Progetto ed esecuzione di strutture isolate: Centro ricerche UniCAM (CHIP)

Il ruolo della sperimentazione nelle costruzioni isolate

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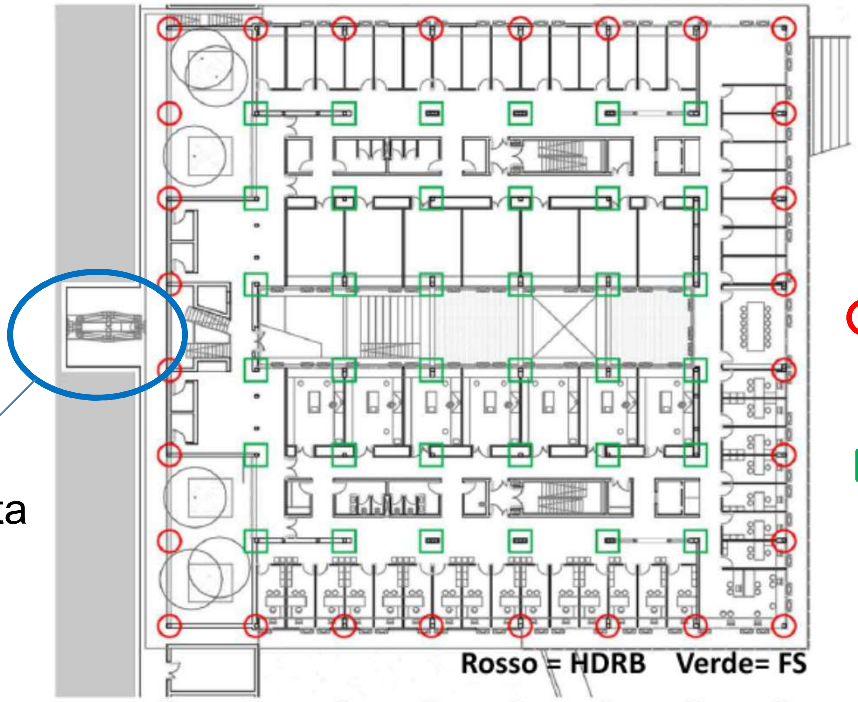
Ordine degli Ingegneri della Provincia di Macerata 29/01/2021

Contenuto dell'intervento

- ✓ Introduzione NTC 2018 (cp.11 prove di qualifica e accettazione dei dispositivi)
- ✓ Prove di qualifica (Type tests EN15129) e di accettazione (Factory production control tests EN15129) dei dispositivi
- ✓ Prova di spinta sull'edifcio (collaudo dinamico del sistema di isolamento)



sistema di spinta

○ isolatori elastomerici SI-S 600/182 (spostamento 350mm)

□ Slitte multidirezionali (spostamento 400mm, attrito 1%)

Fase di progetto

Legenda

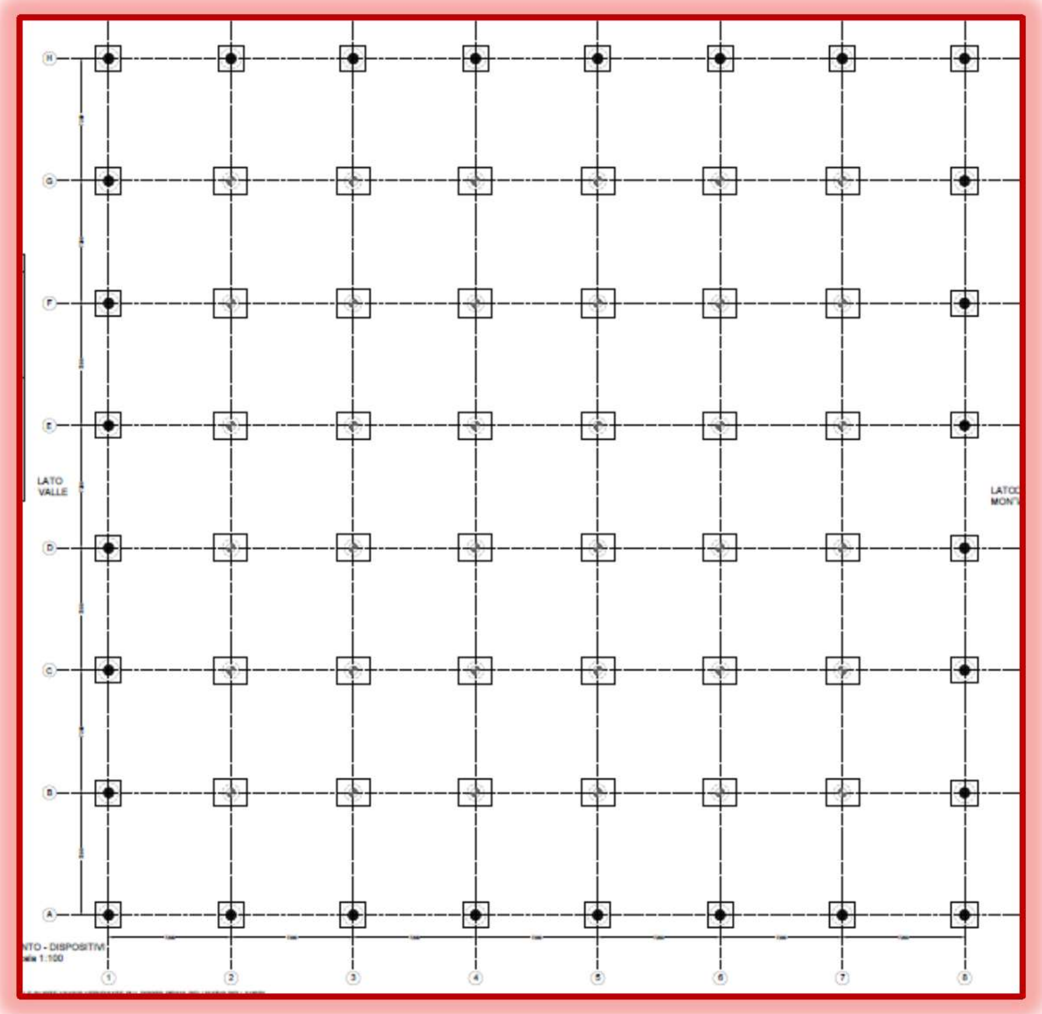
DISPOSITIVO TIPO 1 - Isolatore elastomerico

Isolatore elastomerico in gomma ad alto smorzamento
Modulo di taglio G=0.4N/mmq (γ=100%)
Smorzamento equivalente ξ=0.10 (γ=100%)
Diametro D=600mm
Spessore effettivo gomma te=182mm
Azione verticale in condizioni sismiche: Ns = 1100 kN
Azione verticale allo SLU: Nd = 2100 kN
Spostamento massimo orizzontale 350mm
Qualificazione e accettazione
EN15129-EN1337-NTC2018

DISPOSITIVO TIPO 2 - Appoggio scorrevole

Appoggio scorrevole multidirezionale orizzontale
Coefficiente di attrito dinamico <1%
Coefficiente di attrito statico <2%
Spostamento massimo +/- 400mm
Azione verticale in condizioni sismiche: Ns = 1700 kN
Azione verticale allo SLU: Nd = 2400 kN
Azione verticale allo SLE-QP: Nd = 1100 kN
Qualificazione e accettazione
EN1337-NTC 2018
Richiesta prova tipo E-seismic
(EN15129:2018-8.3.4.1.5) su 4 dispositivi di appoggio

Estratto della tavola del sistema di isolamento



11.9. DISPOSITIVI ANTISISMICI E DI CONTROLLO DI VIBRAZIONI

……

……

Nei casi in cui si applica la norma europea armonizzata UNI EN 15129, le grandezze di riferimento ivi citate andranno desunte da quanto prescritto nelle presenti Norme Tecniche per le Costruzioni; in particolare si intende per d_{bd} lo spostamento valutato per un terremoto riferito allo SLV, e per $\gamma_x \cdot d_{bd}$ lo spostamento valutato per un terremoto riferito allo SLC (d_{bd} e γ_x ·sono i simboli utilizzati nella UNI EN 15129 rispettivamente per lo spostamento di progetto di un dispositivo e per il fattore di amplificazione di al § 4.1.2 della stessa UNI EN 15129).

