**Seismic Design of Foundations: Concepts and applications**
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# Case studies

## Case study 1

Figure 1.17 Dharahara Tower in Kathmandu before and after the 2015 Nepal earthquake

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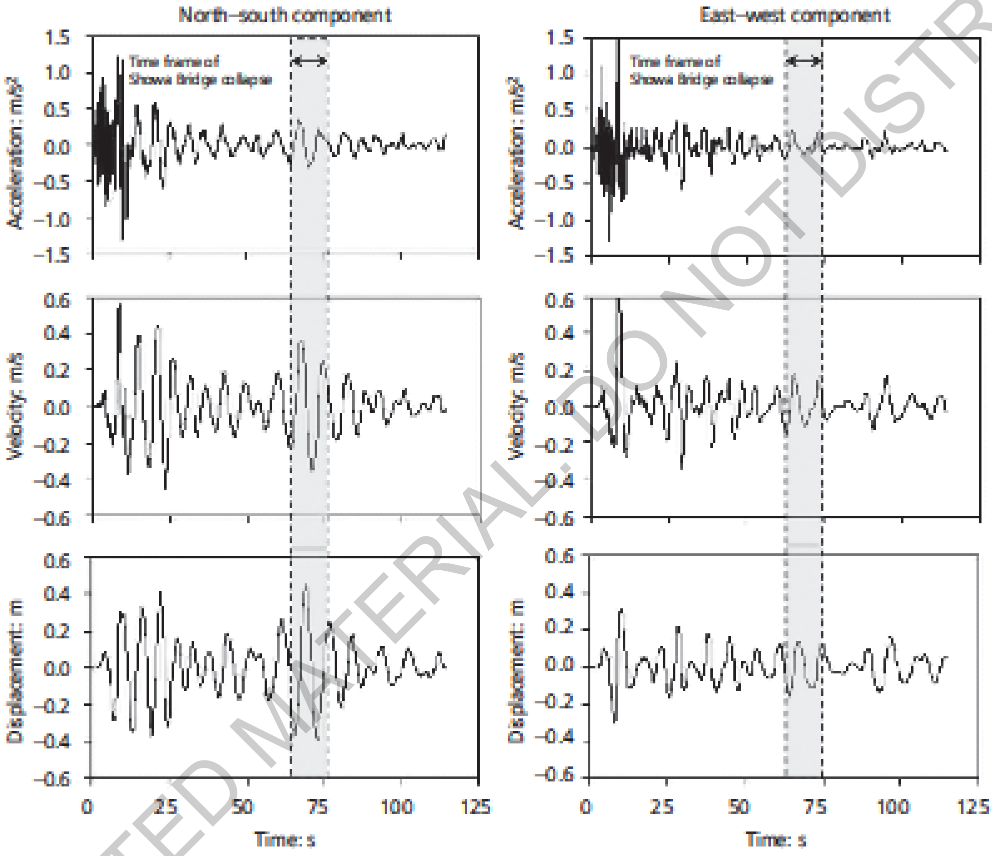
# Case study 2

Figure 5.9 Time history of acceleration (recorded) and the corresponding velocity and displacement histories



spectra for this strong motion are shown in Figure 5.10 for damping ratios of 5% and 20%. Acceleration–displacement response spectra are often useful for comparing the spectral behaviour, and provide the response of structures for different time periods. Structures with periods of 2 and 6 s are shown in Figure 5.11; the significance of the numbers are discussed below. Readers are referred to standard earthquake dynamics textbooks for details on the construction of the spectra.

The 1964 Niigata earthquake was a watershed event for earthquake geotechnical engineering, as many lessons were learnt. Figure 5.9 also shows the window when the Showa Bridge (see Chapter 10) collapsed: readers are referred to the detailed field report collated by Yoshida *et al.* (2007) and discussed by Bhattacharya *et al.* (2014). It is important to note that the time period of the bridge increased from 2 to 6 s with soil liquefaction. Based on the latest research carried out by Lombardi and Bhattacharya (2014), the damping of liquefied soil can be as high as 20%. It is observed from Figure 5.11 that the spectral displacement reached its peak at the period range 6–7 s. While the acceleration drops, the displacement demand increases.

