DATI IDENTIFICATIVI DELL'ELABORATO (DGR Regione Liguria n. 835 del 04/08/2023)
PROVINCIA DI GENOVA
COMUNE DI GENOVA
PROCEDURA: Verifica di assoggettabilita' a VIA - art. 19 D.Lgs. 152/2006
PROGETTO: Variante sostanziale al programma di coltivazione e riqualificazione ambientale della cava di calcare "Montanasco" - Comune di Genova, loc. Molassana (Foglio 39, sez. cens. E)
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Il presente inquadramento sismico è redatto in conformità al D.M. 17 gennaio 2018 «Norme Tecniche per le Costruzioni» (NTC 2018) e alla relativa Circolare applicativa del Consiglio Superiore dei Lavori Pubblici n. 7 del 21 gennaio 2019 («Istruzioni per l'applicazione dell'Aggiornamento delle Norme tecniche per le costruzioni»), nonché alla D.G.R. Regione Liguria n. 216 del 17/03/2017 («Aggiornamento della classificazione sismica del territorio della Regione Liguria»). Le risultanze sono propedeutiche alle verifiche di stabilità globale dei versanti e delle opere geotecniche di progetto, condotte ai sensi del § 6.3.4 e del §

7.11.3 delle NTC 2018. **dr. Guido Carieri** **C.FISC:** **P.IVA:**	

	Data: ottobre 2023
	Il committente
	IL Tecnico
	Il Progettista

Pericolosità sismica di base

1 PREMESSA

Per valutare se un'opera strutturale è sicura bisogna far riferimento a degli *stati limite*, che possono verificarsi durante un determinato *periodo di riferimento* della stessa opera. Quindi per poter stimare l'azione sismica che dovrà essere utilizzata nelle verifiche agli stati limite o nella progettazione, bisognerà stabilire:

- in primo luogo la *vita nominale* dell'opera, che congiuntamente alla *classe d'uso*, permette di determinare il *periodo di riferimento*;
- una volta definito il periodo di riferimento e i diversi stati limite da considerare, dopo aver definito le relative *probabilità di superamento* è possibile stabilire il *periodo di ritorno* associato a ciascun stato limite;
- a questo punto è possibile definire la ***pericolosità sismica di base*** per il sito interessato alla realizzazione dell'opera, facendo riferimento agli studi condotti sul territorio nazionale dal Gruppo di Lavoro 2004 nell'ambito della convenzione-progetto S1 DPC-INGV 2004-2006 e i cui risultati sono stati promulgati mediante l'Ordinanza del Presidente del Consiglio dei Ministri (OPCM) 3519/2006.

2 VITA NOMINALE, CLASSI D'USO E PERIODO DI RIFERIMENTO

Nel **DM 17 gennaio 2018**-Aggiornamento delle «Norme tecniche per le costruzioni» il periodo di riferimento, che non può essere inferiore a 35 anni, è dato dalla seguente relazione:

$$V_R = V_N \cdot C_U \quad (2.1)$$

dove:
$\mathbf{V_R}$ = periodo di riferimento
$\mathbf{V_N}$ = vita nominale
$\mathbf{C_U}$ = coefficiente d'uso

La vita nominale di un'opera strutturale V_N, secondo le NTC 2018, è definita come il numero di anni nel quale la struttura, purché soggetta alla manutenzione ordinaria, deve potere essere usata per lo scopo al quale è destinata e viene definita attraverso tre diversi valori, a seconda dell'importanza dell'opera e perciò delle esigenze di durabilità.

I valori minimi di V_N da adottare per i diversi tipi di costruzione sono riportati nella Tab. 2.1. Tali valori possono essere anche impiegati per definire le azioni dipendenti dal tempo.

Tab. 2.1 – Valori minimi della Vita nominale V_N di progetto per i diversi tipi di costruzioni

TIPI DI COSTRUZIONI		Valori minimi di V_N (anni)
1	Costruzioni temporanee e provvisorie	10
2	Costruzioni con livelli di prestazioni	50
3	Costruzioni con livelli di prestazioni elevati	100

Nel caso specifico $\mathbf{V_N = 50}$ **anni**.

In presenza di azioni sismiche, con riferimento alle conseguenze di una interruzione di operatività o di un eventuale collasso, le costruzioni sono suddivise in classi d'uso. Le NTC 2018 prevedono quattro classi d'uso a ciascuna delle quali è associato un valore del coefficiente d'uso:

Classe I: Costruzioni con presenza solo occasionale di persone, edifici agricoli. $C_U = 0.7$;

Classe II: Costruzioni il cui uso preveda normali affollamenti, senza contenuti pericolosi per l'ambiente e senza funzioni pubbliche e sociali essenziali. Industrie con attività non pericolose per l'ambiente. Ponti, opere infrastrutturali, reti viarie non ricadenti in Classe d'uso *III* o in Classe d'uso *IV*, reti ferroviarie la cui interruzione non provochi situazioni di emergenza. Dighe il cui collasso non provochi conseguenze rilevanti. $C_U = 1.0$;

Classe III: Costruzioni il cui uso preveda affollamenti significativi. Industrie con attività pericolose per l'ambiente. Reti viarie extraurbane non ricadenti in Classe d'uso *IV*. Ponti e reti ferroviarie la cui interruzione provochi situazioni di emergenza. Dighe rilevanti per le conseguenze di un loro eventuale collasso. $C_U = 1.5$;

Classe IV: Costruzioni con funzioni pubbliche o strategiche importanti, anche con riferimento alla gestione della protezione civile in caso di calamità. Industrie con attività particolarmente pericolose per l'ambiente. Reti viarie di tipo A o B, di cui al DM 5/11/2001, n. 6792, "Norme funzionali e geometriche per la costruzione delle strade", e di tipo C quando appartenenti ad itinerari di collegamento tra capoluoghi di provincia non altresì serviti da strade di tipo A o B. Ponti e reti ferroviarie di importanza critica per il mantenimento delle vie di comunicazione, particolarmente dopo un evento sismico. Dighe connesse al funzionamento di acquedotti e a impianti di produzione di energia elettrica. $C_U = 2.0$;

Nel caso in esame viene presa in considerazione la **classe d'uso II** a cui è associato il coefficiente d'uso $\mathbf{C_U = 1}$.

Ricavati i valori di V_N e C_U, è possibile calcolare il periodo di riferimento V_R, che qui vale:
$\mathbf{V_R = 50 * 1 = 50}$ **anni**.

