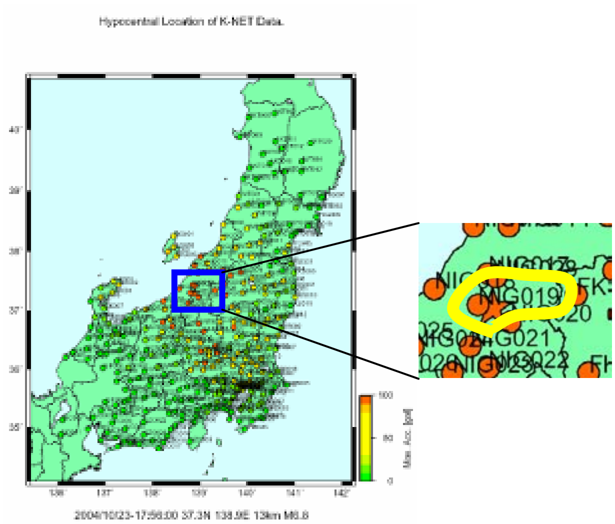


Figure 1 – Epicentre of the Niigata earthquake

Photo 2 – Distribution of the Slim BTS around Niigata region

Photo 3 –Test setup of the Slim BTS in side-to-side direction

CHARACTERISTICS OF EARTHQUAKE WAVEFORMS

Waveform corresponding to Zone 3 Earthquake of GR-63-CORE

The requirement corresponding to Zone 3 earthquake of GR-63-CORE is specified as required response spectrum (RRS). Since it required displacement larger than the stroke of the shaking table, ±100 mm, the waveform generated form the RRS was filtered from 0.8 Hz using the high-pass filter. The random motion was acceleration amplitude-controlled in one-sixth octave bandwidths spaced 1/6 octave apart over the frequency range of 0.5 Hz to 50 Hz. The duration of the random motion was 30 seconds including strong motion portion of 15 seconds.

Figure 2 is the test response spectrum (TRS) analyzed for 2% damping at 1/6 octave frequency interval from the acceleration measured on the shaking table.[4] The TRS could envelop the corresponding RRS at higher frequency range than about 1.25 Hz. The acceleration waveform measured on the shaking table is shown in Figure 3 with maximum acceleration of 9.2 m/s^2 (0.94 g).

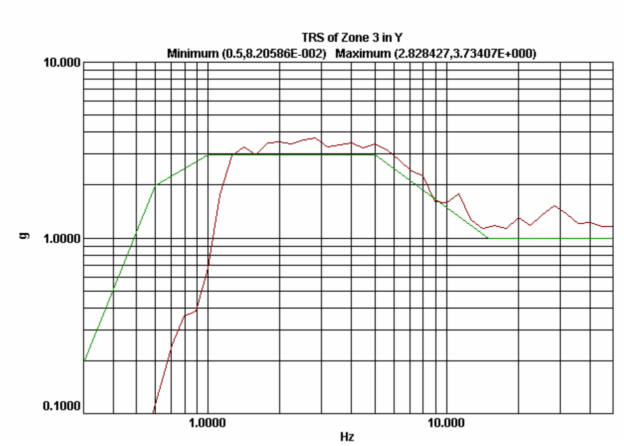


Figure 2 – TRS vs. RRS for Zone 3 earthquake rest of GR-63-CORE for 2% damping

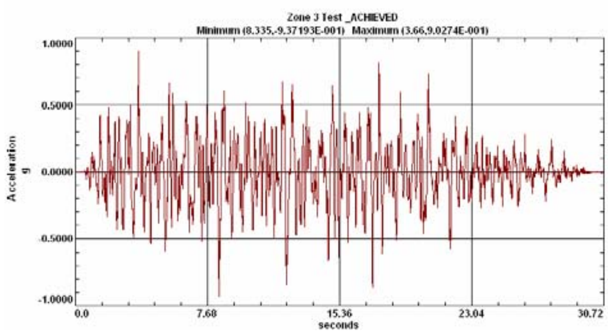


Figure 3 – The acceleration waveform measured on the shaking table for Zone 3 earthquake test of GR-63-CORE

Niigata Earthquake

The biggest waveform recorded at Niigata region was captured at NIG019 station apart 7 km from the epicentre by K-Net, Japan.[1] The maximum acceleration was measured as 13.1 m/s^2 (1.33 g) in EW direction as shown in Figure 4.

The response spectra of these waveforms are shown in Figure 5 compared with the RRS specified in GR-63-CORE. The Niigata earthquake had similar strength and frequency contents to RRS of GR-63-CORE.

