THE SEISMIC BEHAVIOUR OF RIVER VALLEYS

by

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SYNOPSIS

The results of a series of analyses to study the effects of a variety of valley shapes on the seismic behaviour of the valleys is presented. The method of analysis used a refined finite element formulation and both horizontal and vertical seismic accelerations could be used as input excitation to the finite element model. In addition to describing the probable seismic behaviour of a range of idealised river valleys, the results of analyses of two actual valleys are also presented and discussed, with particular reference to the differential horizontal movement that could occur across the top of the valleys under the influence of two specific earthquakes.

INTRODUCTION

A major problem in the design of long span bridges that are to be situated in or across a river valley is the provision of suitable seismic gaps to prevent hammering between the various spans of the bridge and between the bridge and its abutments. This problem is further complicated in those cases where the valley contains a considerable depth of alluvium as then the motion at the ground surface may be significantly enhanced by the softer material overlying the bedrock. Over the last few years the authors have carried out a number of investigations to determine the likely seismic behaviour of particular bridges and river valleys with special reference to the two problems mentioned above.

One of these investigations [refs. 1 and 2] concerned a multi-span beam and slab bridge that was to be sited in a wide river valley that contained a considerable depth of alluvial fill. The bridge designer desired to have some idea of the likely seismic behaviour of the bridge, with particular reference to the total amount of shortening that might occur between the two abutments. It would then be possible to allow for this amount of movement and so avoid, or at least minimise, the damage caused by bridge beams in adjacent spans hammering against each other and by beams hammering against the abutments. Since the depth of alluvium overlying the bedrock in the valley could only be determined as being in the range 150 - 300 m, it was necessary to investigate the effect of different depths of alluvium in filtering out some of the frequencies inherent in an earthquake in the bedrock, thereby altering the seismic response of the bridge.

Another investigation was concerned with the likely seismic behaviour of 110 m cantilevered concrete box girder bridges. The same superstructure was to be used for bridges across two valleys of similar size but of different cross-sectional shape. Foundation conditions at both sites were similar and comprised several metres of gravel overlying strong siltstone that was underlain by a considerable depth of sandstone. Here the

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investigation sought to determine the effect of different valley shapes on the bridge response and the probable longitudinal shortening of the bridges under the action of particular earthquakes.

Arising from these investigations the authors have carried out a number of analyses to investigate the influence of valley size and shape on the seismic response and the likelihood of soil-structure interaction modifying the behaviour of any bridge that might span such valleys.

ANALYSES CARRIED OUT

Approximate outlines of the two valley shapes considered in the initial investigation are shown in figure 1, together with the bridge structure that it was proposed to use in both cases. The valley was modelled by quadrilateral finite elements based on cubic displacement functions [1], while the bridge and its pile foundations were modelled by beam elements. The finite element models were subjected to the El Centro (N-S) earthquake and the artificial A1 earthquake records.

The subsequent investigation analysed a range of valley shapes covering v- and u-shapes, deep rectangular valleys, and a progression from a wide, shallow rectangular valley to a deep, narrow rectangular one. The finite element model used high order triangular elements with a fine mesh in the region of the valley and a coarser one towards the edges. The section (or 'slice') analysed was 400 m wide by 250 m deep.

Values for density and elastic properties used in the analyses were based on those for the siltstone-sandstone that occurred in the valleys indicated in figure 1. While the density was constant with depth, the elastic modulus increased with depth and the value used in the analyses was that for the mid-depth of each element.

RESULTS

The results of subjecting two actual river valleys to particular earthquake records are shown in figure 1. For both the El Centro record and the artificial A1 record, the asymmetrical valley shape at bridge site b shows a greater differential horizontal displacement response than the valley at bridge site a. This difference in response was particularly marked with the artificial A1 earthquake.

Approximate shapes of the two valleys at bridge sites a and b were analysed assuming no overlying gravel layer and the first horizontal displacement mode shapes are indicated in figure 2 together with that for the flat plain. It can be seen that there is some distortion of the displacement profiles and that this distortion is asymmetrical in the case of an asymmetrical valley. This asymmetry in behaviour is one of the factors that leads to the enhanced differential seismic response of bridge site b as compared to site a (figure 1). The analyses showed no significant difference in the period of the first mode. For the second mode, Table 1 shows that the flat plain has a lower period than the two valleys. For the third mode, the flat plain has a marginally higher period than the valleys.

Figure 3 shows the influence of valley depth on the first displacement mode for the case of a v-shaped valley. It can be seen that as the valley depth increases, the displacement pattern shows an increasing concentration of the displacement contours in the top of the valley. From Table 1 it can be seen that the first mode period decreases as the valley depth increases. With the second mode the valleys have an increasing period as the valley depth increases. For the third mode the periods decrease with increasing valley depth except for the 160 m deep v-shaped valley. Table 1 shows that as the depth of the valley increases the first and second mode periods become closer together whilst the difference between the second and third mode periods becomes more distinct.