3 STATI LIMITE, PROBABILITÀ DI SUPERAMENTO E PERIODO DI RITORNO

Le NTC 2018 prendono in considerazione 4 possibili *stati limite* (SL) individuati facendo riferimento alle prestazioni della costruzione nel suo complesso, includendo gli elementi strutturali, quelli non strutturali e gli impianti: due sono *stati limite di esercizio* (SLE) e due sono *stati limite ultimi* (SLU). Uno stato limite è una condizione superata la quale l'opera non soddisfa più le esigenze per la quale è stata progettata.

Più in particolare le opere e le varie tipologie strutturali devono essere dotate di capacità di garantire le prestazioni previste per le condizioni di esercizio (sicurezza nei confronti di SLE) e di capacità di evitare crolli, perdite di equilibrio e di dissesti gravi, totali o parziali, che possano compromettere l'incolumità delle persone o comportare la perdita di beni, oppure provocare gravi danni ambientali e sociali, oppure mettere fuori servizio l'opera (sicurezza nei confronti di SLU).

Gli stati limite di esercizio sono:

- **Stato Limite di Operatività** (SLO): a seguito del terremoto la costruzione nel suo complesso, includendo gli elementi strutturali, quelli non strutturali, le apparecchiature rilevanti alla sua funzione, non deve subire danni ed interruzioni d'uso significativi;
- **Stato Limite di Danno** (SLD): a seguito del terremoto la costruzione nel suo complesso, includendo gli elementi strutturali, quelli non strutturali, le apparecchiature rilevanti alla sua funzione, subisce danni tali da non mettere a rischio gli utenti e da non compromettere significativamente la capacità di resistenza e di rigidezza nei confronti delle azioni verticali ed orizzontali, mantenendosi immediatamente utilizzabile pur nell'interruzione d'uso di parte delle apparecchiature.

Gli stati limite ultimi sono:

- **Stato Limite di salvaguardia della Vita** (SLV): a seguito del terremoto la costruzione subisce rotture e crolli dei componenti non strutturali ed impiantistici e significativi danni dei componenti strutturali cui si associa una perdita significativa di rigidezza nei confronti delle azioni orizzontali; la costruzione

conserva invece una parte della resistenza e rigidezza per azioni verticali e un margine di sicurezza nei confronti del collasso per azioni sismiche orizzontali;

- **Stato Limite di prevenzione del Collasso** (SLC): a seguito del terremoto la costruzione subisce gravi rotture e crolli dei componenti non strutturali ed impiantistici e danni molto gravi dei componenti strutturali; la costruzione conserva ancora un margine di sicurezza per azioni verticali ed un esiguo margine di sicurezza nei confronti del collasso per azioni orizzontali.

Ad ogni stato limite è associata una *probabilità di superamento* P_{VR} (Tabella 3.1), ovvero la probabilità che, nel periodo di riferimento V_R, si verifichi almeno un evento sismico ($n \geq 1$) di $\mathbf{a_g}$ prefissata ($\mathbf{a_g}$ = accelerazione orizzontale massima del suolo) avente frequenza media annua di ricorrenza $\boldsymbol{\lambda}= 1/T_R$ ($\mathbf{T_R}$ = periodo di ritorno).

Tabella 3.1- *Stati limite e rispettive probabilità di superamento, nel periodo di riferimento* V_R

Stato limite di esercizio: operatività	SLO	$\mathbf{P_{VR} = 81\%}$
Stato limite di esercizio: danno	SLD	$\mathbf{P_{VR} = 63\%}$
Stati limite ultimo: salvaguardia della vita	SLV	$\mathbf{P_{VR} = 10\%}$
Stati limite ultimo: di prevenzione del collasso	SLC	$\mathbf{P_{VR} = 5\%}$

Fissati V_R e P_{VR} associata ad ogni stato limite, è possibile calcolare il periodo di ritorno dell'azione sismica T_R**,** espresso in anni, mediante l'espressione:

$$T_R = -\frac{V_R}{\ln(1 - P_{VR})} \quad (3.1)$$

Tale relazione tra P_{VR} (probabilità) e T_R (statistica) risulta biunivoca poiché utilizza la distribuzione discreta Poissoniana.

Poiché è $\mathbf{V_R = 50}$ **anni**, il tempo di ritorno T_R sarà:

Tabella 3.2- *Stati limite e rispettivi tempi di ritorno, nel periodo di riferimento VR*

Stato limite di esercizio: operatività	SLO	$\mathbf{T_R = 30}$
Stato limite di esercizio: danno	SLD	$\mathbf{T_R = 50}$
Stati limite ultimo: salvaguardia della vita	SLV	$\mathbf{T_R = 475}$
Stati limite ultimo: di prevenzione del collasso	SLC	$\mathbf{T_R = 975}$

4 DEFINIZIONE DELLA PERICOLOSITÀ SISMICA DI BASE

La pericolosità sismica di base, cioè le caratteristiche del moto sismico atteso al sito di interesse, nelle NTC 2018, per una determinata probabilità di superamento, si può ritenere definita quando vengono designati un'accelerazione orizzontale massima (a_g) ed il corrispondente spettro di risposta elastico in accelerazione, riferiti ad un suolo rigido e ad una superficie topografica orizzontale.

Per poter definire la pericolosità sismica di base le NTC 2018 si rifanno ad una procedura basata sui risultati disponibili anche sul sito web dell'INGV http://esse1-gis.mi.ingv.it/, nella sezione "Mappe interattive della pericolosità sismica".

Secondo le NTC 2018 le forme spettrali sono definite per 9 differenti periodi di ritorno T_R (30, 50, 72, 101, 140, 201, 475, 975 e 2475 anni) a partire dai valori dei seguenti parametri riferiti a terreno rigido orizzontale, cioè valutati in condizioni ideali di sito, definiti nell'**Allegato A** alle NTC08:

$\mathbf{a_g}$ = accelerazione orizzontale massima;

$\mathbf{F_0}$ = valore massimo del fattore di amplificazione dello spettro in accelerazione orizzontale;

$\mathbf{T_C^*}$ = periodo di inizio del tratto a velocità costante dello spettro in accelerazione orizzontale.

I tre parametri si ricavano per il 50° percentile ed attribuendo a:

$\mathbf{a_g}$, il valore previsto dalla pericolosità sismica S1

$\mathbf{F_0}$ e $\mathbf{T_C^*}$ i valori ottenuti imponendo che le forme spettrali in accelerazione, velocità e spostamento previste dalle NTC08 scartino al minimo dalle corrispondenti forme spettrali previste dalla pericolosità sismica S1 (il minimo è ottenuto ai minimi quadrati, su valori normalizzati).

I valori di questi parametri vengono forniti in tabella (Tabella 4.1), contenuta nell'**Allegato B** delle NTC08 (a cui le NTC 2018 fanno riferimento), per i 10751 punti di un reticolo di riferimento in cui è suddiviso il territorio nazionale, identificati dalle coordinate geografiche longitudine e latitudine.

