Intestazione corso (Arial, Bold, 10,5pt, Interlinea: 1.0) Corso di Laurea in Ingegneria Civile

Titolo (Arial, Bold, 24pt, Interlinea: 1.0, colore: 91,155, 213)

Sottotitolo (Arial, Regular, 18pt, Interlinea: 1.0, colore: 91, 155, 213)

Studente (Arial, Reg., 18pt, Interlinea: 1.0)
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Relatore: Francesca Dezi
Co-relatore: Andrea Grilli

Abstract (Arial, Regular, 10,5pt, Interlinea: 1.0) The paper focuses on the effects of soil-structure interaction in the seismic response of multi-spanviaducts on pile foundations. Analyses are performed by means of the substructure approach: the soil-foundation systems are studied in the frequency domain to obtain the foundation input motion and thedynamic impedance functions; inertial interaction analyses are carried out in the time domainaccounting for the material nonlinear behaviour.
Suitable lumped parameter models are introduced tosimulate the frequency dependent behaviour of the soil-foundation system. A specific procedure forselecting and scaling real ground motions is proposed and used for the definition of the spatial seismicinput. The seismic response of bridges on compliant base is compared with that obtained from fixedbase analyses discussing the significance of soil-structure interaction effects.Keywords: Bridges, Nonlinear behaviour, Soil-structure interaction, Substructure approach

Titoletto (Arial, Regular, 10,5pt, Interlinea: 1.0)

Testo paragrafo (Times New Roman, Regular, 10,5pt, Interlinea: 1.0) Seismic design of bridges are generally performed by assuming piers fixed at the base and consideringcode acceleration response spectra, defined on the basis of local hazard and soil classification.Actually, local soil conditions and soil-foundation interaction may modify the seismic motion to suchan extent that code spectra become not conservativ. In this paper Soil-Structure Interaction (SSI) andsite effects on the seismic response of bridges are evaluated with reference to a set of 10-span viaductshaving different span length L (25, 50 and 75 m)

Valore tabella (Arial, Regular, 10,5pt, Interlinea: 1.0)	1	2
Valore	A	B

Didascalie (Arial, Regular, 10,5pt, allineato al centro, Interlinea: 1.0) Tabella 1: didascalia

Testo paragrafo (Times New Roman, Regular, 10,5pt, Interlinea: 1.0) In both the longitudinal and transverse directions the seismic action is entrusted to the piers, equippedwith lock-up devices, while multi-directional bearings are used at the abutments to exclude a dual-pathmechanism. A single layer soil deposit of type D (Figure 2a), constituted by normally consolidatedclays with properties reported in Figure 2c, is considered; the profile of the shear modulus at lowstrains G0 is shown in Figure 2a.The seismic design of bridges is performed by means of a displacement-based approach byimposing different ductility demands at ultimate: in particular, circular piers of diameter 2.4 m andwith different height have been designed to achieve the ductility demand $\mu \approx 1$ (elastic behaviour),$\mu \approx 2$ and $\mu \approx 4$. The soil type D elastic displacement response spectrum of EN 1998-1 (2004) isadopted by considering a peak ground acceleration of 0.47g. The “30%-rule” is used to account for thebidirectional seismic action. Foundations, constituted by groups of bored concrete piles, are designed according to hierarchyprinciples in order to avoid the pile plasticization (Figure 2d). Depending on the case study, a certainamount of the bearing capacity is entrusted to the rigid cap.

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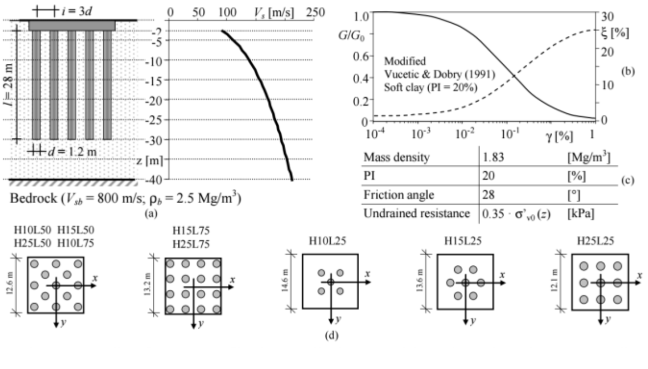
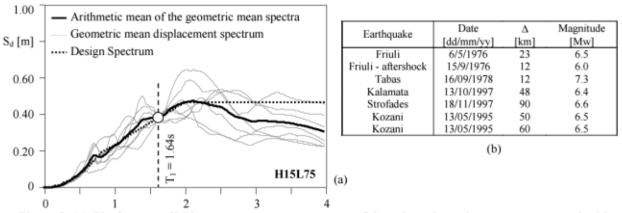


Mass density	1.83	[Mg/m³]
PI	20	[%]
Friction angle	28	[°]
Undrained resistance	$0.35 \cdot \sigma'_{v0}(z)$	[kPa]

Didascalie (Arial, Regular, 10,5pt, Interlinea: 1.0)
Didascalia immagine

Titoletto (Arial, Regular, 10,5pt, Interlinea: 1.0) Seismic input

Testo paragrafo (Times New Roman, Regular, 10,5pt, Interlinea: 1.0) Seismic design of bridges are generally performed by assuming piers fixed at the base and consideringcode acceleration response spectra, defined on the basis of local hazard and soil classification[4]. Actually, local soil conditions and soil-foundation interaction may modify the seismic motion to suchan extent that code spectra become not conservative. In this paper Soil-Structure Interaction (SSI) andsite effects on the seismic is considered since it has been demonstrated to be less sensitive to the orientation of the ground-motion axes (Baker and Cornell 2006). Site effects are captured by performing one-dimensional localresponse analyses in which the nonlinear soil behaviour is taken into account. Propagation analysesare performed in the two separate directions for each bridge and record; the geometric mean spectrumat the ground surface is evaluated and used to verify the matching with the relevant code spectrum atthe fundamental frequency of the bridge, and eventually to scale the ground motion up to convergence.