11.9.2. PROCEDURA DI QUALIFICAZIONE

I dispositivi antisismici, per i quali si applica quanto specificato al punto A) del § 11.1, devono essere conformi alla norma europea armonizzata UNI EN 15129 e recare la Marcatura CE. Si applica il sistema di valutazione e verifica della costanza della prestazione previsto nella suddetta norma europea armonizzata per le applicazioni critiche.

Le procedure di qualificazione hanno lo scopo di dimostrare che il dispositivo è in grado di mantenere la propria funzionalità nelle condizioni d'uso previste durante tutta la vita di progetto.

11.9.3. PROCEDURA DI ACCETTAZIONE

E' possibile impiegare, ai fini delle prove di accettazione, le prove di Controllo di Produzione in Fabbrica effettuate nell'ambito del mantenimento della qualificazione dei dispositivi stessi ai sensi della norma europea sopra detta, nel numero che la stessa norma prevede, a condizione che:

- il campionamento dei dispositivi sia stato effettuato, sui lotti destinati allo specifico cantiere, dal Direttore dei Lavori del cantiere stesso;
- le prove siano eseguite e certificate da un laboratorio di cui all'articolo 59 del DPR 380/2001, dotato di adeguata competenza, attrezzatura ed organizzazione.
- I suddetti certificati riportino esplicitamente l'indicazione del o dei cantieri ove viene utilizzata la fornitura.

11.9.7. ISOLATORI ELASTOMERICI

Le massime differenze tra le caratteristiche meccaniche ottenute nelle prove di qualificazione ed i valori di progetto o nelle normali condizioni d'uso devono essere contenute entro limiti riportati in Tab. 11.9.IV.

Le variazioni devono essere valutate con riferimento al 3° ciclo di prova. Le frequenze di prova per valutare le variazioni delle caratteristiche meccaniche sono 0,1Hz e 0,5Hz.

Tab. 11.9.IV

	Fornitura	Invecchiamento	Temperatura	Frequenza di prova
K_e	±20%	±20%	±20%	±20%
K_v	−30%	-	-	-
ξ_e	±20%	±20%	±20%	±20%

Le variazioni dovute al carico verticale, valutate come differenza tra i valori corrispondenti al carico verticale massimo ed a quello minimo, non dovranno superare il 15% del valore di progetto.

11.9.7.1 PROVE DI ACCETTAZIONE SUI DISPOSITIVI

Le prove di accettazione devono essere effettuate su almeno il 20% dei dispositivi, e comunque non meno di 4 e non più del numero di dispositivi da mettere in opera.

Coerente con EN15129

11.9.7. ISOLATORI ELASTOMERICI

Le massime differenze tra le caratteristiche meccaniche ottenute nelle prove di qualificazione ed i valori di progetto o nelle normali condizioni d'uso devono essere contenute entro limiti riportati in Tab. 11.9.IV.

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K_e	±20%	±20%	±20%	±20%
K_v	−30%	-	-	-
ξ_e	±20%	±20%	±20%	±20%

11.9.8. ISOLATORI A SCORRIMENTO

Gli isolatori a scorrimento devono essere in grado di sopportare, sotto spostamento massimo impresso pari a d_2, almeno 5 cicli di carico e scarico. I cicli si riterranno favorevolmente sopportati se il coefficiente d'attrito (f), nei cicli successivi al primo, non varierà di più del 25% rispetto alle caratteristiche riscontrate durante il terzo ciclo, ossia

$$\left|f_{(i)} - f_{(3)}\right| / f_{(3)} \leq 0{,}25, \qquad [11.9.9]$$

avendo contrassegnato con il pedice "(i)" le caratteristiche valutate all'i-esimo ciclo e con il pedice "(3)" le caratteristiche valutate al terzo ciclo. Detto d_{dc} lo spostamento massimo di progetto del centro di rigidezza del sistema d'isolamento, corrispondente allo SLC, qualora l'incremento della forza nel sistema di isolamento per spostamenti tra 0,5 d_{dc} e d_{dc} sia inferiore all' 1,25% del peso totale della sovrastruttura, gli isolatori a scorrimento debbono essere in grado di garantire la loro funzione di appoggio fino a spostamenti pari ad 1,25 d_2.

11.9.8.1 PROVE DI ACCETTAZIONE SUI DISPOSITIVI

Le prove di accettazione, devono essere effettuate su almeno il 20% dei dispositivi, comunque non meno di 4 e non più del numero di dispositivi da mettere in opera.

11.6. APPOGGI STRUTTURALI

Gli appoggi strutturali sono dispositivi di vincolo utilizzati nelle strutture, nei ponti e negli edifici, allo scopo di trasmettere puntualmente carichi e vincolare determinati gradi di libertà di spostamento.

Gli appoggi strutturali, per i quali si applica quanto specificato al punto A del § 11.1, devono essere conformi alla pertinente norma europea armonizzata della serie UNI EN 1337 e recare la Marcatura CE. Si applica il Sistema di Valutazione e Verifica della Costanza della Prestazione 1, previsto nelle pertinenti specifiche tecniche armonizzate per le applicazioni critiche. Nel caso di appoggi strutturali non ricadenti, o non completamente ricadenti, nel campo di applicazione di una delle norme europee armonizzate della serie UNI EN 1337, si applica il caso C) del §11.1.

Ogni fornitura deve essere accompagnata dalla documentazione di marcatura CE oppure da copia del certificato di valutazione tecnica, nonché dal manuale contenente le specifiche tecniche per la posa in opera e la manutenzione.

Il Direttore dei Lavori è tenuto a verificare nell'ambito delle proprie competenze, quanto sopra indicato ed a rifiutare le eventuali forniture prive della documentazione di qualificazione e che le procedure di posa in opera siano conformi alle specifiche tecniche del fabbricante del sistema stesso; dovrà inoltre effettuare idonee prove di accettazione, che comprendano in ogni caso la verifica geometrica e delle tolleranze dimensionali, nonché la valutazione delle principali caratteristiche meccaniche dei materiali componenti e/o delle principali prestazioni degli appoggi, al fine di verificare la conformità degli appoggi stessi a quanto richiesto per lo specifico progetto.