Tabella 4.1- *Stralcio della tabella contenuta nell'Allegato B delle NTC08, che fornisce i 3 parametri di pericolosità sismica, per diversi periodi di ritorno e per ogni nodo del reticolo che viene identificato da un ID e dalle coordinate geografiche.*

			$T_R = 30$			$T_R = 50$			$T_R = 72$			$T_R = 101$		
ID	**LON**	**LAT**	$\mathbf{a_g}$	$\mathbf{F_0}$	$\mathbf{T^*_c}$	$\mathbf{a_g}$	$\mathbf{F_0}$	$\mathbf{T^*_c}$	$\mathbf{a_g}$	$\mathbf{F_0}$	$\mathbf{T^*_c}$	$\mathbf{a_g}$	$\mathbf{F_0}$	$\mathbf{T^*_c}$
13111	6.5448	45.1340	0.263	2.500	0.180	0.340	2.510	0.210	0.394	2.550	0.220	0.469	2.490	0.240
13333	6.5506	45.0850	0.264	2.490	0.180	0.341	2.510	0.210	0.395	2.550	0.220	0.469	2.490	0.240
13555	6.5564	45.0350	0.264	2.500	0.180	0.340	2.510	0.200	0.393	2.550	0.220	0.466	2.500	0.240
13777	6.5621	44.9850	0.263	2.500	0.180	0.338	2.520	0.200	0.391	2.550	0.220	0.462	2.510	0.240
12890	6.6096	45.1880	0.284	2.460	0.190	0.364	2.510	0.210	0.431	2.500	0.220	0.509	2.480	0.240
13112	6.6153	45.1390	0.286	2.460	0.190	0.366	2.510	0.210	0.433	2.500	0.220	0.511	2.480	0.240
		Boissano, aprile 2026												
13334	6.6210	45.0890	0.288	2.460	0.190	0.367	2.510	0.210	0.434	2.500	0.220	0.511	2.490	0.240
13556	6.6268	45.0390	0.288	2.460	0.190	0.367	2.510	0.210	0.433	2.510	0.220	0.510	2.490	0.240
13778	6.6325	44.9890	0.288	2.460	0.190	0.366	2.520	0.210	0.430	2.510	0.220	0.507	2.500	0.240
14000	6.6383	44.9390	0.286	2.470	0.190	0.363	2.520	0.210	0.426	2.520	0.220	0.502	2.500	0.240
14222	6.6439	44.8890	0.284	2.470	0.190	0.360	2.530	0.210	0.421	2.530	0.220	0.497	2.500	0.240
12891	6.6803	45.1920	0.306	2.430	0.200	0.389	2.500	0.210	0.467	2.470	0.230	0.544	2.490	0.230
10228	6.6826	45.7940	0.283	2.420	0.200	0.364	2.460	0.220	0.430	2.460	0.240	0.505	2.440	0.250
13113	6.6860	45.1430	0.309	2.430	0.200	0.391	2.510	0.210	0.470	2.470	0.230	0.546	2.490	0.230
10450	6.6885	45.7450	0.278	2.440	0.200	0.356	2.480	0.220	0.415	2.500	0.230	0.485	2.470	0.250
13335	6.6915	45.0930	0.310	2.430	0.200	0.392	2.510	0.210	0.470	2.480	0.230	0.546	2.500	0.230
10672	6.6942	45.6950	0.275	2.450	0.200	0.351	2.490	0.210	0.406	2.520	0.230	0.475	2.490	0.250
13557	6.6973	45.0430	0.311	2.440	0.200	0.392	2.520	0.210	0.469	2.480	0.230	0.545	2.500	0.230
13779	6.7029	44.9930	0.310	2.440	0.200	0.391	2.520	0.210	0.467	2.480	0.230	0.543	2.500	0.230

Qualora la pericolosità sismica del sito sul reticolo di riferimento non consideri il periodo di ritorno T_R corrispondente alla V_R e P_{VR} fissate, il valore del generico parametro p ad esso corrispondente potrà essere ricavato per interpolazione (Figura 4.1), a partire dai dati relativi ai tempi di ritorno previsti nella pericolosità di base, utilizzando la seguente espressione dell'Allegato A alle NTC08:

$$\log(p) = \log(p_1) + \log\left(\frac{p_2}{p_1}\right) \cdot \log\left(\frac{p_2}{p_1}\right) \cdot \left[\log\left(\frac{T_{R2}}{T_{R1}}\right)\right]^{-1} \quad (4.1)$$

nella quale p è il valore del parametro di interesse (a_g, F_o, T_C^*) corrispondente al periodo di ritorno T_R desiderato, mentre $p_{1,2}$ è il valore di tale parametro corrispondente al periodo di ritorno $T_{R1,2}$.

Per un qualunque punto del territorio non ricadente nei nodi del reticolo di riferimento, i valori dei parametri p possono essere calcolati come media pesata dei valori assunti da tali parametri nei quattro vertici della maglia elementare del reticolo di riferimento contenente il punto in esame, utilizzando l'espressione dell'Allegato A alle NTC08:

$$p = \frac{\sum_{i=1}^{4} \frac{p_i}{d_i}}{\sum_{i=1}^{4} \frac{1}{d_i}} \quad (4.2)$$

nella quale p è il valore del parametro di interesse (a_g, F_o, T_C^*) corrispondente al punto considerato, p_i è il valore di tale parametro nell'i-esimo vertice della maglia elementare contenente il punto in esame e d_i è la distanza del punto in esame dall'i-esimo vertice della suddetta maglia.

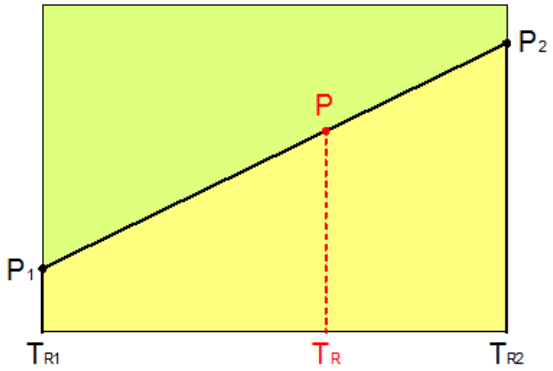


Figura 4.1 - *Interpolazione dei periodi di ritorno, per ottenere i parametri di pericolosità sismica,in accordo alla procedura delle NTC08.*

La procedura per interpolare le coordinate geografiche è schematizzata nella Figura 4.2

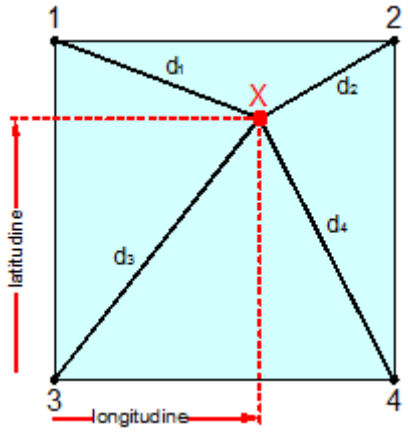


Figura 4.2 - Interpolazione delle coordinate geografiche, per ottenere i parametri di pericolosità sismica, in accordo alla procedura delle NTC08.

