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EFFECTS OF VALLEY GEOMERTY ON STRONG GROUND MOTION PREDICTION

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SUMMARY

In this study an attempt is made to study the effect of valley geometry on strong ground motion response during earthquakes. Response analysis was made for the different shapes and sizes valleys. Input motions and soil properties were kept similar and only 2D valley features were varied. The result showed that the response is strongly influenced by size and shape of valleys. Case study was made by considering the response of the Sumiyoshi Area in Kobe during the Earthquake of 1995. The case study showed good agreement with the analytical study on hypothetical valleys.

INTRODUCTION

Strong ground motions are influenced by the conditions at source, path and site. At site the incoming ground motions are influenced by the shape of the valley, topography and the dynamic characteristics of the site. The surface and subsurface shapes of the valleys, the number, inclination and thickness of layers and sub layers are geometric factors that influence the nature of strong ground motions. The main influence of two-dimensional (2D) or three dimensional(3D) geometry on ground response could be classified as the effects of surface topography, which refers to irregularity like ridges and valleys, and the sub-surface topography, which is related to sediment-basement boundary.

Various theoretical investigations have been made to verify the effects of surface topography. Among them are Aki [1]; Faccioli [2]; Kawase [3]; Sanchez-Sesma [4]. These studies show that amplification and de-amplification of ground motion occurs due to the particular shape of surface topography. In addition to

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theoretical studies, observational evidences has also confirmed influences of surface topography. Some examples are Celbi [5]; Faccioli [1].

The effect of sub-surface topography which is caused by the sediment-basement boundary is related to the basin induced surface waves and body waves that are trapped in a valley. Such valley effects amplify ground motions and elongate the duration of motions. The influence of valleys on ground motion has been noticed and quite a number of studies have been done by Boore *et al*.,[6]; Seo, K. and K. Kobayashi [7]; After the 1985 Michocan earthquake, this effect has been studied intensively and many interesting reports have been made by Sanchez - Sesma *et al,* [8]. Each of these studies confirm that basin induced waves show marked influence on ground response.

Many cities exposed to high seismicity are located in sedimentary basins and valleys, as these formations favor human settlement. Thus there is a practical significance for the study. In this work an attempt was made to study the effects of valleys on strong ground motion predictions. The main emphasis here is to investigate the influence of different valley geometries on propagation of strong ground motions . The effects of inclined wave input and the effects of SV- wave and SH-wave incidence were investigated. Most of the results obtained by SV and SH-wave analysis were similar, therefore, the result will be presented only for SV-wave propagation case.

The 2D geometric features were accounted for by using different valley shapes and sizes. Valley shapes were varied by taking rectangular, trapezoidal, inclined valleys and horizontal and inclined profiles. The average depth was set at 56 m. Soil strength was also kept constant at weak soil formation. Basically the medium depth and weak strength formation was used and parameters that are related to 2D geometry were varied. This gives a better understanding of the additional effects of 2D geometry and makes comparisons more appropriate.

MODELING AND ANALYTICAL PROCEDURE

For 2D analysis the weak-medium depth soil profile (WM) (Fig. 1 ,Tables 1) was taken as the basic soil model. As the interest here was to understand the influence of 2D geometry only feature that are commonly related to 2D analysis were considered. Different models with varying shapes and varied sediment-deposit boundary conditions were investigated. In each of the cases the depth of the models was 56.0 m. For the inclined models the depth of 56m was maintained as an average depth. Based on this base model varies models with different geometric shape and size are constructed and analyzed. For comparison purpose between the 1D and 2D models, the base soil profile shown in Fig 1 is analyzed and compared with the 2D models.

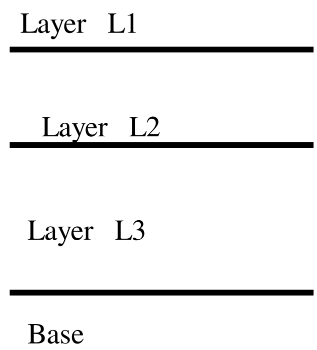

Fig 1. Soil profile Model used in the analysis

Table 1. Soil property for the soil profile model

layer	Layer position	Soil type	Vs (m/s)	Unit wt(kN/M^3)	Thickness m
L1	**Top**	**Clay**	**150**	**1.6**	**8**
L2	**2nd**	**Sand**	**200**	**1.7**	**24**
L3	**3rd**	**gravel**	**300**	**1.8**	**24**
BASE	**Bottom**	**Rock**	**1000**	**2.4**	

The 2D models analyzed are described as follows:

1. Trapezoidal Narrow Valley(TNV) (Fig.2) This is a trapezoidal valley with a base width to depth ratio of 2.

2. Rectangular Narrow Valley(RNV) (Fig.3) This is a rectangular shaped valley . The width was equal to the average of the surface and base dimensions of the TNV. The equivalence in width between the two was maintained for comparison purposes.