Earthquake	Date [dd/mm/yy]	Δ [km]	Magnitude [Mw]
Friuli	6/5/1976	23	6.5
Friuli - aftershock	15/9/1976	12	6.0
Tabas	16/09/1978	12	7.3
Kalamata	13/10/1997	48	6.4
Strofades	18/11/1997	90	6.6
Kozani	13/05/1995	50	6.5
Kozani	13/05/1995	60	6.5

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Figure 3. (a) Single mean displacement response spectrum of the selected accelerograms compared withreference spectra; (b) selected ground motions on site class A

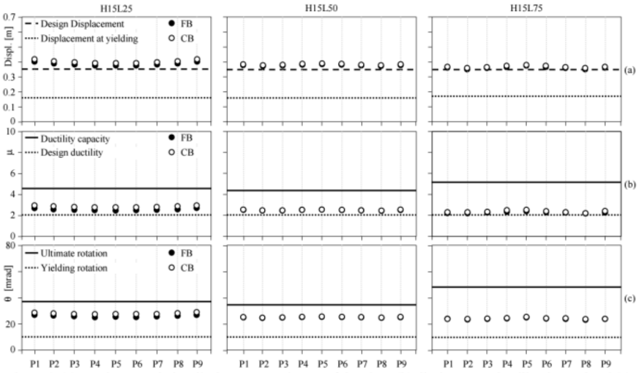

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Figure 4. (a) Maximums relative displacement at the top of the piers, (b) displacement ductility demand and (c)rotation demands and capacity of plastic hinges

Testo paragrafo (Times New Roman, Regular, 10,5pt, Interlinea: 1.0) The modified curves of Vucetic and Dobry (1991) (Figure 2b) are used to account for the nonlinearsoil behaviour according to the maximum shear strain level occurred during the bidirectional shaking.Figure 3 compares, for case H15L75, the mean geometric displacement response spectra at the groundsurface (grey lines) with the relevant design response spectrum (dotted line); the arithmetic meanspectrum (black line) obtained by averaging the individual geometric mean spectra is also reported. Itcan be observed that the arithmetic mean spectrum is able to represent the target code spectrum up to aperiod of about 2.0 s.

Titoletto (Arial, Regular, 10,5pt, Interlinea: 1.0) SSI Analysis

Testo paragrafo (Times New Roman, Regular, 10,5pt, Interlinea: 1.0) The analyses of the soil-foundation systems (kinematic interaction analyses) are performed by meansof the numerical model proposed by Dezi et al (2009) which allows obtaining the Foundation InputMotion (FIM) and the frequency-dependent impedances necessary for the subsequent inertialinteraction analyses. The seismic input is constituted by the bidirectional free-field motion within thedeposit obtained from site analyses. The frequency-dependent impedances are approximated bysuitable Lumped Parameter Models (Carbonari et al. 2013) in the nonlinear time-domain inertialinteraction analyses performed by means of distributed plasticity finite element models. Furthermore,Compliant Base (CB) and Fixed Base (FB) models are developed. With reference to bridges H15L#, effects of SSI on the dynamic response are discussed bycomparing average results (from all the set of ground motions) obtained from the CB and FB modelsin terms of displacements, ductility demand and plastic hinges rotation demand. Figure 4a comparesthe absolute maximum relative displacement of the top of piers with the design displacements; theseare well reproduced by FB models and SSI affects slightly the maximum deck displacements only inthe case of bridge H15L25. Figure 4b compares the ductility demand of each pier with the relevantcapacity. Consistently with displacements, the ductility demand of piers is almost coincident with thedesign one and SSI slightly increases the demand in the piers of bridge H15L25. Finally, Figure 4cshows plastic hinges rotation demands at the base of piers. The yielding (θy) and the ultimate (θu)rotations (EN 1998-2, 2005), are also reported. Consistently with above observations, SSI increasesthe rotation demand of plastic hinges only for piers of bridges H15L25.

Titoletto (Arial, Regular, 10,5pt, Interlinea: 1.0) Conclusions

Testo paragrafo (Times New Roman, Regular, 10,5pt, Interlinea: 1.0) SSI effects on the seismic response of multi-span viaducts on pile foundations have been investigated,by considering bridges characterised by ductile and non-ductile behaviours. A specific procedure forthe selection and scaling of ground motions is proposed for the definition of the bidirectional seismicinput, accounting for site effects and the nonlinear soil behaviour. The seismic response of the bridgeson compliant base is compared with that obtained from fixed base analyses discussing the significanceof SSI effects. Results demonstrate that, despite bridges are founded on a very soft soil, SSI does notplay a significant role in the definition of the structural response.

Titoletto (Arial, Regular, 10,5pt, Interlinea: 1.0) References

Testo references (Times New Roman, Regular, 10,5pt, Interlinea: 1.0) — Baker JW and Cornell A (2006), “Correlation of response spectral values for multicomponent ground motions”,Bulletin of the Seismological Society of America 96, 215–227.
— Carbonari S, Morici M, Dezi F, Leoni G, Nuti C, Silvestri F, Tropeano G and Vanzi I (2012), “Seismic Responseof Viaducts Accounting for Soil-Structure Interaction”, 15 World Conference on Earthquake Engineering,24-28 September, Lisboa, Portugal.
— Dezi F, Carbonari S and Leoni G (2009), “A model for the 3D kinematic interaction analysis of pile groups inlayered soils”, Earthquake Engng Struct. Dyn. 38(11), 1281-305.