Pertanto per poter procedere all'interpolazione delle coordinate geografiche, in accordo alla procedura delle NTC08, bisogna calcolare le distanze che intercorrono tra i 4 punti del reticolo e il punto di interesse. Questo calcolo può essere eseguito approssimativamente utilizzando le formule della trigonometria sferica, che danno la distanza geodetica tra due punti, di cui siano note le coordinate geografiche. Utilizzando quindi il teorema di Eulero, la distanza d tra due punti, di cui siano note latitudine e longitudine, espresse però in radianti, si ottiene dall'espressione seguente:

$$d = R \cdot \arccos\left[\sin(\text{lat}\beta)\cdot\sin(\text{lat}\alpha)+\cos(\text{lat}\beta)\cdot\cos(\text{lat}\alpha)\cdot\cos(\text{lon}\alpha-\text{lon}\beta)\right] \quad (4.3)$$

dove R = 6371 è il raggio medio terrestre in km, mentre latα, lonα, latβ e lonβ sono la latitudine e la longitudine, espresse in radianti, di due punti A e B di cui si vuole calcolare la distanza.

La formula di interpolazione sopra proposta, semplice da usare, presenta però l'inconveniente di condurre a valori di pericolosità lievemente diversi per punti affacciati ma appartenenti a maglie contigue. La modestia delle differenze (scostamenti in termini di PGA dell'ordine di ±0,01g ossia della precisione dei dati) a fronte della semplicità d'uso, rende tale stato di cose assolutamente accettabile.

Qualora si vogliano rappresentazioni continue della funzione interpolata, si dovrà ricorrere a metodi di interpolazione più complessi, ad esempio i polinomi di Lagrange.

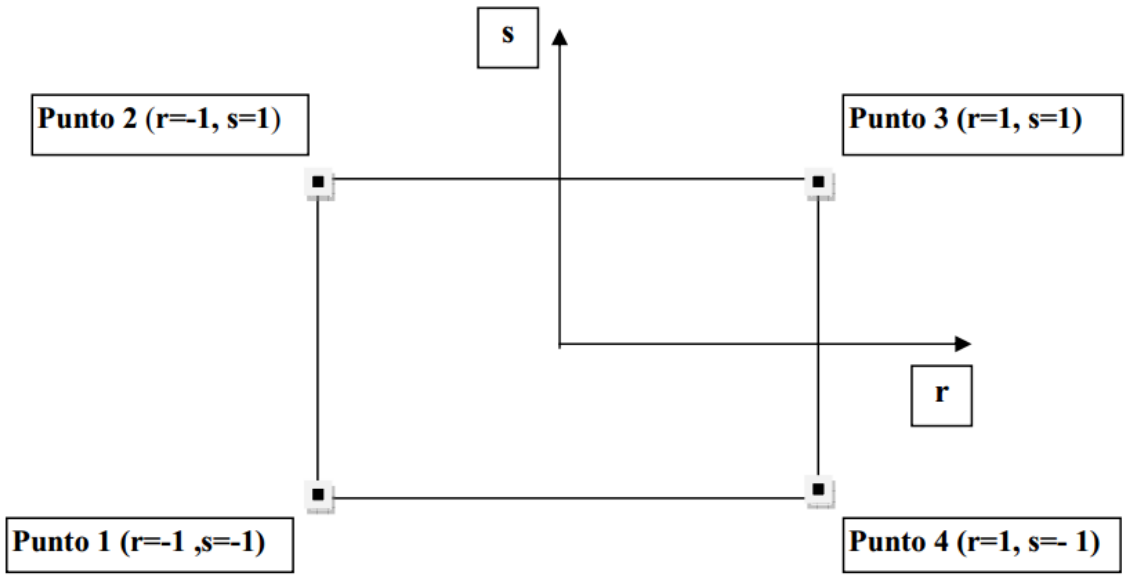


Figura 4.3 - *Applicazione dell'interpolazione bilineare.*

Definiti i 4vertici di una generica maglia i polinomi di Lagrange sono così determinati:

$$h_1 = (1-r)\cdot(1-s)/4 \quad (4.4)$$
$$h_2 = (1-r)\cdot(1+s)/4 \quad (4.5)$$
$$h_3 = (1+r)\cdot(1+s)/4 \quad (4.6)$$
$$h_4 = (1+r)\cdot(1-s)/4 \quad (4.7)$$

Tra le coordinate x, y di un punto generico e le coordinate r, s dello stesso punto valgono le seguenti relazioni:

$$4x = \sum_{i=1}^{4} h_i \cdot x_i = \left[(1-r)\cdot(1-s)\cdot x_1 + (1-r)\cdot(1+s)\cdot x_2 + (1+r)\cdot(1+s)\cdot x_3 + (1+r)\cdot(1-s)\cdot x_4\right] \quad (4.8)$$

$$4y = \sum_{i=1}^{4} h_i \cdot y_i = \left[(1-r)\cdot(1-s)\cdot y_1 + (1-r)\cdot(1+s)\cdot y_2 + (1+r)\cdot(1+s)\cdot y_3 + (1+r)\cdot(1-s)\cdot y_4\right] \quad (4.9)$$

La soluzione del sistema di equazioni non lineari è ottenuta iterativamente e, tramite i valori di r ed s, si determinano i parametri a_g, F_0, T_c^* dall'equazione:

$$4p = \sum_{i=1}^{4} h_i \cdot p_i = \left[(1-r)\cdot(1-s)\cdot p_1 + (1-r)\cdot(1+s)\cdot p_2 + (1+r)\cdot(1+s)\cdot p_3 + (1+r)\cdot(1-s)\cdot p_4\right] \quad (4.10)$$

Dove *p* rappresenta il parametro cercato.

5 Pericolosità sismica di sito

Il moto generato da un terremoto in un sito dipende dalle particolari condizioni locali, cioè dalle caratteristiche topografiche e stratigrafiche dei depositi di terreno e degli ammassi rocciosi e dalle proprietà fisiche e meccaniche dei materiali che li costituiscono. Per la singola opera o per il singolo sistema geotecnico la risposta sismica locale consente di definire le modifiche che un segnale sismico subisce, a causa dei fattori anzidetti, rispetto a quello di un sito di riferimento rigido con superficie topografica orizzontale (sottosuolo di categoria A, definito al § 3.2.2).