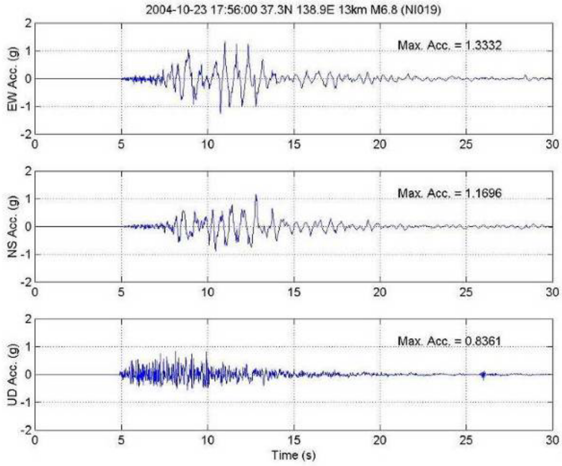


Figure 4 – The biggest waveform recorded during the Niigata earthquake

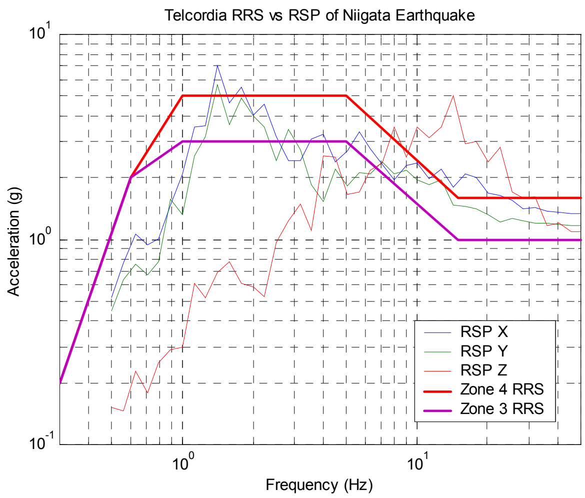


Figure 5 – The response spectra of the Niigata earthquake compared with RRS of GR-63-CORE for 2% damping

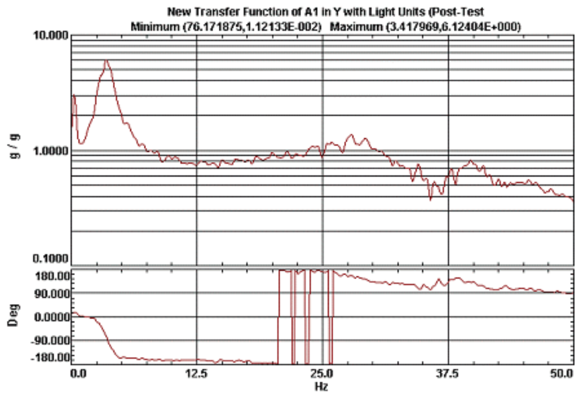


Figure 6 – The transfer function in side-to-side direction derived from the test

MODAL PARAMETERS

The transfer function between the shaking table and acceleration response measured at the frame top in side-to-side direction was derived as shown in Figure 6. The lowest natural frequency was identified as 3.42 Hz with 8.2% damping factor, while the analysis by NASTRAN showed 3.73 Hz which was about 10% higher than the test result.

EARTHQUAKE RESPONSES

Test according to Zone 3 Earthquake of GR-63-CORE

The acceleration response was measured at the frame top with maximum 34.1 m/s^2 (3.47 g) as shown in Figure 7. The maximum relative displacement was measured as 55 mm as shown in Figure 8, which satisfied the requirement that the maximum displacement should be less than 75 mm specified in GR-63-CORE.[3]