FPCTs della EN15129
(prova E della tabella 15)

Prove di qualifica dei dispositivi

Isolatori elastomerici

TECNOLOGIE EDILI COSTRUTTIVE

TECNOLOGIE EDILI COSTRUTTIVE

TECNOLOGIE EDILI COSTRUTTIVE

TECNOLOGIE EDILI COSTRUTTIVE

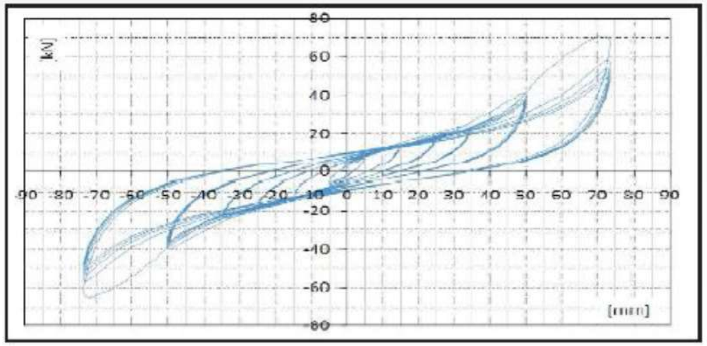
PROGETTAZIONE ISOLATORI IG

Oggi il gruppo Tec presenta tre tipologie di mescola, dalla morbida alla dura con un modulo Gdin pari a 0,4, 0.8 e 1,4 MPa come definito nella norma europea EN UNI 15129 parte 8.
Per tutte le mescole impiegate si ottiene un coefficiente di smorzamento pari al 15% con i limiti di tolleranza previsti dalla normativa.

Caratteristica	Mescola morbida	Mescola media	Mescola dura
Modulo elastico tangenziale "Gdin"	0.4 MPa	0.8 MPa	1.4 MPa
Coefficiente di smorzamento "S"	15%	15%	15%

La sperimentazione dei dispositivi Tec è stata condotta presso i laboratori dell'Università della Basilicata e successivamente presso il Politecnico di Milano. Ad oggi i test di controllo produzione in fabbrica (FPC) per i lotti di produzione vengono condotti presso la Sismalab con la supervisione del Politecnico di Bari in conformità alla normativa NTC 2018 e UNI EN 15129 per la marcatura CE.

I risultati conseguiti durante le prove di tipo "ITT" hanno convalidato le tre mescole per la certificazione CE con deformazioni a taglio fino al 200% dello spessore totale gomma.
Nel grafico è rappresentato il tipico diagramma carico-spostamento di un isolatore durante una prova ciclica con vari livelli di deformazione a taglio.



Isolatori elastomerici

ISOLATORI PER SPOSTAMENTO DA MM. +/- 300								
DISPOSITIVO	Fzd KN	Ned KN	Kb KN/mm	Kv KN/mm	Tq mm	Dg mm	Htot mm	Lpc mm
Tec IG 350/150 S	870	25	0,26	281	150	350	297	400
Tec IG 400/150 S	1480	125	0,34	457	150	400	297	450
Tec IG 450/150 S	2050	285	0,42	539	150	450	282	500
Tec IG 500/150 S	3200	650	0,52	783	150	500	292	550
Tec IG 550/154 S	3950	920	0,62	862	154	550	297	600
Tec IG 600/152 S	5000	1400	0,74	984	152	600	286	650
Tec IG 650/153 S	6150	1900	0,87	1096	153	650	291	700
Tec IG 700/160 S	7200	2400	0,96	1170	160	700	310	750
Tec IG 750/160 S	9000	3200	1,1	1495	160	750	310	800
Tec IG 800/160 S	12200	4100	1,26	1873	160	800	310	850
Tec IG 850/160 S	14000	5000	1,42	2305	160	850	310	900
Tec IG 900/168 S	15500	5500	1,51	2083	168	900	343	950
Tec IG 1000/168 S	20500	7000	1,87	2416	168	1000	333	1050

Progettati ai sensi della NTC 2018 Circolare 2019

DATI PER LA VALUTAZIONE PROGETTUALE

I dimensionamenti dei dispositivi illustrati nelle tabelle a seguire sono da intendersi ad esclusivo scopo esemplificativo; la Tec realizza la progettazione degli isolatori sulla base delle richieste del cliente assicurando l'ottemperanza di tutte le dovute verifiche richieste dalla normativa.
Per tale ragione, al fine di ottenere un corretto dimensionamento e per poter successivamente effettuare le dovute prove sperimentali sul prodotto fornito, occorre, da parte del progettista delle strutture, indicare le caratteristiche dei dispositivi come previsto nella seguente tabella.

EN15129

Tipo dispositivo	Posizione nella struttura	Carico verticale max (kN)	Carico verticale sismico (kN)	Spostamento orizz. Max d2 (+/- mm)	Spostamento orizz. Max SLV (+/- mm)	Rigidezza orizzontale (kN/mm)	Rigidezza verticale (kN/mm)	Smorzamento (%)	Rotazione max (+/- rad)
Isolatore elastomerico									
Isolatore elastomerico									

SI-S 600/182

Isolatori elastomerici

In risposta ai requisiti cogenti attualmente previsti per il territorio italiano e nella Comunità Europea, la Tec si è dotata di opportuni piani per il controllo della produzione in fabbrica "FPC" integrandoli nel sistema di Qualità; ciò ha permesso di presentare ai propri enti di certificazione un sistema di gestione completo e rispondente alle necessità legate alla marcatura di prodotto CE che viene riconosciuta a livello internazionale.

Ad oggi la Tec ha completato il suo primo ciclo di certificazione presentando sul mercato l'intera gamma di isolatori a marcatura CE conforme alla EN UNI 15129 "Dispositivi antisismici" e alla EN UNI 1337 parte 3 "Apparecchi d'appoggio elastomerici" e alla EN UNI 1337 parte 9 "protezioni anticorrosive", nonchè, corrispondenti alle prescrizioni del D.M. 2018 "Normativa Tecnica sulle Costruzioni".

La produzione degli isolatori viene condotta interamente presso gli stabilimenti della Tec con controlli specifici e selettivi effettuati in produzione, dall'approvvigionamento delle materie prime fino alle fasi di vulcanizzazione. A garanzia delle prestazioni di ogni lotto di fabbricazione, i controlli sul prodotto finito e le prove sperimentali previste vengono affidati ad enti terzi che ne convalidano i risultati in conformità alle prescrizioni della EN UNI 15129. A richiesta della committenza, i controlli possono essere supervisionati da enti accreditati (ad es. strutture Universitarie) nel rispetto delle prescrizioni richieste dal D.M. 2018

SISMALAB
>>Soluzioni Ingegneristiche Sperimentali Antisismiche

ADDRESS	Via Taranto C.da Alezza n°6
C.A.P.	74012 CRISPIANO (TA)
TEL	099 8110037
P. IVA E C.F.	02775290733
INTERNET	www.sismalab.it
MAIL	prove@sismalab.it

Le prove di qualifica degli isolatori richiesti raramante sono già disponibili (isolatori molto simili già qualification) quindi vanno effetuate "prima della produzione del lotto destinato al cantiere e sono a carico del produttore

Isolatori elastomerici – TTs EN15129

8.2.4.1.2 Type Testing

The type tests listed in Table 11 shall be performed on the minimum number of samples specified in 8.2.4.1.4, according to the methods specified in 8.2.4.1.5. For low damping bridge isolators subjected to small seismic actions, only the tests marked with an asterisk in Table 11 are required as type tests by this European Standard; the type tests in EN 1337-3 shall be perfomed for such isolators.