5.1 Coefficienti sismici

I coefficienti sismici orizzontale k_h e verticale k_v dipendono del punto in cui si trova il sito oggetto di analisi e del tipo di opera da calcolare. Il parametro di entrata per il calcolo è il tempo di ritorno (T_R) dell'evento sismico che è valutato come segue:

$$T_R = -\frac{V_R}{\ln(1-P_{VR})} \quad (5.1)$$

Con V_R vita di riferimento della costruzione e PVR probabilità di superamento, nella vita di riferimento, associata allo stato limite considerato. La vita di riferimento dipende dalla vita nominale della costruzione e dalla classe d'uso della costruzione (in linea con quanto previsto al punto 2.4.3 delle NTC). In ogni caso V_R non può essere inferiore a 35 anni.

5.2 Stabilità dei pendii e fondazioni

Nel caso di stabilità dei pendii i coefficienti k_h e k_v sono così determinati:

$$k_h = \beta_s \cdot \left(\frac{a_{max}}{g}\right) \quad (5.2)$$

$$k_v = \pm 0.5 \cdot k_h \quad (5.3)$$

Con

β_S coefficiente di riduzione dell'accelerazione massima attesa al sito;
a_{max} accelerazione orizzontale massima attesa al sito;
g accelerazione di gravità.

I valori di β_S sono riportati nella tabella 5.1.

Tabella 5.1- *Coefficienti di riduzione dell'accelerazione massima attesa al sito.*

	Categoria di sottosuolo	
	A	B, C, D, E
	β_S	β_S
$0.2 < a_g(g) \leq 0.4$	0.30	0.28
$0.1 < a_g(g) \leq 0.2$	0.27	0.24
$a_g(g) \leq 0.1$	0.20	0.20

Tutti i fattori presenti nelle precedenti formule dipendono dall'accelerazione massima attesa al sito di riferimento rigido e dalle caratteristiche geomorfologiche del territorio.

$$a_{max} = S_S \cdot S_T \cdot a_g \quad (5.4)$$

S_S (effetto di amplificazione stratigrafica) ($0.90 \leq Ss \leq 1.80$) è funzione di F_0 (Fattore massimo di amplificazione dello spettro in accelerazione orizzontale) e della categoria di suolo (A, B, C, D, E). e del rapporto a_g/g. S_T (effetto di amplificazione topografica), varia con il variare delle quattro categorie topografiche:

T1: $S_T = 1.0$; **T2**: $S_T = 1.20$; **T3:** $S_T = 1.20$; **T4:** $S_T = 1.40$.

5.3 Fronti scavo e rilevati

Il comportamento in condizioni sismiche dei fronti di scavo e dei rilevati può essere analizzato con gli stessi metodi impiegati per i pendii naturali; specificamente mediante metodi pseudostatici, metodi degli spostamenti e metodi avanzati di analisi dinamica.

Nei metodi pseudostatici l'azione sismica è rappresentata da un'azione statica equivalente, costante nello spazio e nel tempo, proporzionale al peso W del volume di terreno potenzialmente instabile. Le componenti orizzontale e verticale di tale forza devono essere ricavate in funzione delle proprietà del moto atteso nel volume di terreno potenzialmente instabile e della capacità di tale volume di subire spostamenti senza significative riduzioni di resistenza.

In mancanza di studi specifici, le componenti orizzontale e verticale della forza statica equivalente possono esprimersi come

$$F_h = k_h \cdot W \text{ ed } F_v = k_V \cdot W$$

con k_h e k_V rispettivamente pari ai coefficienti sismici orizzontale e verticale definiti nel § 7.11.3.5.2 e

adottando i seguenti valori del coefficiente di riduzione dell'accelerazione massima attesa al sito:

βs = 0.38 nelle verifiche dello stato limite ultimo (SLV)
βs = 0.47 nelle verifiche dello stato limite di esercizio (SLD).

Nelle verifiche di sicurezza si deve controllare che la resistenza del sistema sia maggiore delle azioni (condizione [6.2.1]) impiegando lo stesso approccio di cui al § 6.8.2 per le opere di materiali sciolti e fronti di scavo, ponendo pari all'unità i coefficienti parziali sulle azioni e sui parametri geotecnici (§ 7.11.1) e impiegando le resistenze di progetto calcolate con un coefficiente parziale pari a $\gamma_R = 1.2$.

Si deve inoltre tener conto della presenza di manufatti interagenti con l'opera.

5.4 Muri di sostegno

Per i muri di sostegno pendii i coefficienti k_h e k_v sono così determinati:

$$k_h = \beta_m \cdot \left(\frac{a_{max}}{g} \right) \quad (5.5)$$

$$k_v = \pm 0.5 \cdot k_h \quad (5.6)$$

Con:

β_m coefficiente di riduzione dell'accelerazione massima attesa al sito, per i muri che non siano in grado di subire spostamenti relativi rispetto al terreno assume valore unitario altrimenti assume i valori riportati di seguito.

β_m = 0.38 nelle verifiche allo stato limite ultimo (SLV)

β_m = 0.47 nelle verifiche allo stato limite di esercizio (SLD).

I valori del coefficiente β_m possono essere incrementati in ragione di particolari caratteristiche prestazionali del muro, prendendo a riferimento il diagramma di in Figura 5.2.

a_{max} accelerazione orizzontale massima attesa al sito;
g accelerazione di gravità.

Tutti i fattori presenti nelle precedenti formule dipendono dall'accelerazione massima attesa sul sito di riferimento rigido e dalle caratteristiche geomorfologiche del territorio.

$$a_{max} = S_S \cdot S_T \cdot a_g \quad (5.7)$$

S è il coefficiente comprendente l'effetto di amplificazione stratigrafica Ss e di amplificazione topografica S_T.
a_g accelerazione orizzontale massima attesa su sito di riferimento rigido.