It can also be seen from Table 1 that the idealised valleys a and b with a depth of 80 m have periods comparable with those of the 80 m deep v-shaped valley.

REFERENCE

1. Carr, A.J. and Moss, P.J., "Elastic soil-structure interaction", Bull. N.Z. Soc. Earthquake Eng., vol. 4, no. 2, April 1971, pp.258-269.

2. Carr, A.J. and Moss, P.J., "The dynamic behaviour of structures as influenced by soil-structure interaction", 5th World Conf. on Earthquake Eng., Rome, June 1973, vol. 2, pp.2058-60.

TABLE 1

Valley shape	Period (secs)		
	1st mode	2nd mode	3rd mode
Idealised valley a (fig. 2)	66.9	59.5	38.5
Idealised valley b	66.4	58.4	38.3
Flat plain	68.8	50.1	40.3
v-shape : 40 m deep	68.0	52.4	39.6
: 80 m deep	66.6	56.6	38.0
: 120 m deep	65.5	60.6	37.8
: 160 m deep	65.4	63.5	38.5

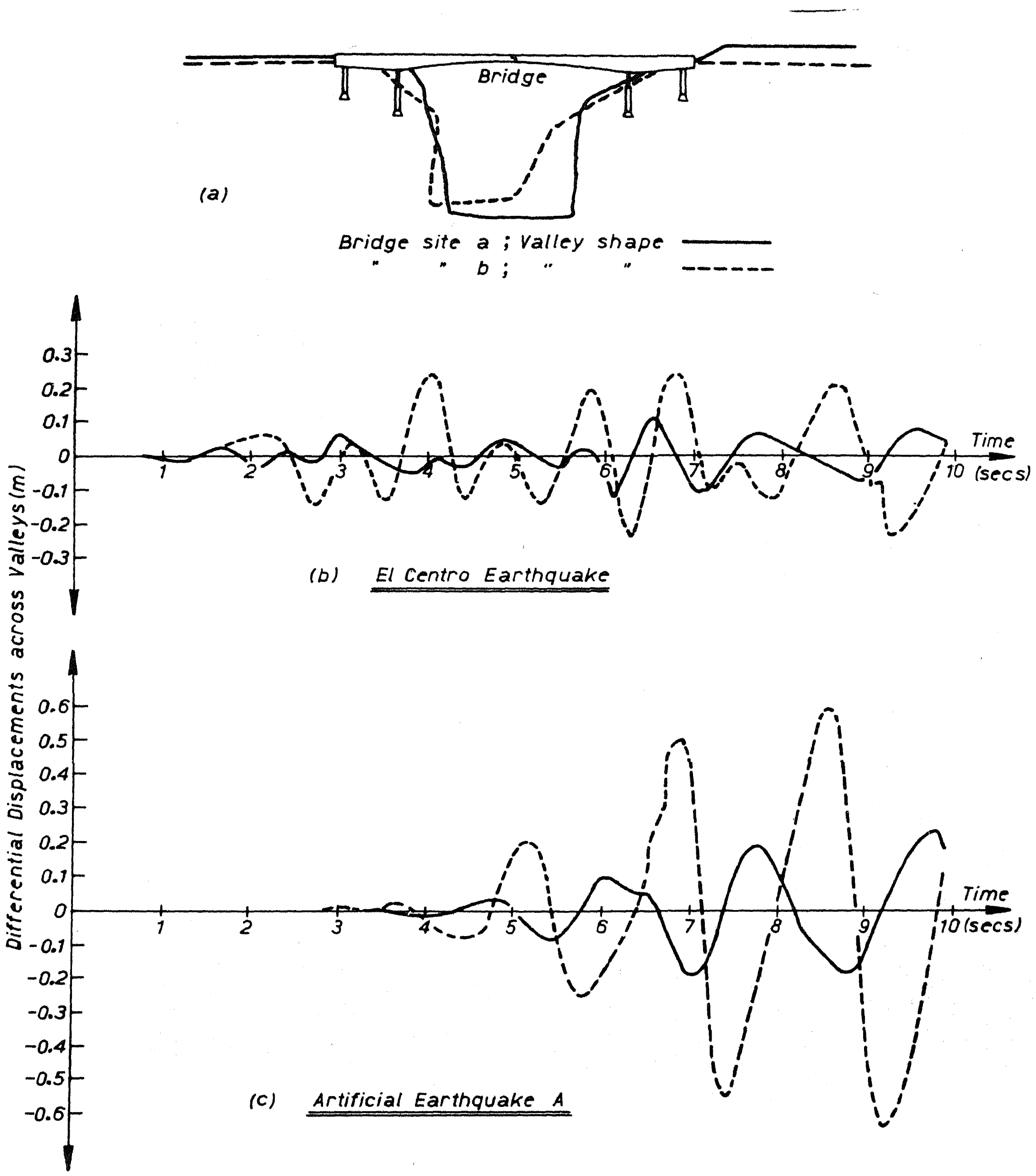


Figure 1: (a) valley shapes at bridge sites a and b.