Due isolatori per ogni lotto di produzione

For those tests required to be performed on an isolator, it shall be full-scale, except the tests on LRB and PPRB to determine the influence of frequency, temperature and repeated cycling on the horizontal characteristics may use isolators scaled according to the following rules:

— isolators of plan dimension ≤ 500 mm shall be tested full-scale;

— for larger isolators, linear dimensions may be reduced by factor up to maximum of 2. All dimensions shall be scaled by same factor. Minimum allowed plan dimension for bearing after scaling is 500 mm.

The following modifications to an isolator shall require a new set of type tests:

a) different elastomer compound;

b) variation of the shape factor of the elastomer layers of more than 10 % with respect to that of a device already tested;

c) increase of any external dimension of the isolator or of the plan dimension of the intemal reinforcing plates of more than 10 %;

d) decrease of any external dimension of the isolator or of the plan dimension of the internal reinforcing plates of more than 50 %

e) a different type of attachment system is used;

f) different moulding conditions are used.

NOTE In e) the term 'different types of attachment system' refers to bolted, recess or dowelled.

Isolatori elastomerici – TTs EN15129

8.2.4.1.2 Type Testing

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characteristics may

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be scaled by sa

The following modifi

a) different elastom

b) variation of the
already tested;

c) increase of any
plates of more th

d) decrease of any
plates of more th

e) a different type

f) different mouldin

NOTE In e) the te

Any smaller differences in the design of the isolator shall require the following type tests to be carried out to provide reference values for the factory production control tests:

g) compression stiffness (8.2.1.2.8);

h) horizontal stiffness and damping at the two rubber shear strains given in 8.2.1.2.2 that bracket the design rubber shear strain, $\varepsilon_{q,E}$.

An extension of the ranges of use of a particular isolator type beyond those covered by previous type tests shall require additional type tests to be performed. Extensions of use shall include the following:

i) increase of $\varepsilon_{q,E}$ sufficient to necessitate additional cyclic tests according to Table 10;

j) increase of upper service temperature by more than 5 °C;

k) decrease of lower service temperature by more than 3 °C;

l) increase of the permanent load plus combination of non-seismic live loads, N_{Sd}, by more than 30 %;

m) increase of $\gamma_b d_{Ed}$, by more than 5 %;

n) increase of maximum vertical load including effect of seismic actions, $N_{Ed,max}$, by more than 10 %;

o) decrease of minimum vertical load including effect of seismic actions, $N_{Ed,min}$, by more than 0,1 N_{Sd} or by amount sufficient to change $N_{Ed,min}$ from compressive to tensile.

Isolatori elastomerici – TTs EN15129

Table 11 — Isolator testing and requirements

Test	Type test requirements	Factory production control test requirements
Capacity in compression under zero lateral displacement	Support N_{Sd} . No defects visible. See 8.2.1.2.6.	N/A
Compression stiffness	Report value. See 8.2.1.2.8.	Within ±30% of type test value. No defects visible. See 8.2.1.2.8
*Horizontal characteristics K_b and ξ_b (or K_2 and Q_d) under cyclic deformation	Report strain dependence. At design displacement, d_{bd}, values within ±20% of design value. See 8.2.1.2.2	Values within ±20% of required values. See 8.2.1.2.2
*Horizontal stiffness under a one-sided ramp loading (Required if cyclic horizontal stiffness and damping from production control test not measured at shear strain amplitude close to value corresponding to, d_{bd})	Report value at design displacement, d_{bd}. See 8.2.1.2.2	Within ± 20 % of adjusted type test value
Variation of horizontal characteristics K_b and ξ_b (or K_2 and Q_d) with frequency	Report variation. Maximum variation ± 20 %. See 8.2.1.2.3	N/A
*Variation of horizontal characteristics K_b and ξ_b (or K_2 and Q_d) with temperature	Report variation. Maximum variation within limits set in 8.2.1.2.4	N/A
Dependence of horizontal characteristics K_b and ξ_b (or K_2 and Q_d) on repeated cycling	Dependence within limits specified in 8.2.1.2.5	N/A
*Lateral capacity under maximum and minimum vertical loads	Force-displacement curve increasing up to $\gamma_b d_{Ed}$. No defects. See 8.2.1.2.7.	N/A
Change of horizontal characteristics K_b and ξ_b of the isolator (or K_2 only for LRB manufactured using low damping elastomer) due to ageing	Change ≤ 20 %	N/A
Creep test under vertical load[a]	Total Creep rate < 20 % per decade. See 8.2.1.2.10.	N/A

[a] Optional test
N/A = Not Applicable

*For low damping bridge isolators subjected to small seismic actions, only the tests marked with * shall apply. See 8.2.1.2.11 for requirements.

Possono essere sostituite dalle prove sul materiale

facoltativa

8.2.4.1.4 Sampling frequency

Each type test shall be carried out at least twice, using a different test isolator in each case. If the double shear test arrangement is used for a type test, only one pair of isolators need be tested.

A test isolator may be subjected to several different type tests provided they are performed in the following order:

a) compression stiffness (8.2.1.2.8);

b) dependence of horizontal characteristics on rubber shear strain (8.2.1.2.2), ~~frequency (8.2.1.2.3), temperature (8.2.1.2.4) and repeated cycling (8.2.1.2.5);~~

~~c) effect of creep (8.2.1.2.10);~~

d) capacity in compression under zero lateral displacement (8.2.1.2.6).

Provided the isolator meets the requirement of the preceding tests:

e) horizontal displacement capacity (8.2.1.2.7).

There shall be a summary test report stating the order of the tests on the isolator and the dates and times of each test.

Isolatori elastomerici – TTs EN15129

8.2.1.2.6 Capacity in compression under zero lateral displacement

The isolator shall be able to support a vertical load equal to N_{Sd} [where in 8.2 N_{Sd} is the permanent load plus combination of non-seismic live load(s) according to EN 1990:2002, A.1 (for buildings) or A.2 (for bridges)]

N_{sd} allo SLU non sismico

when zero lateral displacement is applied. This requirement shall be checked by applying a vertical load up to N_{Sd} and maintaining that load constant for at least 3 min whilst the isolator is examined for signs of failure. Other test conditions shall conform to the relevant parts of 8.2.4.1.

The requirement is that the load-displacement relation shall be monotonically increasing up to N_{Sd}, and that the isolator shall show no visual evidence of manufacturing imperfections or failure. The visual evidence referred to shall include:

— signs of bond failure;

— laterally misaligned or vertically misplaced reinforcing plates;

— surface cracks or imperfections over 2 mm wide or deep.

NOTE See EN 1337-3:2005, 4.3.3 and the manufacturing tolerances given in EN 1337-3, Clause 6 for further guidance regarding the requirements.

8.2.1.2.8 Compression stiffness

The secant compression stiffness K_v of the isolator shall be determined between (1/3) N_{Sd} and N_{Sd}. The test conditions, equipment and other parts of the procedure shall conform to the relevant parts of 8.2.4.1.

The requirement is that K_v shall be reported.

This test shall also be used as a factory production control test. The requirement is that K_v shall be within ± 30 % of the value determined in the type test, and the visual inspection at the maximum load shall show no signs of imperfection or failure as given in the requirements in 8.2.1.2.6.

NOTE The force-deflection curve at low loads generally has a low gradient. This phenomenon, termed lead-in or bedding down, is caused by the slight misalignment of the top and bottom bearing surfaces normally present.