5.5 Paratie

In mancanza di studi specifici, a_h (accelerazione orizzontale) può essere legata all'accelerazione di picco a_{max} attesa nel volume di terreno significativo per l'opera mediante la relazione:

$$a_h = k_h \cdot g = \alpha \cdot \beta \cdot a_{max} \quad (5.8)$$

dove:
g è l'accelerazione di gravità;

k_h è il coefficiente sismico in direzione orizzontale;

$\alpha \leq 1$ è un coefficiente che tiene conto della deformabilità dei terreni interagenti con l'opera. Può essere ricavato a partire dall'altezza complessiva **H** della paratia e dalla categoria di sottosuolo mediante il diagramma in Figura 5.1:

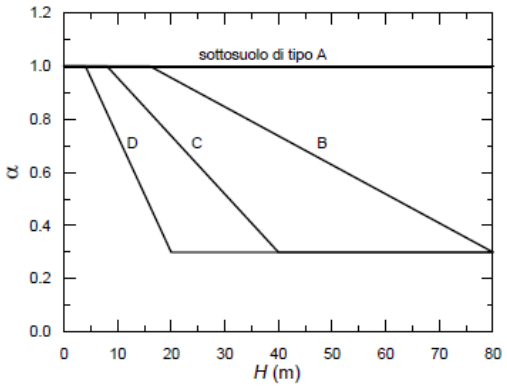


Figura 5.1 - *Diagramma per la valutazione del coefficiente di deformabilità α.*

Per il sottosuolo di categoria E si utilizzano le curve dei sottosuoli C o D in dipendenza dei valori assunti dalla velocità equivalente Vs.Per la valutazione della spinta nelle condizioni di equilibrio limite passivo deve porsi $\alpha = 1$.
Il valore del coefficiente β può essere ricavato dal diagramma riportato in Figura 5.2, in funzione del massimo spostamento u_S che l'opera può tollerare senza riduzioni di resistenza.

Per $u_S = 0$ si ha $\beta = 1$; $u_s \leq 0.005 \cdot H$

Se $\alpha \cdot \beta \leq 0.2$ deve assumersi $k_h = 0.2 \cdot a_{max}/g$

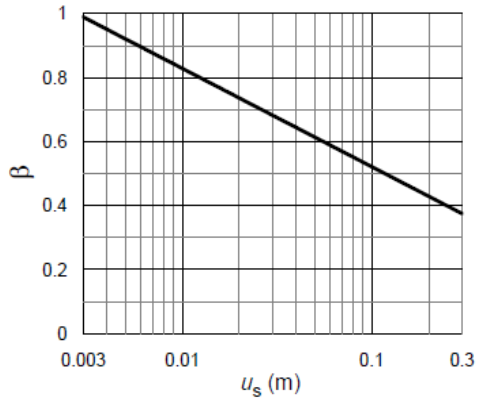


Figura 5.2 - *Diagramma per la valutazione del coefficiente di spostamento β.*

L'accelerazione di picco a_{max} è valutata mediante un'analisi di risposta sismica locale, ovvero come

$$a_{max} = S_S \cdot S_T \cdot a_g \quad (5.9)$$

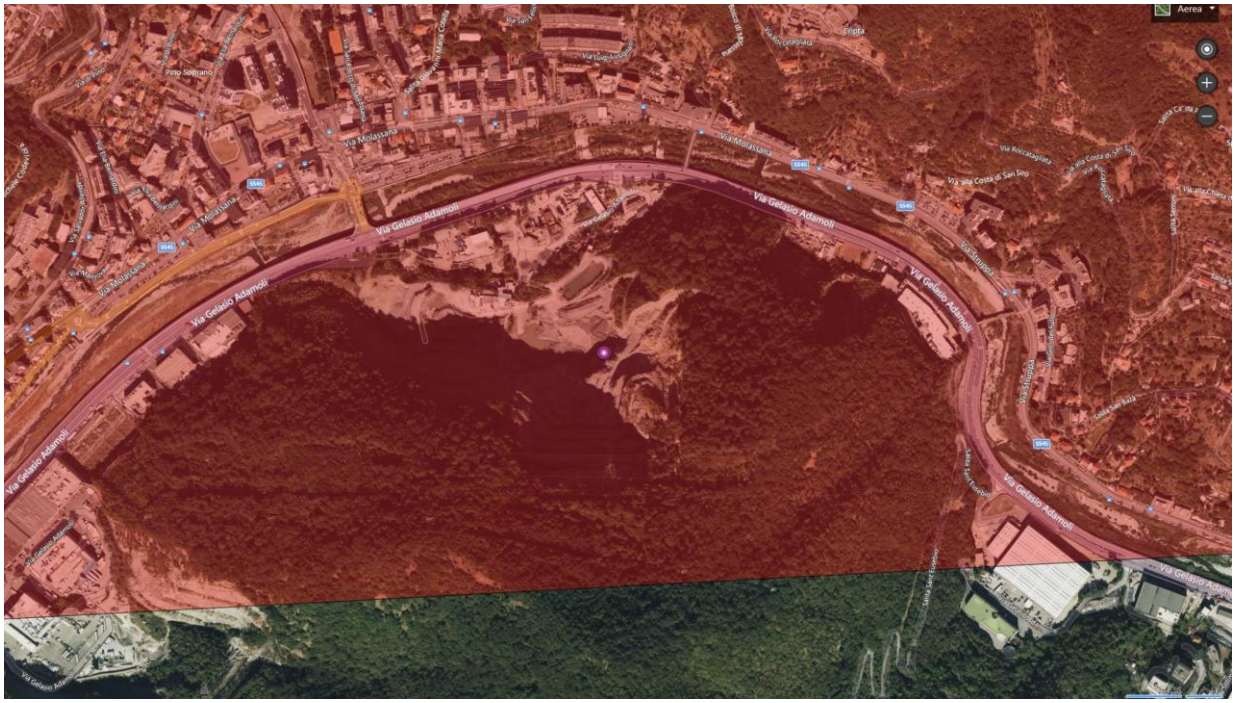
dove:

S è il coefficiente che comprende l'effetto dell'amplificazione stratigrafica (S_S) e dell'amplificazione topografica (S_T), di cui al § 3.2.3.2;

a_g è l'accelerazione orizzontale massima attesa su sito di riferimento rigido.