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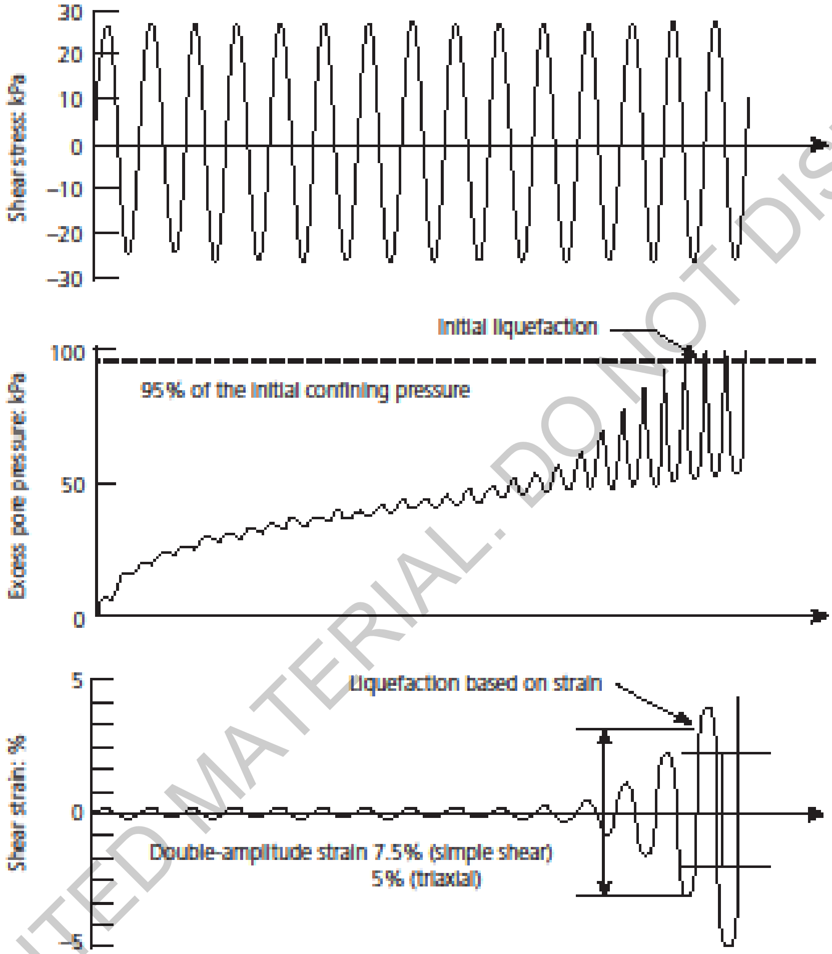
# Case study 3

Figure 6.10 Response of saturated sand under cyclic loading in the undrained condition



