SITE SEISMICITY AND PILE DESIGN FOR THE ALEX FRASER BRIDGE NORTH APPROACH PIERS

by

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ABSTRACT

The Alex Fraser cable-stayed bridge is a six-lane, high level highway bridge, which spans the main channel of the Fraser River about 6 km downstream from New Westminster, British Columbia. Design of the bridge and its foundations included consideration of seismic loading. A detailed evaluation of the seismicity in the vicinity of the site was carried out to develop a rational design earthquake motion. Design of the foundations for the main bridge span and the approach piers included consideration of soil dynamics and soil-pile interaction. A summary of the methodology and results for the north approach piers is presented below.

Key words: bridge, case history, earthquake, pile.

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SITE SEISMICITY AND DESIGN EARTHQUAKE MOTION

A detailed evaluation of the site seismicity was carried out to develop seismic design parameters for use in design of the various elements of the bridge (Hofmann, 1982).

TECTONIC SETTING

The site is located about 200 km from what is presently regarded as the interface between the North American and Pacific Tectonic Plates. From this interface eastward to Vancouver is an area of underthrusting by elements of oceanic crust beneath the continental land mass. The site lies near the possibly still active Juan de Fuca plate which has underthrust the continent. To the northwest of Vancouver strike slip interplate motion takes place along the Queen Charlotte fault resulting in large earthquakes.

EVALUATION OF SEISMIC RISK

The study was carried out using a combination of deterministic and probalistic techniques. A review of established references and seismicity records for an area extending 500 km from Vancouver was carried out. This was used with the recorded earthquake data to develop a seismic source zone model.

The method of Cornell (1968), as applied by the computor program EQRISK of McGuire (1976), was used to determine probabilistic levels of shaking at the bridge site.

SEISMIC SOURCE ZONES AND PARAMETERS

Several source zone configurations were developed on the basis of known faulting and observed seismicity. One is shown on Figure 1 along with the the assigned source zone parameters.

Data for the entire area investigated were used to establish a slope for the recurrence curve and the overall earthquake rate.

Three functions, derived from a study of strong motion records, were used to model the attenuation of acceleration with distance from the source, namely:

- Hasegawa et al (1981) as recommended for Western Canada;
- McGuire (1976), derived from a similar data set to Hasegawa;
- Schnabel and Seed (1973), derived for hard rock sites in California.

RESULTS OF SEISMIC RISK EVALUATION

Two principal seismic source zones contribute to the risk at the bridge site, namely the Puget Sound Shallow and Deep Source Zones (Figure 1). The recommended design earthquake characteristics are summarized on Table 2.

Table 2. Recommended Design Earthquake Characteristics

Source Zone	Maximum Magnitude	Depth (km)	Epicentral Distance (km)	Peak Acceleration (% g)	
				100 yr	475 yr
Puget Sound Shallow	6.0	15 to 20	20 to 30	8 to 11	17 to 23
Puget Sound Deep	7.3	50	80	8 to 11	17 to 23

Six strong motion records obtained from earthquakes having similar magnitudes, and at stations with similar epicentral distances, were recommended as input for design. Among others, these include:

- the 1949 Olympia record (Deep Source), and
- the C.I.T. record from the 1971 San Fernando earthquake (Shallow Source).

CONSIDERATION OF SURFACE WAVE EFFECTS

Since the main bridge span is 465 m long there was concern regarding differences in motion at the main bridge piers. Surface waves, not usually of concern in design, would contribute more to such differential motion than the shorter period motions.

Approximate estimates indicate that surface wave predominant periods could be in the order of 3 to 4 seconds with amplitudes in the order of 110 to 140 mm.

FOUNDATION CONDITIONS AT THE BRIDGE SITE

The foundation strata which underly the bridge site were investigated using test borings, and in-situ and laboratory testing . The general stratigraphy is illustrated on Figure 2. The in-situ testing included cross-hole geophysics to determine the shear wave velocity (Figure 3).

SEISMIC DESIGN CONSIDERATIONS FOR THE APPROACH PIER PILES

The following summarizes the approach used in analysing the North approach pier piles with respect to earthquake loading.

PILE DETAILS AND SOIL CONDITIONS AT THE NORTH APPROACH PIERS

The proposed pile layout and details are illustrated on Figure 4. Both concrete and concrete-filled steel piles, having flexural stiffness (EI) values of 169,000 and 300,000 kN-m^2 respectively, were analyzed.