PERICOLOSITÀ SISMICA DI BASE

Data: 31/10/2023


Via Gelasio Adamoli
Via Molassana
Via Roccatagliata
Via alla Costa di San Siro
Via Struppi
Via Sant'Eusebio
Via Cremeno
Via Sopranis
Via Sopranino
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Via Sopranuzzuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuo
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Via Sopranuzzuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuu
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Via Sopranuzzuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuu
Via Sopranuzzuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuuo
Via Sopranuzzu

4	16474	44.497600	8.934609	6459.32

Parametri di pericolosità sismica per TR diversi da quelli previsti nelle NTC, per i nodi della maglia elementare del reticolo di riferimento

Punto 1

Stato limite	Tr [anni]	ag [g]	F0 [-]	Tc* [s]
SLO	30	0.024	2.519	0.193
SLD	50	0.031	2.526	0.210
	72	0.036	2.544	0.223
	101	0.040	2.553	0.251
	140	0.047	2.498	0.265
	201	0.054	2.530	0.267
SLV	475	0.074	2.522	0.283
SLC	975	0.097	2.504	0.291
	2475	0.135	2.482	0.296

Punto 2

Stato limite	Tr [anni]	ag [g]	F0 [-]	Tc* [s]
SLO	30	0.026	2.487	0.198
SLD	50	0.033	2.533	0.213
	72	0.038	2.550	0.224
	101	0.043	2.517	0.255
	140	0.050	2.511	0.261
	201	0.057	2.539	0.267
SLV	475	0.080	2.523	0.280
SLC	975	0.106	2.481	0.289
	2475	0.147	2.483	0.292

Punto 3

Stato limite	Tr [anni]	ag [g]	F0 [-]	Tc* [s]
SLO	30	0.027	2.475	0.199
SLD	50	0.034	2.529	0.213
	72	0.039	2.547	0.225
	101	0.045	2.488	0.255
	140	0.052	2.508	0.258
	201	0.060	2.533	0.269
SLV	475	0.086	2.482	0.279
SLC	975	0.114	2.456	0.286
	2475	0.159	2.468	0.289

Punto 4

Stato limite	Tr [anni]	ag [g]	F0 [-]	Tc* [s]
SLO	30	0.025	2.502	0.194

SLD	50	0.032	2.522	0.211
	72	0.037	2.540	0.223
	101	0.042	2.518	0.252
	140	0.049	2.495	0.261
	201	0.057	2.525	0.266
SLV	475	0.080	2.509	0.279
SLC	975	0.107	2.469	0.287
	2475	0.149	2.476	0.290

Punto d'indagine

Stato limite	Tr [anni]	ag [g]	F0 [-]	Tc* [s]
SLO	30	0.025	2.494	0.196
SLD	50	0.032	2.529	0.212
SLV	475	0.079	2.514	0.280
SLC	975	0.105	2.480	0.289

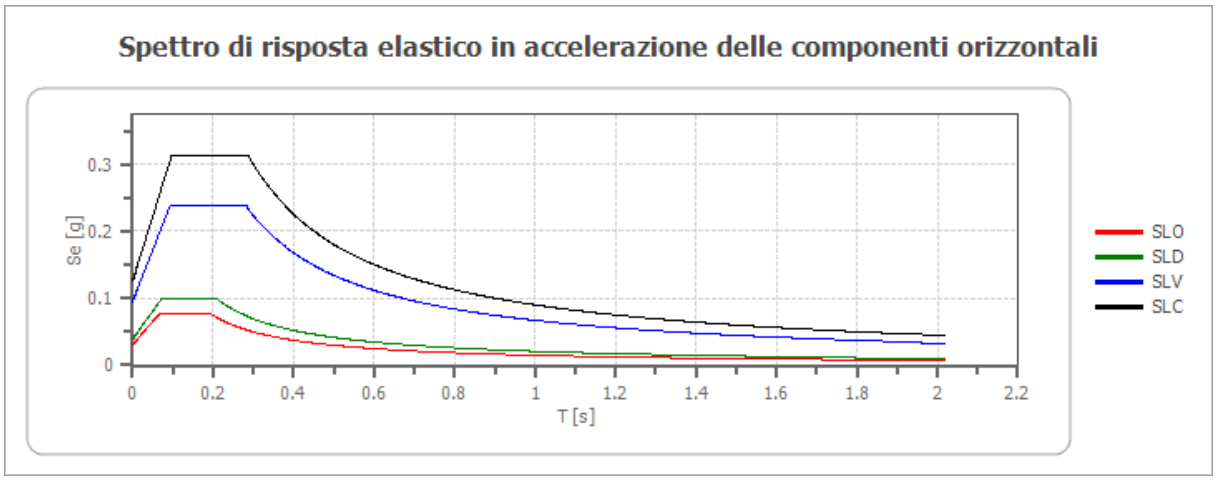
PERICOLOSITÀ SISMICA DI SITO

Coefficiente di smorzamento viscoso ξ: 5 %
Fattore di alterazione dello spettro elastico η=[10/(5+)ξ]^(1/2): 1.000
Categoria sottosuolo: A
Categoria topografica:
T3: Rilievi con larghezza in cresta molto minore che alla base e inclinazione media compresa tra 15° e 30°

Fronti di scavo e rilevati

Coefficienti	SLO	SLD	SLV	SLC
kh	--	0.018	0.036	--
kv	--	0.009	0.018	--
amax [m/s²]	0.300	0.381	0.934	1.236
Beta	--	0.470	0.380	--

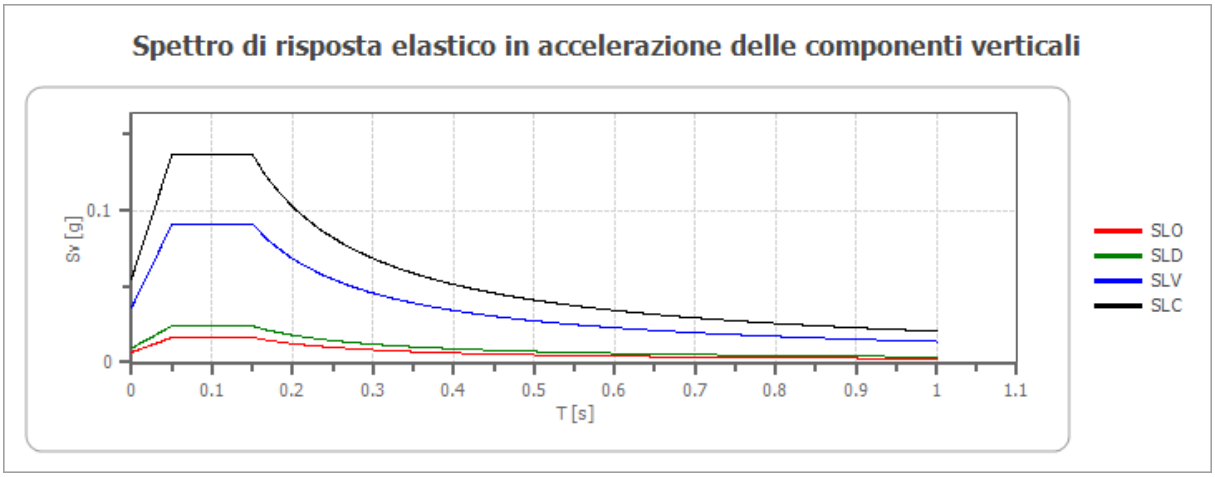
Spettro di risposta elastico in accelerazione delle componenti orizzontali



	cu	ag [g]	F0 [-]	Tc* [s]	Ss [-]	Cc [-]	St [-]	S [-]	η [-]	TB [s]	TC [s]	TD [s]	Se(0) [g]	Se(TB) [g]
SLO	1.0	0.025	2.494	0.196	1.000	1.000	1.200	1.200	1.000	0.065	0.196	1.702	0.031	0.076
SLD	1.0	0.032	2.529	0.212	1.000	1.000	1.200	1.200	1.000	0.071	0.212	1.730	0.039	0.098
SLV	1.0	0.079	2.514	0.280	1.000	1.000	1.200	1.200	1.000	0.093	0.280	1.918	0.095	0.240
SLC	1.0	0.105	2.480	0.289	1.000	1.000	1.200	1.200	1.000	0.096	0.289	2.020	0.126	0.313