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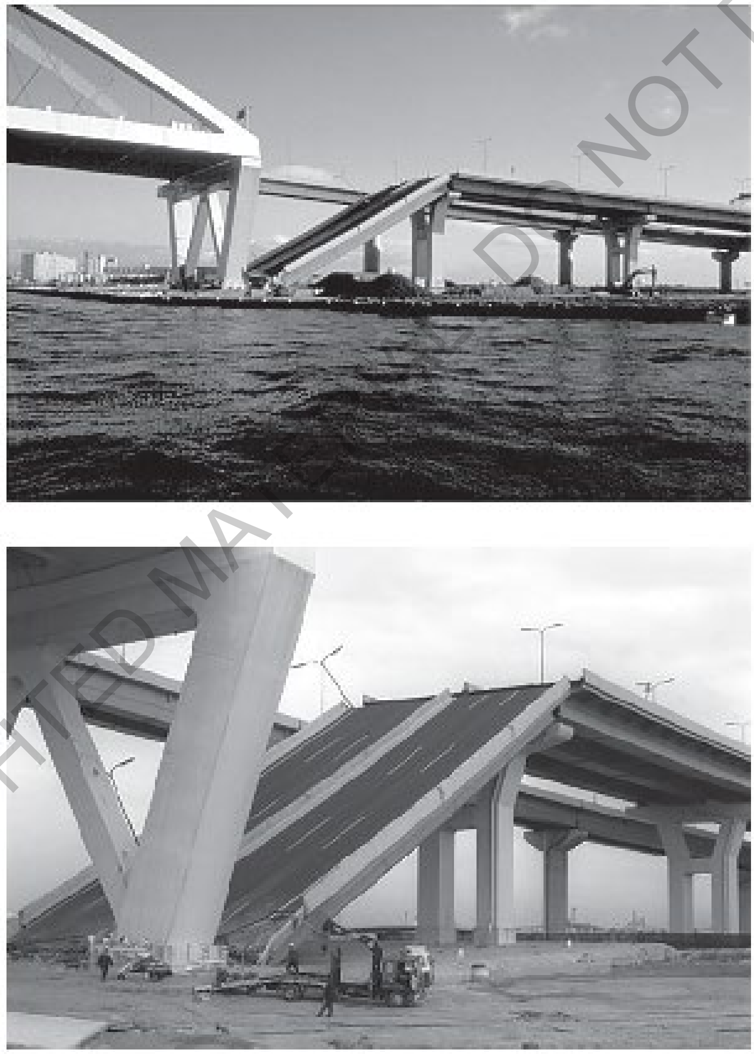
# Case study 4

### 10.2.4 Performance of the Nishinomiya Bridge, 1995 Kobe earthquake (Japan)

This arch bridge linked two reclaimed islands, Nishinomiya and Koshien. The top 6–8 m portion basically comprised loose reclaimed sand, with an standard penetration test (SPT) *N* value of 10 or less. During the 1995 Kobe earthquake the soil liquefied, and the span resting in between pier P99 and P98 fell off (Figure 10.4).

Figure 10.4 Failure of the Nishinomiya Bridge (Alim, 2014) (Ref: Alim, Hafizul (2014) 'Reliability Based Seismic Performance Analysis of Retrofitted Concrete Bridge Bent', Thesis, Lamar University, Texas, US)



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# Case study 5

### 12.3.4 Reinforcement and containment method

When saturated sand deposits are sheared during seismic loading, excess pore water pressure is generated, reducing the stiffness and strength of the soil and increasing strains. The aim of reinforcement is to reduce shear deformation in the ground during an earthquake, to mitigate the development of excess pore water pressures and, at the same time, provide support to the overlying structure. Reinforcement can also be used to prevent excessive deformation of structures by restraining the lateral flow of the ground after liquefaction. The principle behind this is illustrated in Figure 12.7.

Reinforcement of the ground can be achieved by underground diaphragm walls, sheet piles or lattice-shaped walls using deep-mixing techniques or through installation of a grid of stiff columnar elements such as concrete, timber or steel piles, or soil–cement mixed or jet grout columns. One disadvantage of reinforcement techniques is that there are no simple methods to verify the effectiveness of the reinforcement to mitigate shear strains that would cause a substantial reduction in the development of excess pore water pressures.

### 12.3.5 Drainage

Excess pore water pressure generated by cyclic loading can be reduced and/or dissipated by installing a permeable drain within the deposit. The methods employed can be divided into two categories, depending on the material used for the drain: gravel drain and artificial drain methods. These methods rely on two mechanisms to reduce damage due to liquefaction

- delaying the development of excess pore water pressure due to earthquake shaking
- preventing the migration of high excess pore water pressure from untreated liquefied zones into non-liquefied areas (e.g. underneath the structure), to prevent secondary liquefaction caused by pore water pressure redistribution.

Gravel drains are typically installed either as column-like drains in a closely spaced grid pattern or as backfill around underground structures to control the levels of the maximum excess pore water pressure ratio during earthquake shaking. They can also be installed as wall-like or column-like perimeter drains at both sides of

Figure 12.7 Principle of reinforcement and containment: (a) suppression of shear deformation in the ground during an earthquake; (b) suppression of the lateral flow of the ground after liquefaction