Isolatori elastomerici – TTs EN15129

8.2.1.2.2 Dependence of horizontal characteristics on rubber shear strain

The horizontal characteristics under cyclic loading shall be measured at the following rubber shear strains: ± 5 %, ± 10 %, ± 20 %, ± 50 % and ± 100 % under the test conditions and using the procedures given in the relevant suclauses of 8.2.4.1. The horizontal characteristics shall be expressed in terms of effective horizontal stiffness, K_b, and equivalent damping factor, ξ_b, except that LRB and PPRB may be characterised in terms of second branch (or post-yield) stiffness, K_2, and characteristic strength, Q_d (this is defined as the force at which the force –displacement loop intersects the force axis). If the tests are carried out at a frequency other than 0,5 Hz or the isolation frequency, the horizontal characteristics reported shall be referred to one of those frequencies by correcting for the effect of test frequency according to the procedure given in 8.2.2.1.3.3. If the shear strain, $\varepsilon_{q,E}$, at the design displacement, d_{bd}, is higher than 100 %, tests at additional strain amplitudes shall be added as detailed in Table 7. γ_b is a partial factor for elastomeric isolators (see 8.2.1.2.7). The tests may all be performed on the same isolator, in which case they shall be conducted in order of increasing strain amplitude and only at the strains specified in this subclause. The cyclic displacement shall be applied about zero shear displacement; no offset displacement shall be applied.

Table 7— Cyclic test rubber strain amplitudes

Strains in %

Design rubber shear strain, $\varepsilon_{q,E}$	Additional test strains
$100 < \varepsilon_{q,E} \leq 150$	150 or $\gamma_b \gamma_x \varepsilon_{q,E}$
$150 < \varepsilon_{q,E} \leq 200$	150, 200
$200 < \varepsilon_{q,E} \leq 250$	150, 200, 250

$\varepsilon_{q,E} = \dfrac{d_{bd}}{T_q}$ d_{bd} = spostamento allo SLV T_q = spessore della gomma

d_{bd} = 290mm → $\varepsilon_{q,E} = \frac{290}{184}$=1.57 → 200% (368mm)

8.2.1.2.2 Dependence of horizontal characteristics on rubber shear strain

The horizontal characteristics under cyclic loading shall be measured at the following rubber shear strains: ± 5 %, ± 10 %, ± 20 %, ± 50 % and ± 100 % under the test conditions and using the procedures given in the relevant suclauses of 8.2.4.1. The horizontal characteristics shall be expressed in terms of effective horizontal stiffness, K_b, and equivalent damping factor, ξ_b, except that LRB and PPRB may be characterised in terms of second branch (or post-yield) stiffness, K_2, and characteristic strength, Q_d (this is defined as the force at which the force –displacement loop intersects the force axis). If the tests are carried out at a frequency other than

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NOTE The test strain amplitudes are well spaced so that, if tests are performed on the same isolator, strain history effects are small.

The requirements are that:

— the values of K_b and ξ_b (or K_2 and Q_d) for the third cycle are reported for all the rubber shear strains tested;

— if the design rubber shear strain is not included in the test strains listed, the values of K_b and ξ_b (or K_2 and Q_d) for the third cycle at the design rubber shear strain shall both be determined from the test results by linear interpolation;

— the test frequency and reference frequency, if applicable, be reported;

— the values of K_b and ξ_b (or K_2 and Q_d) for the third cycle at the design rubber shear strain shall both be within ± 20 % of the design value;

— the value K_b at 5 % shear strain (or Q_d) shall be sufficient to provide adequate restraint, as determined by the structural engineer, against wind loading.

Valori superiori o inferiori ai limiti consentiti devono essere comunicati al progettista che provvederà a dare il suo parere e a modificare se necessario il progetto (ξ=14% invece che ξ=10% assunto in fase di progetto)

8.2.1.2.2 Dependence of horizontal characteristics on rubber shear strain

The horizontal characteristics under cyclic loading shall be measured at the following rubber shear strains: ± 5 %, ± 10 %, ± 20 %, ± 50 % and ± 100 % under the test conditions and using the procedures given in the relevant suclauses of 8.2.4.1. The horizontal characteristics shall be expressed in terms of effective horizontal stiffness, K_b, and equivalent damping factor, ξ_b, except that LRB and PPRB may be characterised in terms of second branch (or post-yield) stiffness, K_2, and characteristic strength, Q_d (this is defined as the force at which the force –displacement loop interse...

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NOTE The test strain am...
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The requirements are that:

— the values of K_b and ... tested;

— if the design rubber sh... Q_d) for the third cycle ... linear interpolation;

— the test frequency and...

— the values of K_b and ... within ± 20 % of the de...

— the value K_b at 5 % sh... the structural engineer...

FCPTs:
ciclica a 150%
o rampa a d_{bd}

A cyclic test to determine K_b and ξ_b (or K_2 and Q_d), performed at the shear strain amplitude listed in this subclause that is closest to the rubber shear strain, $\varepsilon_{q,E}$, at the design displacement, d_{bd}, should be performed as a factory production control test with the requirement that the values of K_b and ξ_b (or K_2 and Q_d) for the third cycle shall both be within ± 20 % of the design value corrected, if necessary, for the difference between the test and design shear strain.

In the case that measurement of the cyclic horizontal characteristics at the shear strain amplitude listed in this subclause that is closest to the rubber shear strain, $\varepsilon_{q,E}$, at the design displacement, d_{bd}, is not to be performed as a factory production control test, the following two tests shall be carried out as factory production control tests:

— measurement of the horizontal secant stiffness under a one-sided ramp loading;

— cyclic test to determine K_b and ξ_b (or K_2 and Q_d), performed at one of the lower shear strain amplitudes listed in this subclause. The shear strain amplitude shall be at least 20 %.

The ramp test shall also be performed as a type test in order to establish the requirement for the factory production control test. The isolator used for the cyclic tests shall be deformed up to the rubber shear strain listed in this subclause that is closest to the rubber shear strain, $\varepsilon_{q,E}$, at the horizontal design displacement, d_{bd}. The ramp test shall be performed after the cyclic test at that strain and before the cyclic tests at higher strains. The other test conditions and procedures shall conform to the relevant parts of 8.2.4.1. The requirement in the type test is that the secant stiffness at the test shear strain shall be determined. The requirement of the ramp factory production control test is that the secant stiffness shall be within ± 20 % of the value determined from the type test, adjusted, if necessary, by the procedure given in 8.2.4.1.3 to allow for the difference between the design value of the cyclic stiffness K_b at the design displacement, d_{bd}, and the value determined from the type tests. The requirement in the cyclic factory production control test is that the values of K_b and ξ_b (or K_2 and Q_d) for the third cycle shall both be within ± 20 % of the values obtained in the type test, the value of K_b (or K_2) being adjusted, if necessary, by the procedure given in 8.2.4.1.3 to allow for the difference between the design value of the cyclic stiffness K_b (or K_2) at the design displacement, d_{bd}, and the value determined from the type tests.

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8.2.1.2.7 Horizontal displacement capacity

The horizontal displacement capacity of an isolator shall be checked up to a displacement of $\gamma_b d_{Ed}$ or a load of $\gamma_b V_{Ed,}$ whichever is reached first (where V_{Ed} is the horizontal load corresponding to d_{Ed}) under the axial loads $N_{Ed,max}$ and $N_{Ed,min}$

γ_b is a partial factor for elastomeric isolators, and its value shall be taken as 1,15.

The value of $N_{Ed,min}$ shall not be a tension force producing a stress greater than 2G, where G is the shear modulus measured at 100 % strain (see 8.2.2.1.3.2).