ANALYSIS OF CYCLIC LATERAL LOAD PERFORMANCE

The C.I.T. record of the 1971 San Fernando earthquake scaled to an acceleration of 20 per cent g was applied at the assumed bedrock elevation of -240 m (Geodetic Datum). The computer program ITER was used to calculate the dynamic response of the overlying soil strata. The stratigraphy was modelled by a series of springs and dashpots with properties determined from shear moduli and damping values. Initial shear moduli were calculated using the in-situ shear wave velocity measurements, and other test data. The maximum damping values, and both modulii and damping attenuation with strain level, were calculated by the program according to Hardin and Drnevich (1972).

The most critical free field displacement profiles, as predicted by ITER, with respect to the proposed pile installations were selected as input to the modified program LATPILE. This program was used to calculate the induced forces in the piles due to the free field deflections and structural loads.

SOIL-PILE INTERACTION MODEL

The soil-pile model is illustrated on Figure 5. The pile group, including the pile cap, was modelled by a single pile with corrections to soil resistance for group interaction and cyclic loading effects.

Corrected moduli and strength values were used to develop equivalent post-cyclic lateral load versus deflection curves (P-Y curves) which define the lateral compliance springs in the LATPILE model.

RESULTS OF SOIL-PILE INTERACTION EVALUATION

The results of our analysis of the cyclic lateral performance of the north approach pier piles are presented on Figure 5.

The most critical free field deflection profile at this location is the one which produces the maximum differential displacement across the silt stratum. The more flexible piles tend to follow the input free field motion with resulting lower shear forces and bending moments. The maximum bending moment at this pier location occurs at the top of the pile, with high bending moments also indicated below the soft silt stratum. It was estimated that 50 per cent of the predicted maximum bending moment is due to the free field ground motion alone, with the remainder due to the structural base shear load.

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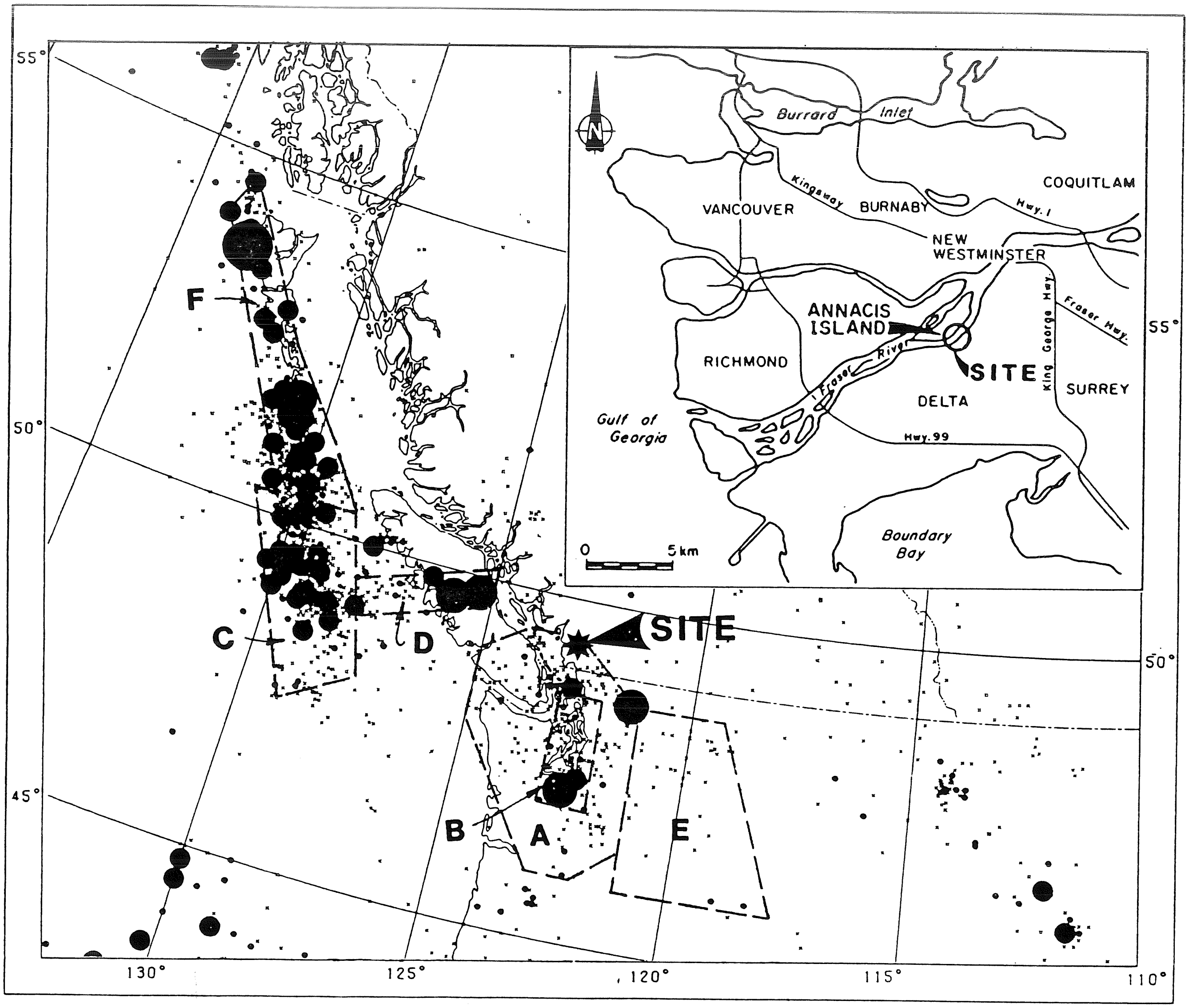
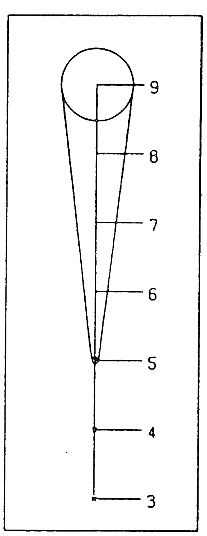