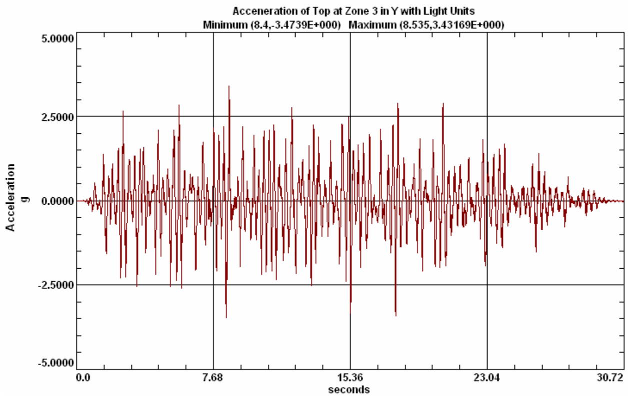


Figure 7 – The acceleration response measured at the frame top during the test

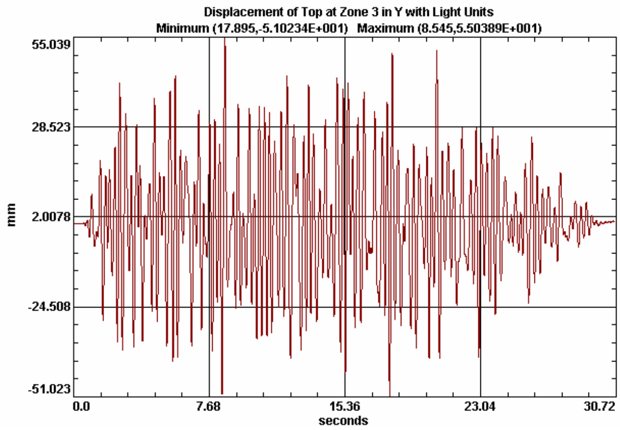


Figure 8 – The relative displacement measured at the frame top during the test

Earthquake Analysis

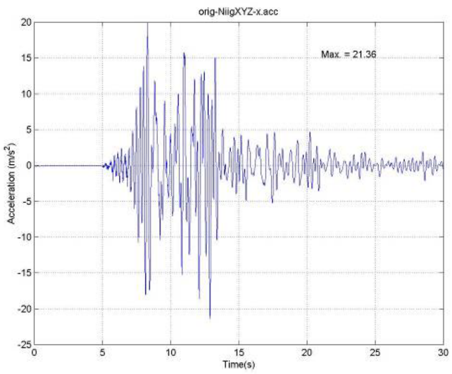
The earthquake response analysis was performed on the Slim BTS model in side-to-side direction by FEM with NASTRAN for 5 kinds of waveform. Table 1 shows the results for acceleration responses and relative displacements of the frame top. Figure 9 is an example of responses for the earthquake waveform of Niigata recorded at NI019 station in EW direction(NIX).

The characteristics of waveforms are as follows: (1) T3A: derived from the RRS of GR-63-CORE for Zone 3, (2) FT3A: high-pass filtered at 0.8 Hz from T3A, (3) TBL3A: achieved at the shaking table during test with FT3A increased 10%, (4) NIX: Niigata earthquake recorded at NI019 station in EW direction, (5) NIY: Niigata earthquake recorded at NI019 station in NS direction.

Since the lowest natural frequency of the Slim BTS was 3.42 Hz, seismic analysis results by the high-pass filtered waveform, FT3A, showed 7% less dynamic responses than those by the unfiltered waveform, T3A. However the results by TBL3A achieved from the shaking table with 10% margin of FT3A were slightly higher responses than those by T3A. From these results, it could be addressed that the test could simulate the required earthquake level enough.

The results by TBL3A were a little less than the results by NIX with difference within 3%, which was the biggest waveform recorded at Niigata earthquake. This fact could be expected from the response spectrum shown in Figure 5, since the acceleration responses were very similar to each other around the natural frequency, 3.42 Hz. Hence it could be concluded that the effect of Niigata earthquake was almost simulated by the earthquake test based on Zone 3 earthquake specified in GR-63-CORE.

Since the structural integrity and the functional operability were qualified by the earthquake test, the Slim BTS could be operated without malfunctions except blackout after the earthquake by interruption of electricity under severe earthquakes at Niigata. The test results had much larger than the analysis results with TBL3A more than 50%. The difference could be considered due to the nonlinearity in stiffness and damping at large responses.



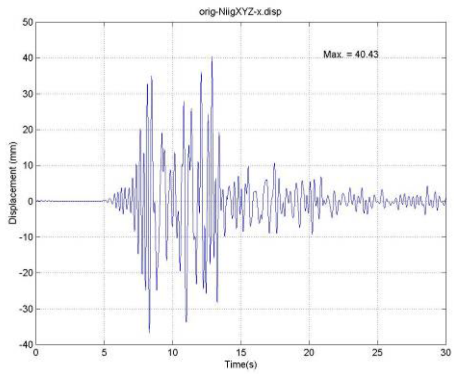


Figure 9 – The analyzed responses at the frame top by the Niigata earthquake waveform in EW direction

Table 1 – Seismic Analysis Results at the Frame Top with Various Waveforms

Waveform	Description	Acceleration Response (m/s^2)	Relative Displacement (mm)
T3A	Derived from the RRS of GR-63-CORE for Zone 3	19.8	36.6
FT3A	High-pass filtered at 0.8 Hz of TZ	18.4	34.3
TBL3A	Achieved at the shaking table during test with FTZ increased 10%	20.9	39.3
NIX	Niigata earthquake of NI019 station in EW direction	21.4	40.4
NIY	Niigata earthquake of NI019 station in NS direction	18.7	35.4
Test	Measured	34.1	55.0

SUMMARY

Seismic analysis results by the high-pass filtered waveform, showed 7% less dynamic responses than those by the unfiltered waveform. However the results by waveform TBL3A achieved from the shaking table with 10% margin of filtered waveform were slightly higher responses than those by unfiltered. From these results, it could be addressed that the test could simulate the required earthquake level enough.

The results by TBL3A were a little less than the results by NIX with difference within 3%, which was the biggest waveform recorded at Niigata earthquake in EW direction. Since the acceleration responses were very similar to each other around the natural frequency, 3.42 Hz, it could be concluded that the effect of Niigata earthquake was almost simulated by the earthquake test based on Zone 3 earthquake specified in GR-63-CORE.

Since the structural integrity and the functional operability were qualified by the earthquake test, the Slim BTS could be operated without malfunctions except blackout after the earthquake by interruption of electricity under severe earthquakes at Niigata.

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