3. Trapezoidal Wide Valley(TWV) (Fig. 4) This model has the same shape as the TNV, but the base width is twice that of the TNV.

4. Trapezoidal Inclined Narrow Valley (TIV) (Fig. 5) In this model the base and top width and average depth are similar to the TNV, but the deposit layers are inclined and the valley is non-symmetrical.

5. Horizontal Open Profile (HOP) (Fig. 6) This model has one of the ends open, meaning that an extension to infinity was assumed at one edge. The finite width at which the transmitting boundary was introduced was equal to the width of TNV.

6. Inclined Open profile (IOP) (Fig. 7) This model is similar with HOP
except that the layers are inclined.

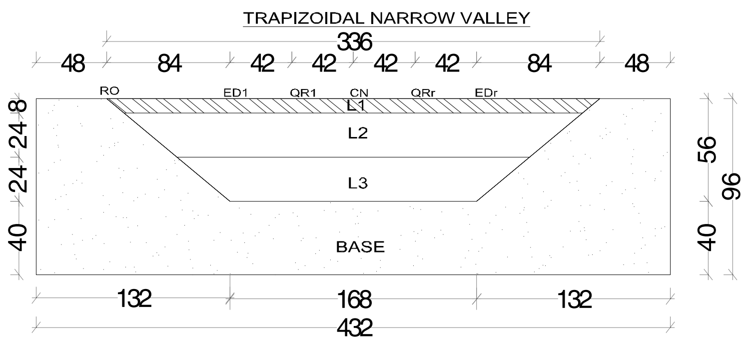

Fig. 2. 2D FEM model , trapizoidal narrower valley (TNV)

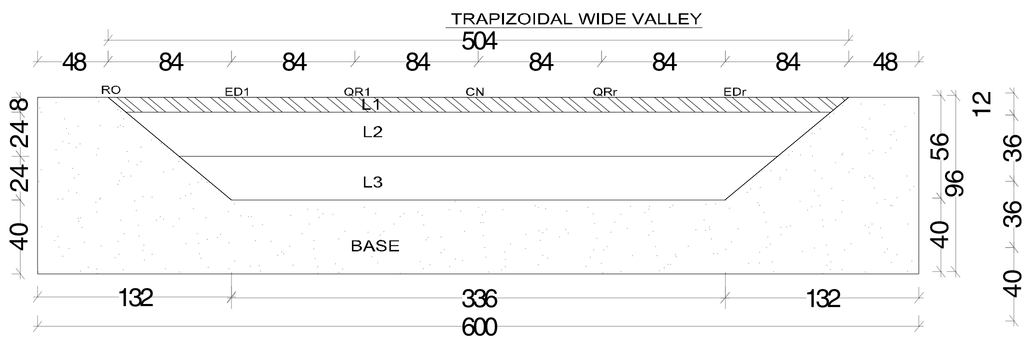

Fig. 4. 2D FEM model , Trapizoidal wide valley (TWV)

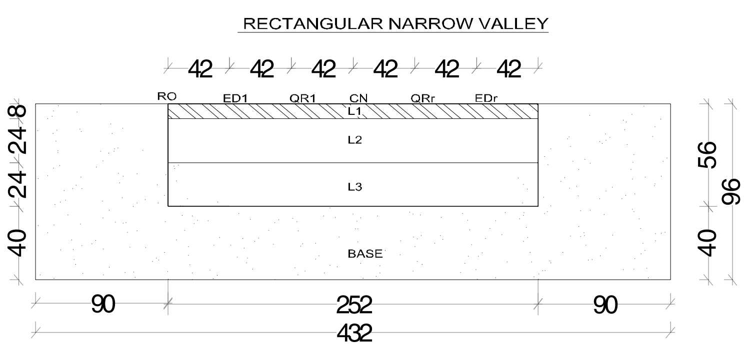

Fig. 3. 2D FEM model , rectangular narrower valley (RNV)