EARTHQUAKE MAGNITUDE

	SOURCE ZONE	MAXIMUM MAGITUDE	DEPTH (km)	CONTRIBUTION TO RISK AT SITE (%)
A	Puget Sound (shallow)	6.0	18	82.7
B	Puget Sound (deep)	7.3	40	14.6
C	Offshore	7.5	18	0.1
D	Nootka Fault	7.5	18	2.0
E	Eastern Washington	6.0	5	0.1
F	Queen Charlotte	8.5	18	0.6

Figure 1 - SEISMICITY and SOURCE ZONE MODEL

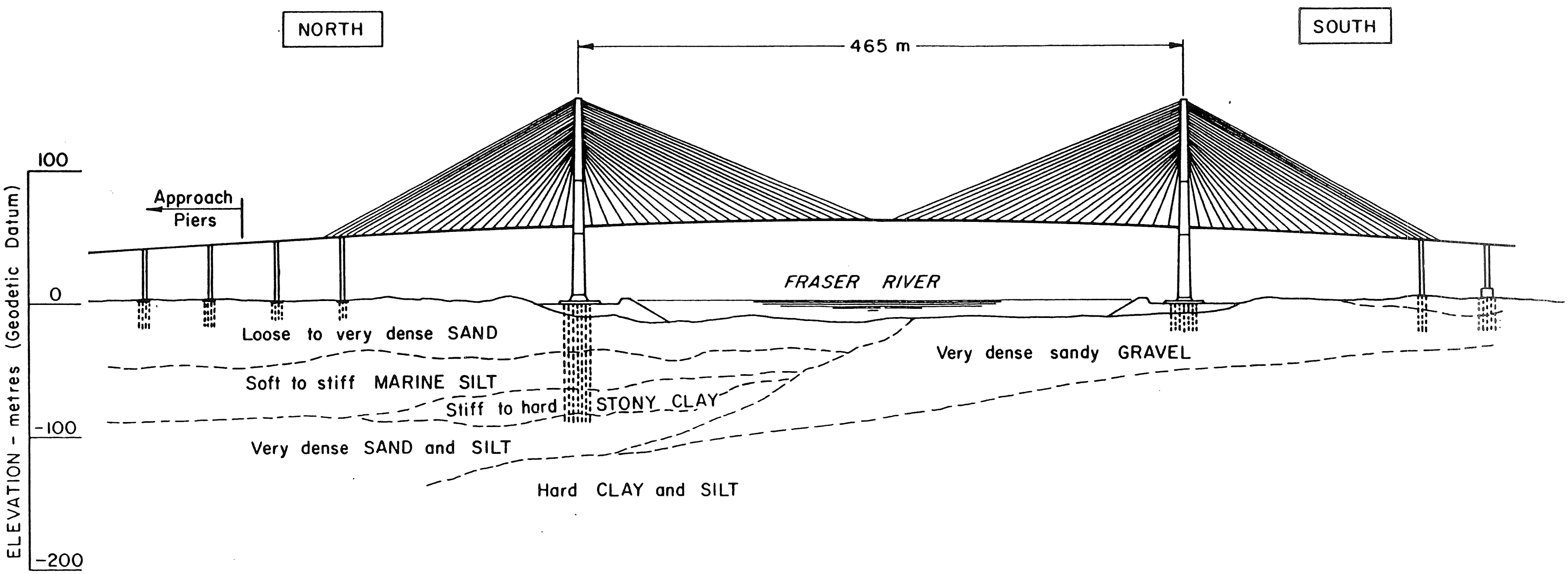