NOTE 1 The value of the minimum vertical load may be tensile. The imposition of tensile stresses above the level specified here is avoided as cavitation of the rubber occurs at relatively low tensile hydrostatic stresses. A tensile stress of up to 2G is normally sustained without significant cavitation occurring. Special connections between the isolator and the structure that remove the possibility of the vertical load on the isolator becoming tensile can be used.

The test shall be carried out under a ramp input. The other test conditions shall conform to those given in the relevant parts of 8.2.4.1.

The requirements are that the load shall be monotonically increasing up to the maximum displacement and that the isolator shall not show any significant signs of failure at the end of the test. The visual evidence of failure referred to shall include:

— signs of bond failure;

— surface cracks or imperfections over 2 mm wide or deep.

The isolator connections to the load platens shall not show any signs of failure or yielding.

NOTE 2 See EN 1337-3:2005, 4.3.3 for further guidance regarding visual evidence of failure in the isolator.

If $N_{Ed,max}$ differs from $N_{Ed,min}$ by less than 20 % and the minimum load is compressive, only one test at the mean of the two loads needs to be performed; the same requirements shall be met.

Sarebbe opportuno una prova a rottura in fase di qualifica per la determinazione del margine di sicurezza

$d_{Ed} = \gamma_x d_{bd}$ = 1.2*290mm=350mm ⇒ $\gamma_b d_{ed}$ = 1.15*350mm=402.5mm ⇒ $\varepsilon_{q,E} = \frac{402.5}{184}$=2.18 (218%)

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SISMALAB
>>Soluzioni Ingegneristiche Sperimentali Antisismiche

TEST REPORT

Type Test – Reference EN 15129 – NTC2008

DEVICE	Tec IG 600-184-S
CLIENT	Tec Group
PROJECT	Comune di Camerino – CRU Centro Ricerca Universitaria

CLIENT ORDER	---------------
TEST REPORT NUMBER	00199/2019
TEST REPORT CODE	TR_199_19_LAB_109_19
SISMALAB ORDER	000109_2019
TEST PERFORMER	CARAMIA CIRO

Rev	00	01	02	03	04	05	06
Data	09/10/2019						

THIS TEST REPORT CONSISTS OF 19 PAGES

THIS TEST REPORT CAN BE REPRODUCED ONLY INTEGRALLY AND SHALL BE SUBJECTED TO DUTY STAMP FOR USE ACCORDING TO ITALIAN LAW D.P.R. 642/72

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INTERNET	*www.sismalab.it*
MAIL	*prove@sismalab.it*

SECTION 1 TEST REFERENCES

GENERAL REFERENCES

TYPE OF TEST	*TYPE. TEST in accordance to the EN 15129 - NTC 2008*	
LOCATION	*Sismalab Laboratory*	
APPLICANT	*Tec Group*	
SUPERVISION	*Dipl. Eng. Carmen Alexandru – ICECON CERT* *Geom. Roberto Maurantonio – Tec Group srl* *Ing. Pasquale Martimucci - Tec Group srl* *Ing. Andrea Dall'Asta – Progettista* *Ing. Cristiano Bordo – D.L.* *Ing. Micozzi Fabio – Progettista Collaboratore*	
JOB REFERENCE CLIENT JOB	*G19_018* *L'internazionale soc.coop. – Altamura* *Comune di Camerino –CRU Centro Ricerca Universitaria*	
DEVICE TESTED	*Tec IG 600-184-S*	
SISMALAB DEVICE CODE	*5145*	*5146*
SERIAL NUMBER	*IG0419*	*IG0420*
RUBBER CODE	*96*	*99*
DATA OF ARRIVAL	*30/09/2019*	
DATA OF TEST	*09/10/2019*	
TEST REPORT CODE	*TR_199_19_LAB_109_19*	
TEST REPORT ISSUE DATE	*09/10/2019*	

DEVICE CHARACTERISTICS - *Ref. drawing code IG-600-184-S*

RUBBER OUTER DIAMETER	R_{DEX}	*600*	mm
RUBBER INNER DIAMETER	R_{DIN}	*0*	mm
PLATES OUTER DIAMETER	P_{DEX}	*580*	mm
PLATES INNER DIAMETER	P_{DIN}	*0*	mm

DESIGN PARAMETERS - *Ref. Tec_IG_600_184_S_pr_ITT*

TOTAL THICKNESS (ACTIVE DURING SHEAR)	Tq	*184*	mm
DESIGN DISPLACEMENT OF DEVICE	dbd	*290*	mm
MAXIMUM DESIGN DISPLACEMENT	d_{ED}	*350*	mm
VERTICAL LOAD AT 6 MPa	N	*1696*	kN
MAXIMUM/MINIMUM SEISMIC VERTICAL LOAD	$Ned_{max/min}$	*1100/650*	kN
NO SEISMIC VERTICAL LOAD	Nsd	*2100*	kN

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SECTION 2 TESTING PROTOCOL

N	TEST	DISPLACEMENT - mm	V.LOAD - kN	F - Hz	S. FUNCTION	CYCLE
1	C.S.	-	2100	-	ramp	1
2	C.C.	-	2100	-	ramp	1
3a	H.C.C 5%	9.2	1696	0.5	sinusoidal	5
3b	H.C.C 10%	18.4	1696	0.5	sinusoidal	5
3c	H.C.C 20%	36.8	1696	05.	sinusoidal	5
3d	H.C.C 50%	92	1696	0.5	sinusoidal	5
3e	H.C.C 100%	184	1696	0.5	sinusoidal	5
3f	H.C.C 150%	276	1696	0.5	sinusoidal	5
4	O.S.R.	290	1696	-	ramp	1
3g	H.C.C 200%	368	1696	0.5	sinusoidal	5
5a	L.C. max V.Load	402	1100	-	ramp	1
5b	L.C. min. V.Load	402	650	-	ramp	1

Details

C.C	*Capacity compression under zero lateral displacement test*	*Ref. 8.2.1.2.6*
C.S	*Compression stiffness test*	*Ref. 8.2.1.2.8*
H.C.C.	*Horizontal characteristics under cyclic deformation test*	*Ref. 8.2.1.2.2*
O.S.R.	*Ramp test*	*Ref. 8.2.1.2.2*
L.C.	*Lateral displacement capacity*	*Ref. 8.2.1.2.7*

SECTION 3 DATA ANALYSIS

EFFECTIVE STIFFNESS K_b

$$K_b = (F^+ - F^-) / (d^+ - d^-)$$

F^+ : Maximum Load
F^- : Minimum Load
d^+ : Maximum displacement
d^- : Minimum displacement

EQUIVALENT VISCOUS DAMPING RATIO

$$\xi = 2H / [\pi K_b (d^+ - d^-)^2]$$

H : Hysteresis loop area
K_b : Effective stiffness
$d+$: Maximum displacement
$d-$: Minimum displacement

STIFFNESS K_2

$$K_2^{+-} = (K_2^+ + K_2^-)/2 = 1/2 \{ [(F_1 - F_2) / (d_1 - d_2)] + [(F_3 - F_4) / (d_3 - d_4)] \}$$

$d_{1/4}$: 0.9 of the maximum/minimum displacement
$d_{2/3}$: 0.5 of the maximum/minimum displacement
$F_{1/4}$: Load corresponding to the 0.9 of Maximum/Minimum displacement
$F_{2/3}$: Load corresponding to the 0.5 of Maximum/Minimum displacement