NON SYMMETRICAL NARROW VALLEY

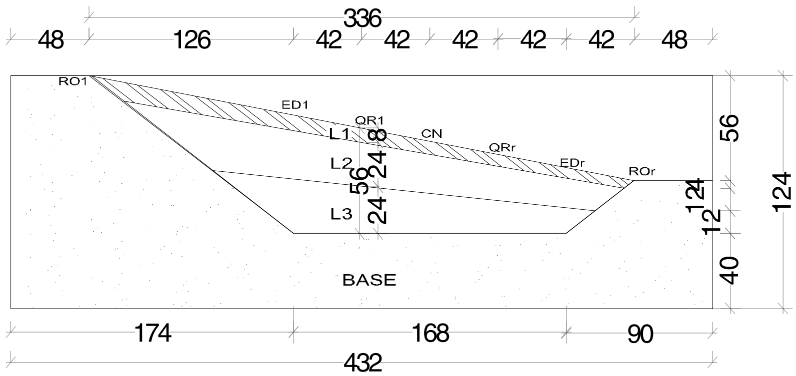

Fig. 5. 2D FEM model , Trapizoidal Inclined valley (TIV)

HORIZONTAL OPEN PROFILE

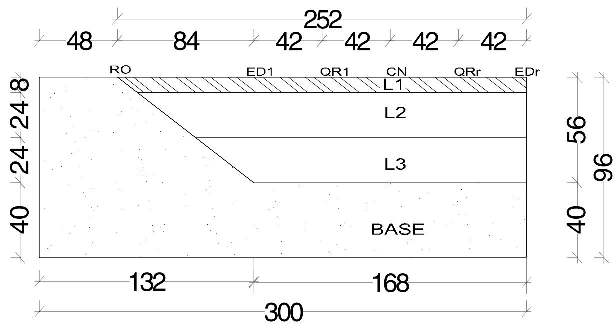

Fig. 6. 2D FEM model , horizontal open profile (HOP)

INCLINED OPEN PROFILE

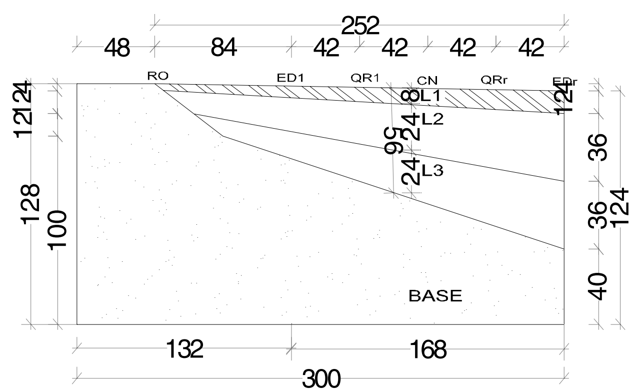

Fig.7. 2D FEM model , inclined open valley (IOP)

A viscous dash pot boundary was used at the base to allow for some absorption. For the side boundaries, both for the free field and for the sediment, the transmitting boundary was used. The models were constructed such that most parameters for the different models were kept similar, and only the 2D features that were intended to be investigated were varied. All of the models had the same soil strength property. The rectangular and the trapezoidal narrow valleys have the same depths, similar equivalent width and same boundary conditions, only the shape of the edge was varied. Therefore, for the same input ground motion the difference in response can be attributed to the difference in shape at the edges. The TWV has twice the width of the TNV. The TIV differs from TNV only in the inclination of the deposit layers. The open profiles differ from the valleys in edge conditions. While HOP has horizontal layers the HIP has inclined layers. Basically all of the models are related to the TNV and additional feature were included. Therefore, the TNV was the standard model in this study.