Spettro di risposta elastico in accelerazione delle componenti verticali

Coefficiente di smorzamento viscoso ξ: 5 %
Fattore di alterazione dello spettro elastico η=[10/(5+)ξ]^(1/2): 1.000

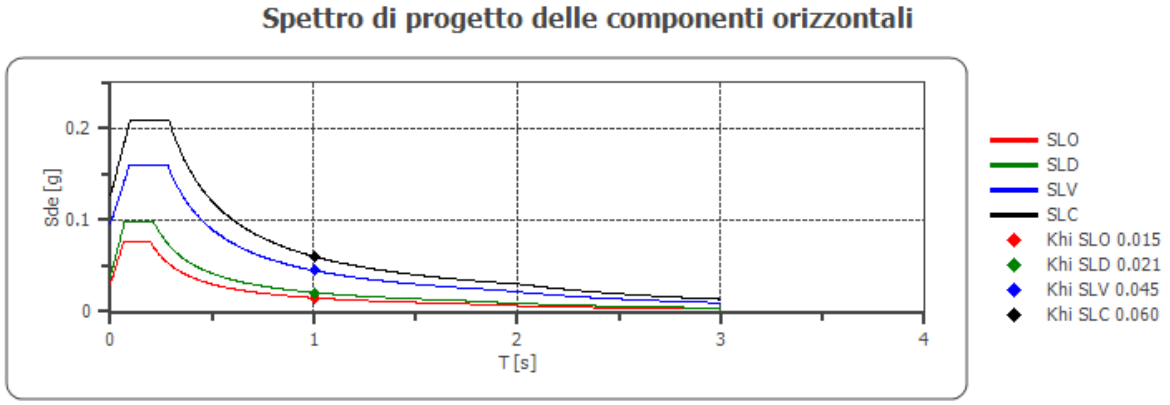


	cu	ag [g]	F0 [-]	Tc* [s]	Ss [-]	Cc [-]	St [-]	S [-]	η [-]	TB [s]	TC [s]	TD [s]	Se(0) [g]	Se(TB) [g]
SLO	1.0	0.025	2.494	0.196	1	1.000	1.200	1.200	1.000	0.050	0.150	1.000	0.007	0.016
SLD	1.0	0.032	2.529	0.212	1	1.000	1.200	1.200	1.000	0.050	0.150	1.000	0.009	0.024
SLV	1.0	0.079	2.514	0.280	1	1.000	1.200	1.200	1.000	0.050	0.150	1.000	0.036	0.091
SLC	1.0	0.105	2.480	0.289	1	1.000	1.200	1.200	1.000	0.050	0.150	1.000	0.055	0.137

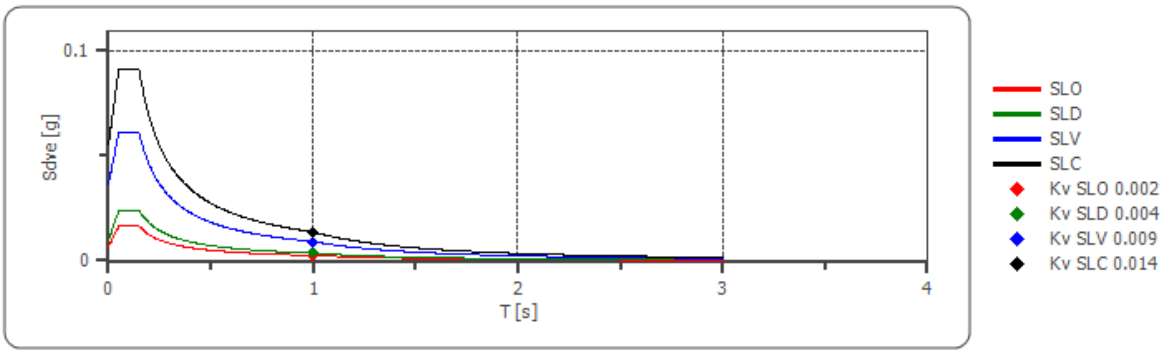
Spettro di progetto

Fattore di struttura spettro orizzontale q: 1.50
Fattore di struttura spettro verticale q: 1.50
Periodo fondamentale T: 1.00 [s]

	SLO	SLD	SLV	SLC
khi = Sde(T) Orizzontale [g]	0.015	0.021	0.045	0.060
kv = Sdve(T) Verticale [g]	0.002	0.004	0.009	0.012



Spettro di progetto delle componenti verticali



	cu	ag [g]	F0 [-]	Tc* [s]	Ss [-]	Cc [-]	St [-]	S [-]	q [-]	TB [s]	TC [s]	TD [s]	Sd(0) [g]	Sd(TB) [g]
SLO orizzontale	1.0	0.025	2.494	0.196	1.000	1.000	1.200	1.200	1.000	0.065	0.196	1.702	0.031	0.076
SLO verticale	1.0	0.025	2.494	0.196	1.000	1.000	1.200	1.200	1.000	0.050	0.150	1.000	0.007	0.016
SLD orizzontale	1.0	0.032	2.529	0.212	1.000	1.000	1.200	1.200	1.000	0.071	0.212	1.730	0.039	0.098
SLD verticale	1.0	0.032	2.529	0.212	1.000	1.000	1.200	1.200	1.000	0.050	0.150	1.000	0.009	0.024
SLV orizzontale	1.0	0.079	2.514	0.280	1.000	1.000	1.200	1.200	1.500	0.093	0.280	1.918	0.095	0.160
SLV verticale	1.0	0.079	2.514	0.280	1.000	1.000	1.200	1.200	1.500	0.050	0.150	1.000	0.036	0.061
SLC orizzontale	1.0	0.105	2.480	0.289	1.000	1.000	1.200	1.200	1.500	0.096	0.289	2.020	0.126	0.208
SLC verticale	1.0	0.105	2.480	0.289	1.000	1.000	1.200	1.200	1.500	0.050	0.150	1.000	0.055	0.091