VERTICAL STIFFNESS K_v

$$K_V = (F^+ - F^-) / (d^+ - d^-)$$

F^+ : Maximum Load
F^- : 33% of the Maximum Load
d^+ : Displacement corresponding to the Maximum Load
d^- : Displacement corresponding to the 33% of the Maximum Load

SHEAR MODULUS (Ramp Test - Ref. EN 1337)

$$G = [(F_2 - F_1) / (d_2 - d_1)] * tq/A$$

d_1 : 26.8 % of the tq value
d_2 : 57.7 % of the tq value
F_1 : Load corresponding to the 26.8 % of the tq value
F_2 : Load corresponding to the 57.7 % of the tq value
A : Rubber Area
tq : Total thickness (active during shear)

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SECTION 4 DATA PROCESSING *Devices 5145-5146 Serial Numbers IG0419-IG0420*

***Test Number 1** - Compression Stiffness – device 5145*

The test has been performed by applying a vertical load up to N_{SD} and keeping it constant for at least 2 minutes. The secant compression stiffness K_v of the isolator has been determined between (1/3) N_{SD} and N_{SD}. At the maximum load the isolator has been examined to look for signs of failure. The requirements have been fulfilled and the load-displacement relation has increased monotonically up to N_{sd} and the isolator has shown no visual evidence of manufacturing imperfections or failure.

The visual evidence has included :

-signs of bond failure

-laterally misaligned or vertically misplaced reinforcing plates

-surface cracks or imperfections over 2 mm wide or deep.

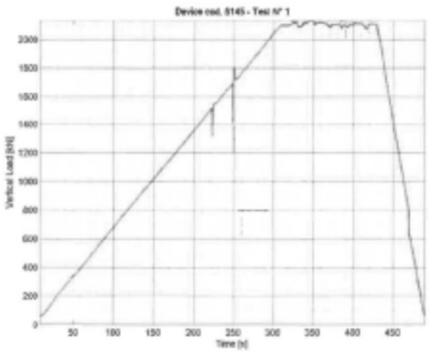

Fig. Load - Time

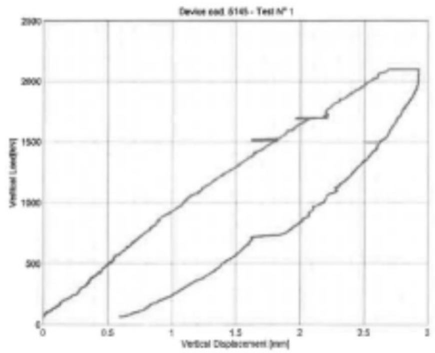

Fig. Load - Displacement

Results

Displacement corresponding to the maximum load reached	2.7	*mm*
Displacement corresponding to the 33% of the max. load	0.7	*mm*
Maximum Force reached	2100	*kN*
33% of the Maximum load reached	700.5	*kN*
Vertical Stiffness k_v	713.11	*kN/mm*

***Test Number 2** - Compression Capacity – device 5145-5146*

The test has been performed by applying a vertical load up to N_{SD} and keeping it constant for at least 2 minutes. At the maximum load the isolator has been examined to look for signs of failure. The requirements have been fulfilled and the load-displacement relation has increased monotonically up to N_{sd} and the isolator has shown no visual evidence of manufacturing imperfections or failure.

The visual evidence has included :

-signs of bond failure

-laterally misaligned or vertically misplaced reinforcing plates

-surface cracks or imperfections over 2 mm wide or deep.

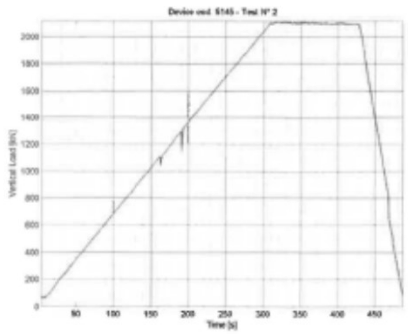

Fig. Load - Time

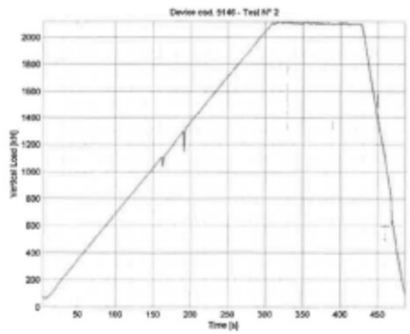

Fig. Load - Time

Results

Maximum Force reached	*2100*	*kN*

***OBSERVATIONS** – The visual evidence has been fulfilled.*

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10%

Test Number 3b - *Horizontal characteristics under cyclic deformation test 10% of Tq*

The test has been carried out by applying on the device a vertical load corresponding to 6 MPa and keeping it constant during the test. After having fully applied the vertical load, three sinusoidal cycles characterized by amplitude equal to ±10% of the total thickness active during shear and frequency of 0.5 Hz have been performed. During the test, the horizontal load, the vertical load and the horizontal deflection have been recorded. The horizontal characteristics are expressed in terms of effective horizontal stiffness, K_{effb}, and equivalent damping factor, ξ_b.

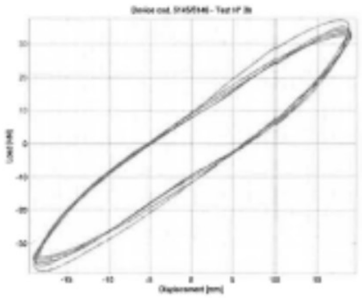

Fig.: Displacement – Load - Total Cycles

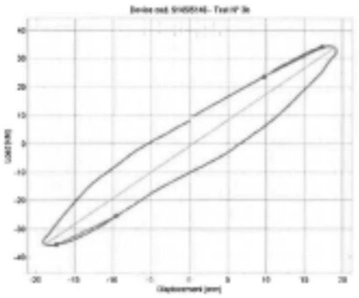

Fig.: Displacement – Load - Cycle n°3

Results	*Cycle 1*	*Cycle 2*	*Cycle 3*	*Cycle 4*	*Cycle 5*	
Maximum displacement	18.9	19	19.2	19	18.7	*mm*
Minimum displacement	-19	-19.1	-19.1	-18.7	-18.5	*mm*
Maximum load	37.3	35.3	34.3	33.4	32.7	*kN*
Minimum load	-38.5	-36.8	-35.8	-34.9	-34.2	*kN*
Effective stiffness $keff_b$	2	1.89	1.83	1.81	1.8	*kN/mm*
Dissipated energy	685.7	634.3	593.6	583.4	578.1	*J*
Damping	15.2	14.7	14.08	14.43	14.84	*%*
Second branch stiffness k_2	1.26	1.34	1.33	1.2	1.15	*kN/mm*
Shear Modulus	1.3	1.23	1.19	1.18	1.17	
Load Q_d (Average value)	10.4	10.2	9.8	8.7	8.9	*kN*
Vertical Load	1690.6	1692.6	1694.6	1695.4	1695.8	*kN*
Maximum Velocity	66.2	69.9	72.2	70.8	66.6	*mm/s*

50%

Test Number 3d - *Horizontal characteristics under cyclic deformation test 50% of Tq*

The test has been carried out by applying on the device a vertical load corresponding to 6 MPa and keeping it constant during the test. After having fully applied the vertical load, three sinusoidal cycles characterized by amplitude equal to ±50% of the total thickness active during shear and frequency of 0.5 Hz have been performed. During the test, the horizontal load, the vertical load and the horizontal deflection have been recorded. The horizontal characteristics are expressed in terms of effective horizontal stiffness, K_{effb}, and equivalent damping factor, ξ_b.