Figure 2 - GENERAL STRATIGRAPHY AT BRIDGE SITE

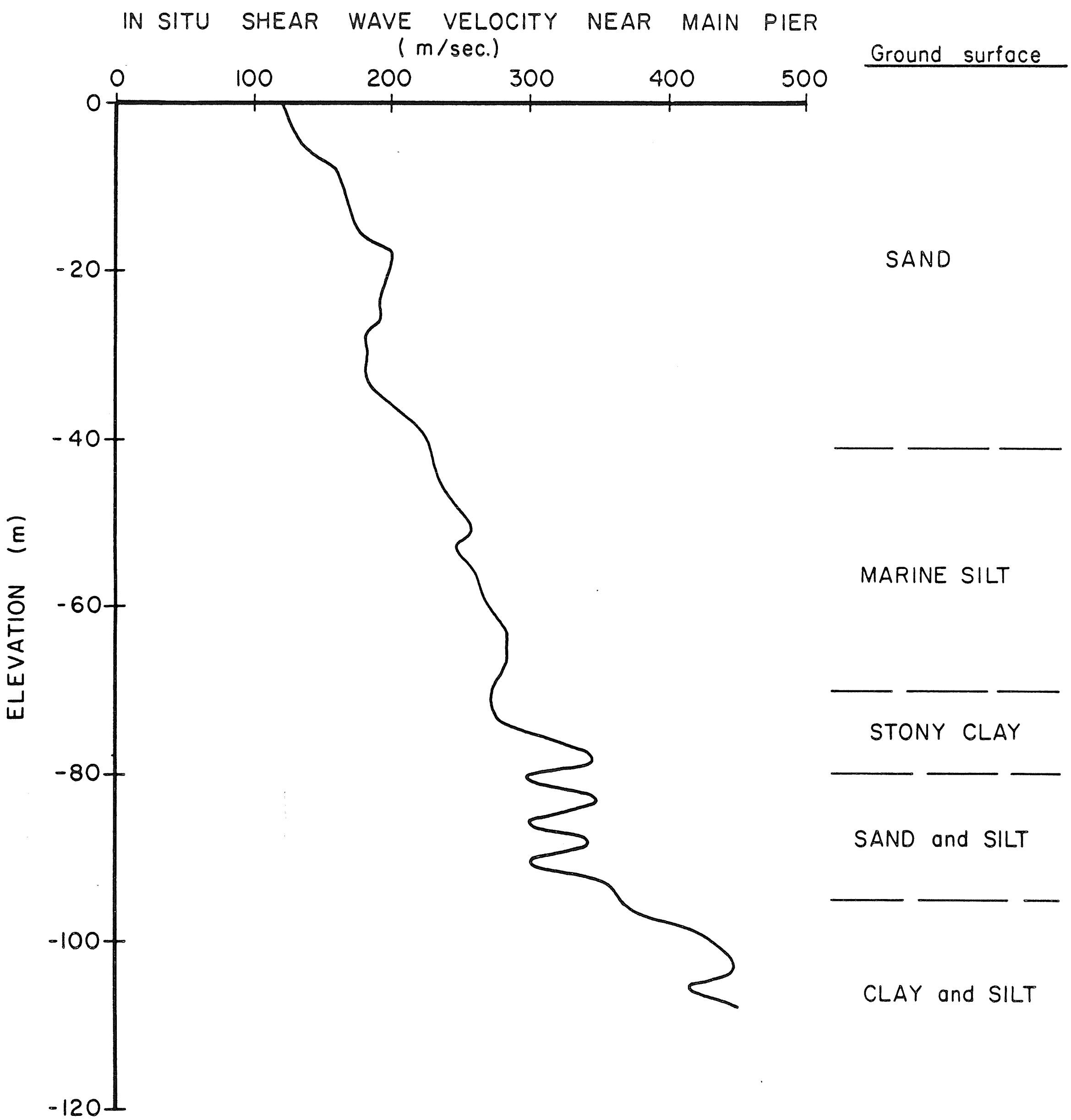
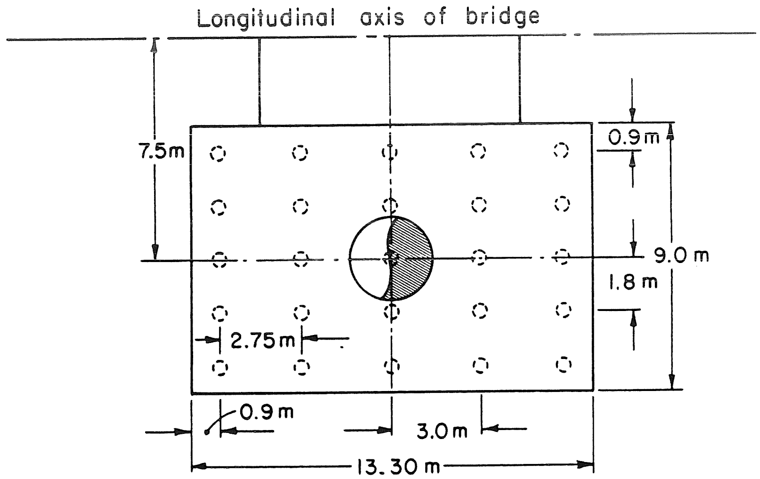
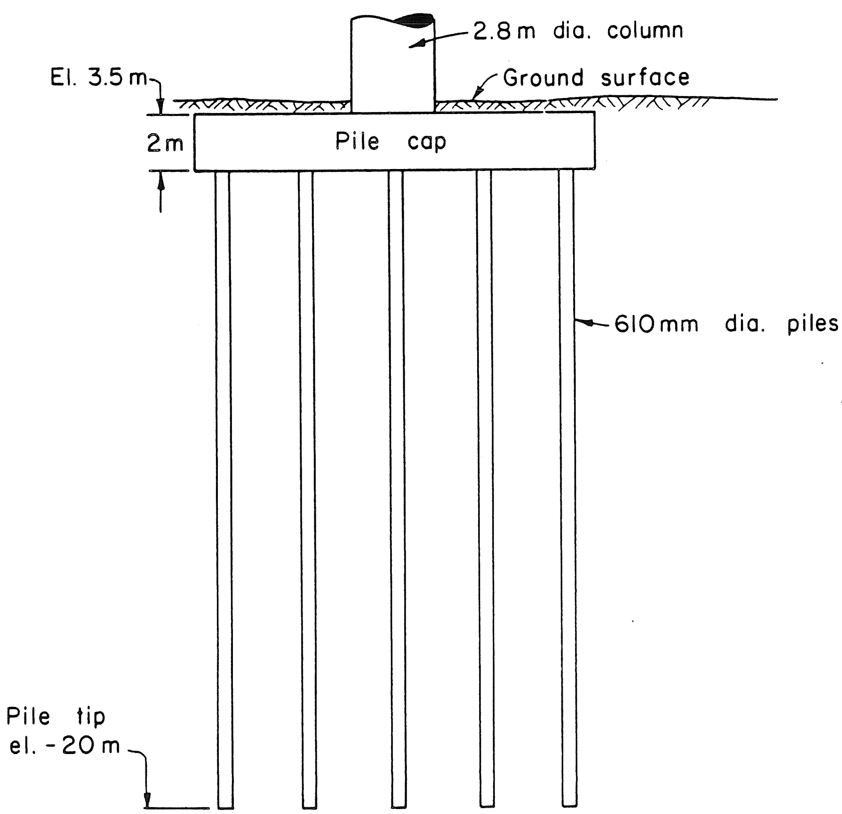


