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Liquefaction potential and strain dependent dynamic properties of Kasai River sand

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ABSTRACT

The availability of efficient numerical techniques and high speed computation facilities for carrying out the nonlinear dynamic analysis of soil-structure interaction problems and the analysis of ground response due to earthquake loading increase the demand for proper estimation of dynamic properties of soil at small strain as well as at large strain levels. Accurate evaluation of strain dependent dynamic properties of soil such as shear modulus and damping characteristics along with the liquefaction potential are the most important criteria for the assessments of geotechnical problems involving dynamic loading. In this paper the results of resonant column tests and undrained cyclic triaxial tests are presented for Kasai River sand. A new correlation for dynamic shear damping (D_s) and maximum dynamic shear modulus (G_{max}) are proposed for the sand at small strain. The proposed relationships and the observed experimental data match quite well. The proposed relationships are also compared with the published relationships for other sands. The liquefaction potential of the sand is estimated at different relative densities and the damping characteristics at large strain level is also reported. An attempt has been made to correlate the G_{max} with the cyclic strength of the soil and also with the deviator stress (at 1% strain) from static triaxial tests.

1. Introduction

A number of important structures including railway bridges, road bridges, embankments and other water retaining and intake/outlet structures are constructed over the Kasai River and with the rapid industrialization and increase in population in the area several more such structures have been proposed. The existing twin railway bridges which connect two important cities in the area, Midnapore and Kharagpur, located on either banks of the river in the state of West Bengal is shown in Fig. 1. The proximity of a number of faults, like Pingla fault, Garhmayna Khandaghosh Fault and Eocene Hinge Zone, to the Kasai River [7] has caused mild seismic shaking a number of times in the recent past. A magnitude of $M_w = 4.9$ was recorded at Kharagpur during the 06/02/2008 Earthquake [23]. The area under consideration comes under the Seismic Zone III in the seismic zonation map of India. The Peak Ground Acceleration (PGA) predicted by GSHAP Model [16] for the area is between 0.2–0.3 g. Thus the seismic vulnerability assessment of the structures located on Kasai River is very much required to minimise the potential loss during a seismic event. The dynamic analysis of buried structures, embankments and foundations structures require that the constitutive relationships for the soils or the foundation soils be known a priory. A number of advanced constitutive relationships like that by Prevost [21], Dafalias et al. [6], Lade [19], Yang et al. [35], Elgamal et al. [10] and others are existing for this purpose. However, these advanced constitutive relationships for soils require extensive experience or knowledge regarding them and regarding their implementation in a software package. The most of the commercial analytical software for the dynamic analysis of soils/foundation soils require one to define the curves for the modulus degradation with strain and development of damping ratio with strain for the soils under consideration. These set of curves are popularly known as 'back bone curves'. These two curves are obtained from the laboratory dynamic tests on the soils and they incorporate the inelastic and nonlinear behaviors of a soil with the increment of strains. They are relatively easy to implement in a software due to their simplicity and thus they are more popular among the practicing engineers than the other more sophisticated models for the soils. In the literature, such sets of curves are available for sands [28], clays [33] and other materials.

In this research work, these back bone curves are developed for a local sand known as Kasai River sand. Often practicing engineers, instead of developing these curves from the laboratory tests on the specific soil, choose a set of curves from the literature. The set of

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Nomenclature

B	Pore pressure parameter
CSR	Cyclic stress ratio
D_s	Dynamic shear damping
e	Void ratio
G	Shear modulus
G_{max}	Maximum dynamic shear modulus
N	Number of cycles
r_u	Pore water pressure ratio
Δu	Change in sample pore pressure
V_s	Shear wave velocity
Pa	Atmospheric pressure
$\Delta\sigma_c$	change in cell pressure
ρ	Density of the soil specimen
τ	Shear stress
γ	Shear strain
σ_0	Effective confining pressure
σ_d	Deviator stress