The FEM based SuperFLUSH(KKI [9] program is used for the 2D analysis and the SHAKE ,Schnabel et al, [10], is used for 1D analysis. The ground motion records of the ElCentro(1940), the Taft(1952), the Hachinohe (1968) and the Kobe JMA (1995) records were used as an input motion. The input acceleration levels were also varied to 0.1g and 0.2g. These input motions are input to the TNV and the acceleration response spectra of the horizontal component is plotted for input acceleration levels of 0.1g and 0.2g(Fig 8). The two figures show that even for the same valley, the nature of the ground motion and level of acceleration shows marked difference in response. Therefore, it is important to note that as the same ground motion may be amplified or de-amplified differently by the different valley geometries. the different types of ground motion inputs are also amplified or de-amplified differently for the same valleys

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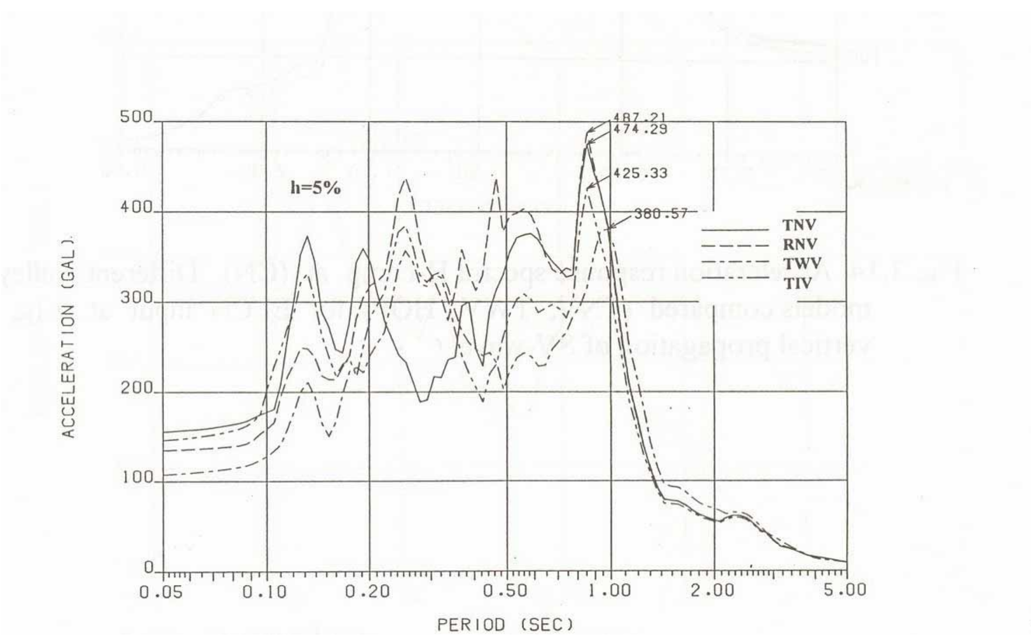

Fig. 8. Acceleration response spectra H-comp. at center (CN). Different valley models Compared (TNV, RNV, TWV, TIV) for ELCN input at 0.2g, vertical propagation of -wave

COMPARISON OF 1D AND 2D ANALYSOIS AND LIMITS OF ITS APPLICATION

In site effect studies one of the most significant aspect is the simulation of the site geometry. In reality sites spread in three dimensions (3D). Theoretically however, the best analytical model is a 3D model. in this respect much research has been done by Horike [11]; Toshinawa and Ohmachi [12]. The problem associated with 3D simulation is that much simplification has to be made to come to computationally feasible models, otherwise complicated models which require a lot of parameters must be used. In both cases many of this parameters have to be assumed in the modeling process; as a result the desired high level of accuracy is compromised. When 3D basins have strong one directional variation and are more uniform in the other direction two dimensional (2D) simulation yields a satisfying result. When there are uniform variation in both direction a one dimensional (1D) simulation becomes feasible.

Previously some studies have been made in this regard and some limits of geometric conditions for which effects of 2D geometry are minimal or insignificant are given by Noda[13]; Silva [14]. But such studies are far from complete. In this study comparison of the 1D and the 2D analysis was made with the purpose of finding the limits at which 2D geometric effects become insignificant. such knowledge will help to make 1D simulation of actual basins and valleys possible and will lead to simpler and economical solutions. Analysis was made for the 1D profile model shown in Fig 1 in order to make comparison with trapezoidal valley shape. The effect of 2D geometry depends on the width to depth ratios of valleys, the shape of valley and the nature of input motion. In order to take these factors into account trapezoidal valley with different H/D ratios (H/D = 1,2,4,6,8) and one cycle sine wave input with periods of 0.125, 0.25, 0.5, 1 and 2 s were taken as input motion. The weak soil profile was used and valley depth was kept constant at 56.0m. The obtained response velocities were plotted vs the distance from the edge normalized over the half width of the valley ($X/H^{/}$). Fig. 9 show the peak response velocity plotted for the different valley shapes for periods of input of 0.5s. in both cases, for the total valley width to depth ratio (H/D > 4), at most positions in the valley, the response curves are flat indicating less effect of 2D geometry. Fig. 10 shows an example of response for the valley with H/D=2 normalized over the wave length to reduce the effects of the frequency characteristics of the input motions. up to a distance of $X/H^{/} = 0.6$ (which means X/H = 0.3) the effect of the shape of the edge of valley is significant except on the long period, 2s motion which has a longer wave length than the valley width. For distances above X/H = 0.3 the effect of valley is minimal for all periods of input motion.