Figure 3 - IN SITU SHEAR WAVE VELOCITY MEASUREMENTS



PLAN



SECTION

Figure 4 - TYPICAL PROPOSED PILE/PILE CAP LAYOUT FOR NORTH APPROACH PIERS

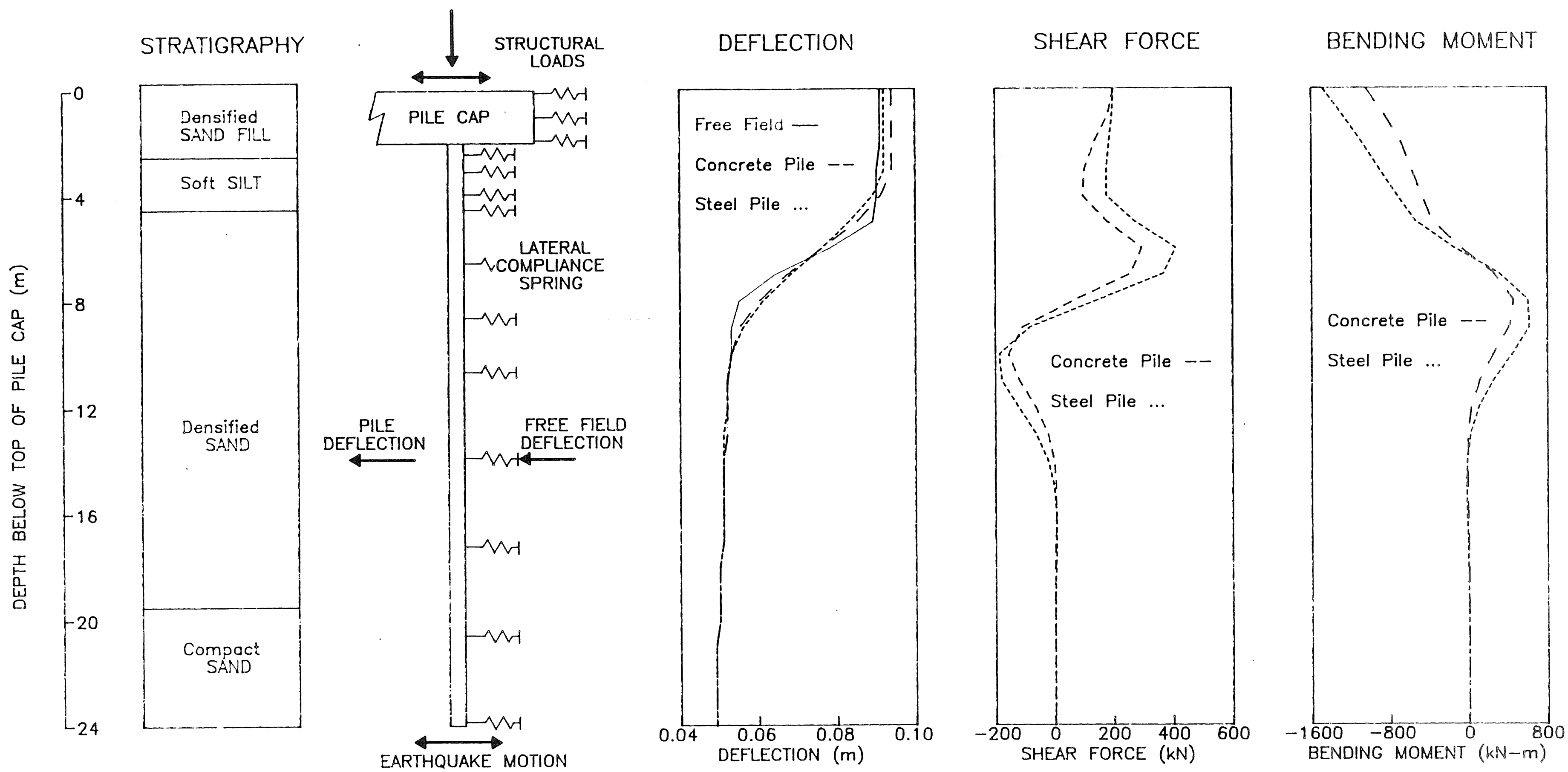


Figure 5 - SOIL-PILE INTERACTION MODEL and RESULTS