(b) and (c) differential horizontal displacements across valleys.

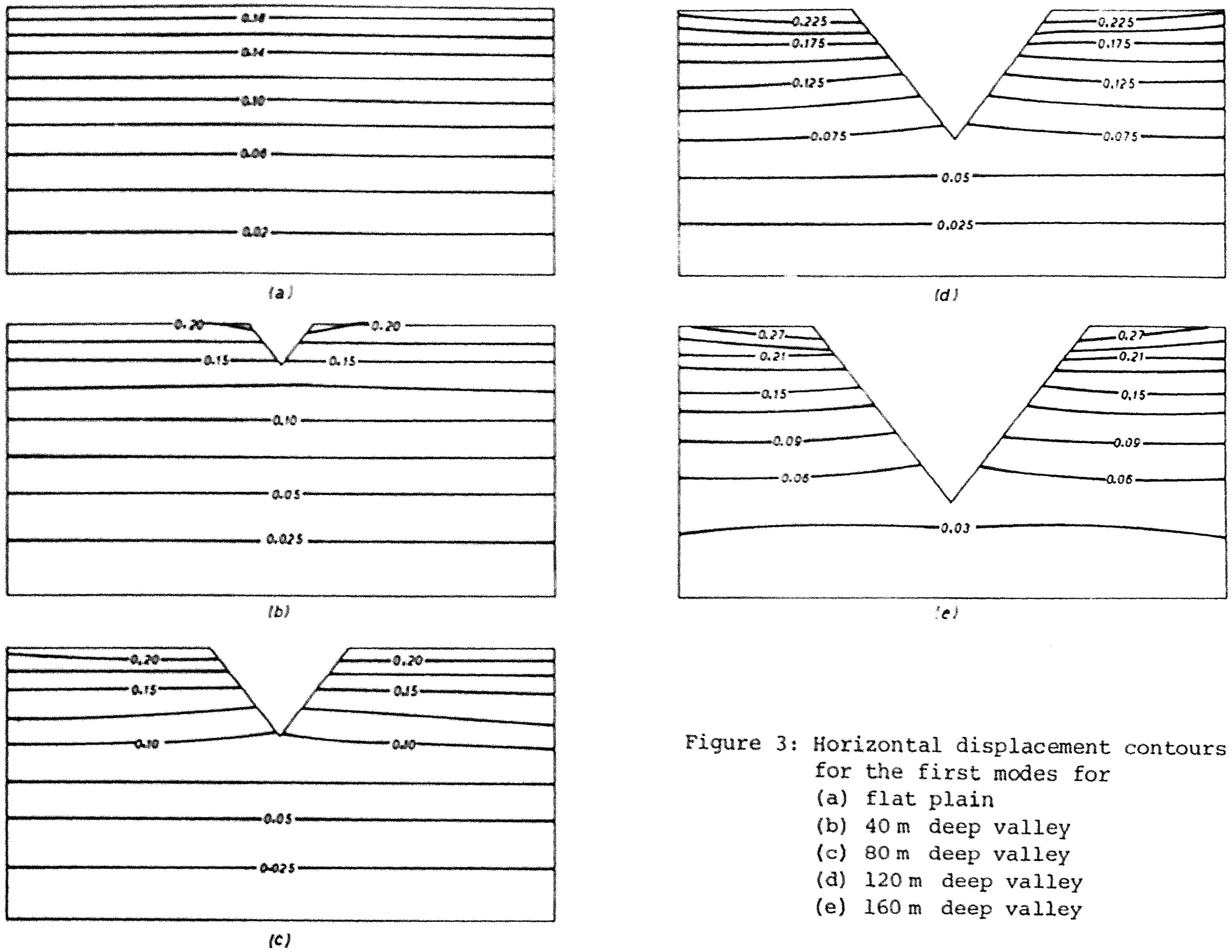
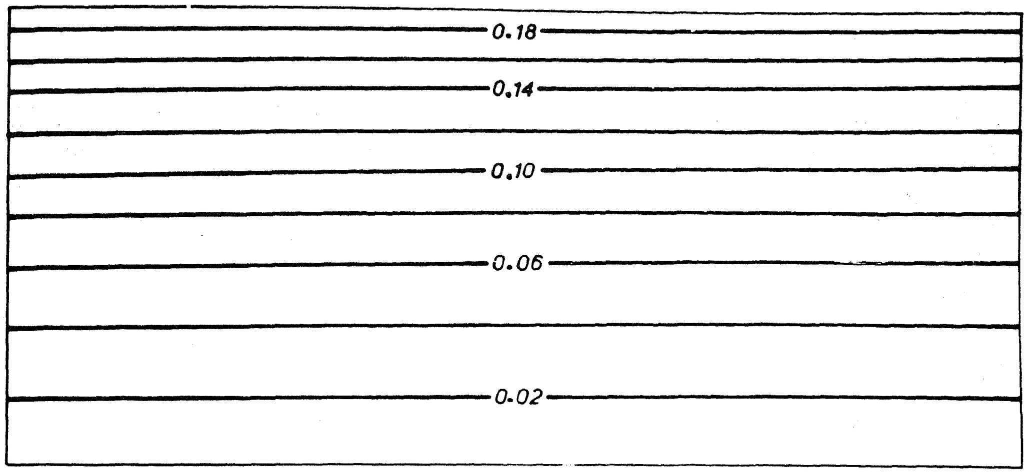
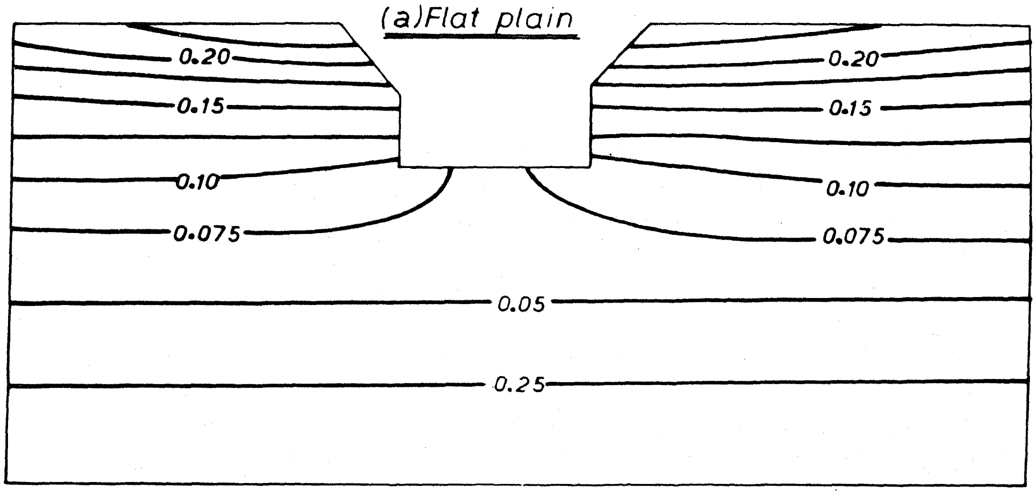