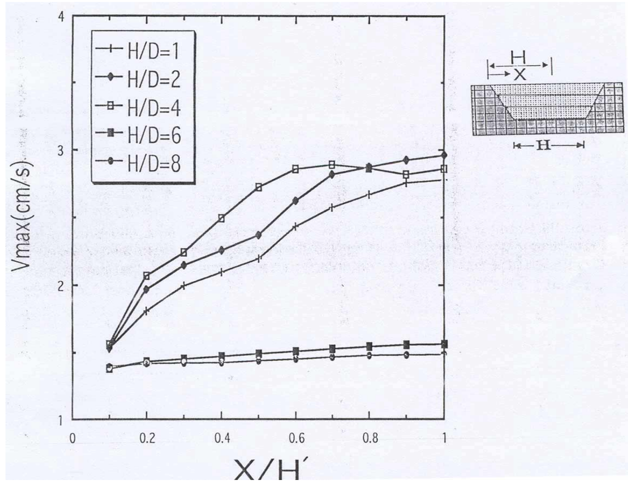

Fig 9. Value of V_{max} at varies distances from edge 0.5s since wave input.

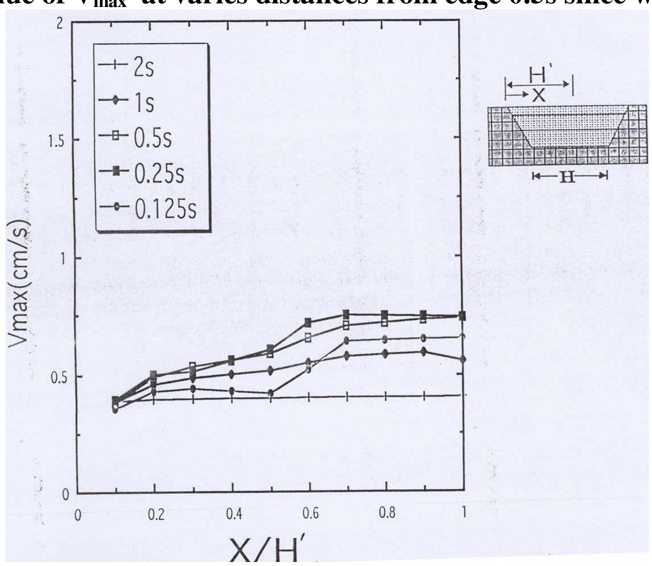

Fig. 10. Normalized over wave length of input motion valley of V_{max} at varies distances from edge valley with H/D=2.

VALIDATION

In order to validate the theoretical study made on hypothetical models, a real ground model was constructed for the Sumiyoshi area, Kobe city, the Sumiyoshi area suffered strong damage during the January 17,1995, Hyogoken-nanbu earthquake (M=7.2, H=14.3) the ground model shown in Fig 11, was constructed based on borehole data for shallow profiles and on the results of explosive survey for the deep formation. The ground motion recorded at Kobe University was input at the rock outcrop. Analysis was made by using the Super FLUSH program for the whole model. The acceleration time history response obtained just below the top soft soil(at –20 m below natural ground level) are again input into a 1D model constructed for the top 20m softer soil, which was considered in more detail. In effect a 2D+1D analysis was made. The maximum acceleration response is shown in Table 2 for the transverse valley starting from the Rokko mountain ranges to the sea. The results indicate that the effects of the 2D valley geometry is evident from the response. Around the edge of the valley where the soil deposit is very small the response is also smaller, but gradually increases with increment in depth of soil and reflections from the valley edge. Gradually the maximum responses are obtained between the distances of 2000m to 2400 m(Fig 11) from the valley edge. For the average valley depth of 1000m to 1200m for the middle to lower part of the valley. This area is within a ration of 2: 1 of width to depth ratio of the valley. As the ration of width to depth increase to above 2 the response starts to decrease. This findings confirms to the actual damage pattern observed during the Kobe earthquake. The area where maximum acceleration response is obtained(Fig 11 and Table 2) coincides to the area where the damage intensity was the highest, VII in JMA Intensity Scale. This area falls within the geometric ratio which has been found to be significant in amplifying ground motions.