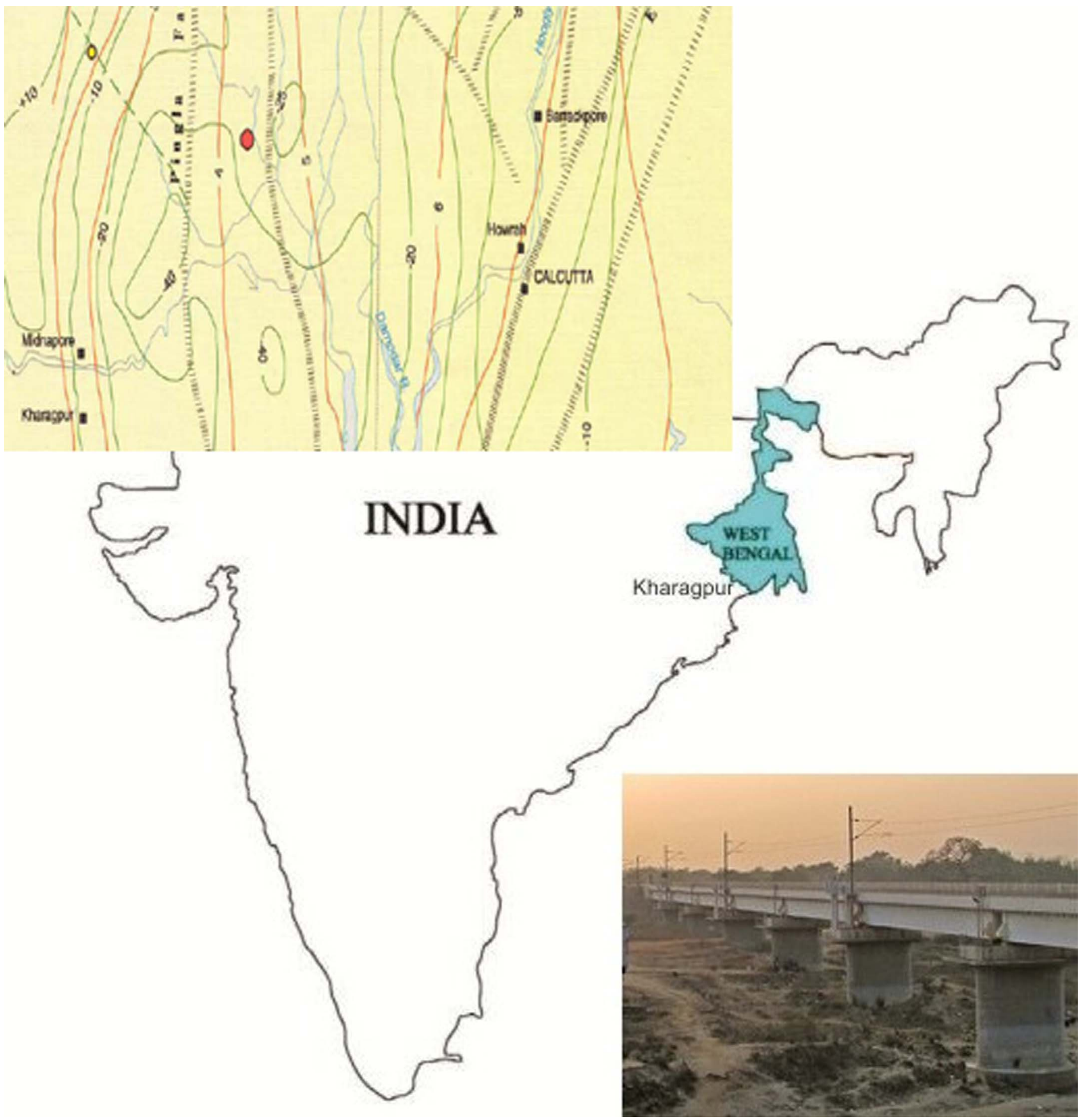

Fig. 1. Twin rail bridges connecting Kharagpur and Midnapore.