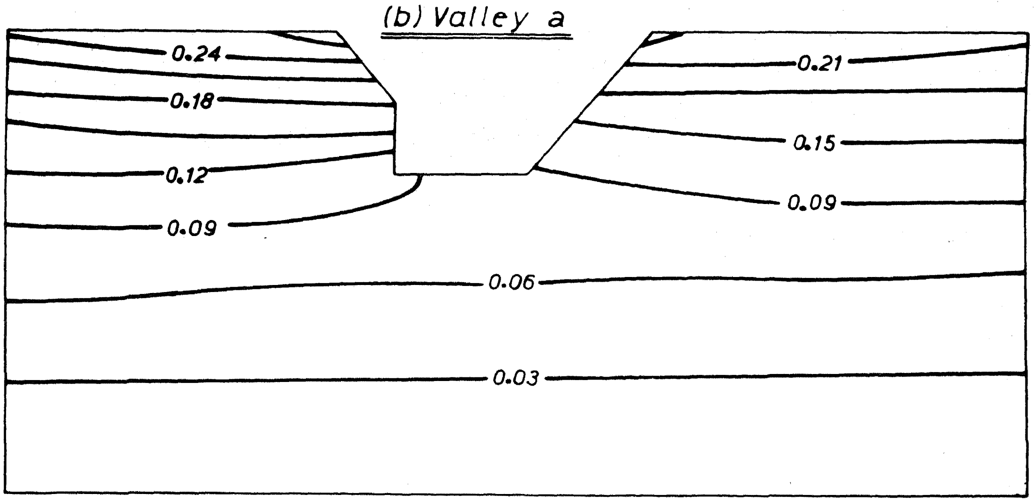
Figure 3: Horizontal displacement contours
for the first modes for
(a) flat plain
(b) 40 m deep valley
(c) 80 m deep valley
(d) 120 m deep valley
(e) 160 m deep valley



(a)Flat plain



(b) Valley a



(c) Valley b

Figure 2: Horizontal displacement contours for the first modes for the flat plain and idealised valleys a and b.