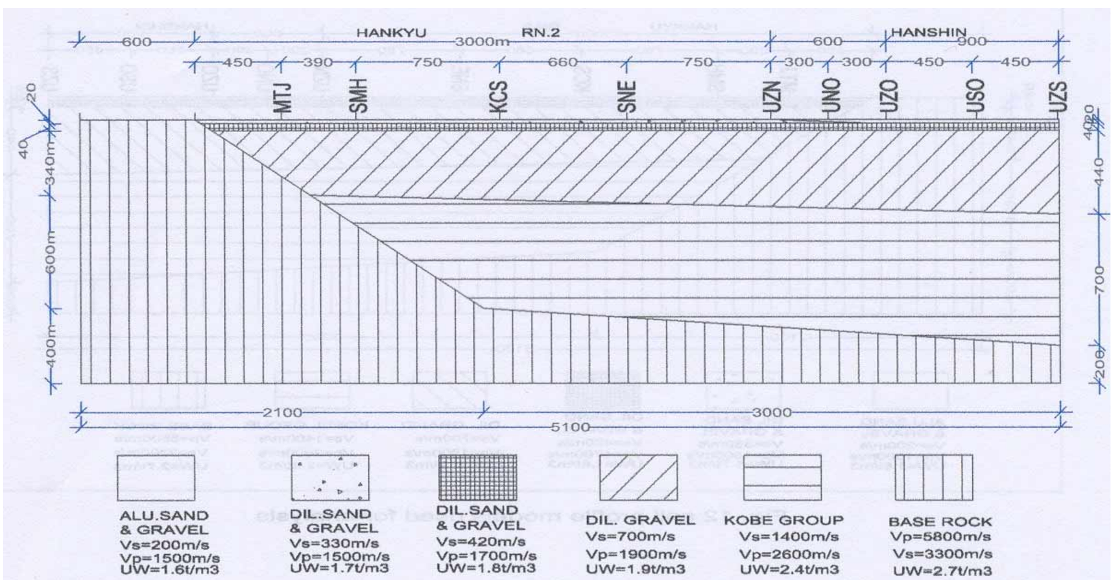

Fig. 11 Soil profile models used for analysis for Sumiyoshi area in Kobe

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Table 2 Maximum values of Accelerations obtained at Sumiyoshi, Kobe

Location As per Fig 11	MTJ1*	SMH1	KCS1	SNE2	UZN2	UNC2	UZC2	USC21	UZS2
Amax m/s^2	384.49	440.16	579.86	721.89	871.32	814.42	742.4	751.33	673.00

*** 1 02 after the location indicates that one two locations are taken near the point**

CONCLUSION

1. The different input ground motions, even when capped to same input accelerations and input to the same valley showed different responses. Therefore, when analyzing the effects of valley geometry on strong ground motion response, the nature(frequency) of the incoming ground motion should be taken into considerations.

2. The effect of the shape of valley was substantial up to a distance equal to up to twice the depth from the edge. Around the center of valleys, the effect of shape of edge was small, more variation was observed due to the difference in width/depth ratios of valleys. Around the center wide valley showed less response which were comparable with open profiles. More precise positions in a valley where effect of 2D geometry becomes insignificant can be determined by using simple curves based on knowledge of H/D ratio, position of point from edge (H/D) and wave length of input motion. After such positions from the edge, 1D analysis could be made as an approximation to 2D valleys.

3. For most wave lengths of input motion, when the width to length (H/D) ratio of a valley is greater than 3 the effect starts to decrease and for H/D greater than 4, the effect of basin included surface waves is very minimal on a peak values of velocity and response in general. Thus, open profiles, closed valley and 1D analysis give similar results. Hence 2D valleys can be approximated by 1D analysis.

4. The analytical result made on the hypothetical valley, on the ground model of the Sumiyoshi area in Kobe City and the damage patterns observed in the same area showed resemblance, showing the influence of shape of valley on strong ground motions

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