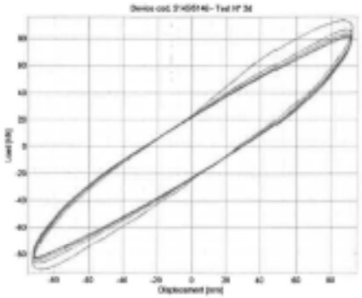

Fig.: Displacement – Load - Total Cycles

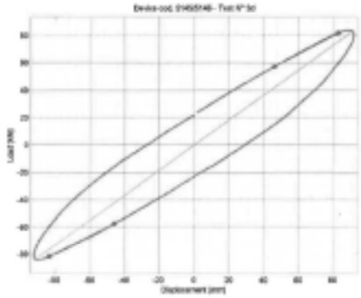

Fig.: Displacement – Load - Cycle n°3

Results	*Cycle 1*	*Cycle 2*	*Cycle 3*	*Cycle 4*	*Cycle 5*	
Maximum displacement	92.3	92.3	92.2	91.8	91.6	*mm*
Minimum displacement	-92.8	-92.7	-92.2	-92	-92.4	*mm*
Maximum load	93.9	86.9	83.9	82.4	81.4	*kN*
Minimum load	-91.8	-86.7	-84.3	-83	-82.4	*kN*
Effective stiffness $keff_b$	1	0.94	0.91	0.9	0.89	*kN/mm*
Dissipated energy	8009.2	7202.5	6902.8	6823.8	6761.8	*J*
Damping	14.83	14.27	14.17	14.29	14.28	*%*
Second branch stiffness k_2	0.66	0.68	0.66	0.64	0.63	*kN/mm*
Shear Modulus	0.65	0.61	0.59	0.59	0.58	
Load Q_d (Average value)	24	23.2	23.2	22.2	21.8	*kN*
Vertical Load	1679.2	1687.5	1690.6	1692	1693.4	*kN*
Maximum Velocity	300.9	300.8	299.6	297.4	296.3	*mm/s*

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100%

Test Number 3e - *Horizontal characteristics under cyclic deformation test 100% of tq*

The test has been carried out by applying on the device a vertical load corresponding to 6 MPa and keeping it constant during the test. After having fully applied the vertical load, three sinusoidal cycles characterized by amplitude equal to tq and frequency of 0.5 Hz have been performed. During the test, the horizontal load, the vertical load and the horizontal deflection have been recorded. The horizontal characteristics are expressed in terms of effective horizontal stiffness, K_{effb}, and equivalent damping factor, ξ_b.

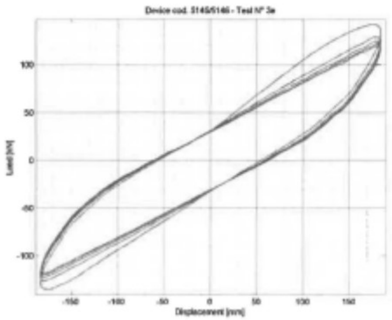

Fig. : Displacement – Load - Total Cycles

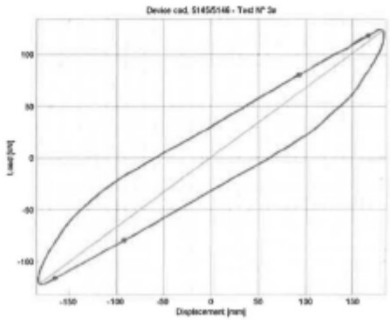

Fig. : Displacement – Load - Cycle n°3

Results	*Cycle 1*	*Cycle 2*	*Cycle 3*	*Cycle 4*	*Cycle 5*	
Maximum displacement	183.8	183.8	183.6	183.5	183.1	*mm*
Minimum displacement	-183.3	-183.2	-183.3	-183.1	-182.9	*mm*
Maximum load	142.1	128.8	124.6	122	119.7	*kN*
Minimum load	-135.6	-126.4	-122.6	-120.1	-118.4	*kN*
Effective stiffness k_{effb}	0.76	0.7	0.67	0.66	0.65	*kN/mm*
Dissipated energy	23386.3	20826.7	20314.8	19929.5	19651	*J*
Damping	14.61	14.16	14.26	14.3	14.35	*%*
Second branch stiffness k_2	0.57	0.52	0.51	0.5	0.49	*kN/mm*
Shear Modulus	0.49	0.45	0.44	0.43	0.42	
Load Q_d (Average value)	31	31.8	30.6	30	30.5	*kN*
Vertical Load	1684.5	1698.6	1702.8	1704.3	1704.2	*kN*
Maximum Velocity	585.4	583.8	582.1	584.9	580.7	*mm/s*

150%

Test Number f - *Horizontal characteristics under cyclic deformation test 150% of Tq*

The test has been carried out by applying on the device a vertical load corresponding to 6 MPa and keeping it constant during the test. After having fully applied the vertical load, three sinusoidal cycles characterized by amplitude equal to ±150% of the total thickness active during shear and frequency of 0.5 Hz have been performed. During the test, the horizontal load, the vertical load and the horizontal deflection have been recorded. The horizontal characteristics are expressed in terms of effective horizontal stiffness, K_{effb}, and equivalent damping factor, ξ_b.

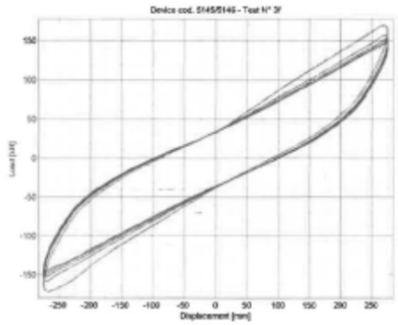

Fig. : Displacement – Load - Total Cycles

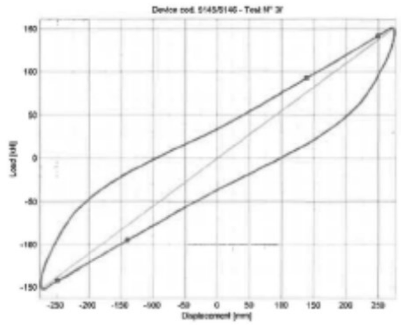

Fig. : Displacement – Load - Cycle n°3

Results	*Cycle 1*	*Cycle 2*	*Cycle 3*	*Cycle 4*	*Cycle 5*	
Maximum displacement	274.8	275.3	275.2	275.3	275.3	*mm*
Minimum displacement	-274.8	-274.8	-274.9	-274.7	-274.3	*mm*
Maximum load	170	157	151.5	148.5	146.9	*kN*
Minimum load	-171.9	-158	-152.5	-149.2	-146.8	*kN*
Effective stiffness k_{effb}	0.62	0.57	0.55	0.54	0.53	*kN/mm*
Dissipated energy	41672.3	38679.3	37659.1	36997.2	36559.4	*J*
Damping	14.12	14.21	14.33	14.39	14.42	*%*
Second branch stiffness k_2	0.53	0.46	0.44	0.44	0.43	*kN/mm*
Shear Modulus	0.4	0.37	0.36	0.35	0.35	
Load Q_d (Average value)	34.1	35.2	35.9	35.3	34.9	*kN*
Vertical Load	1673	1692.7	1695.4	1694.6	1693	*kN*
Maximum Velocity	809.9	808.1	797.7	794.2	779.3	*mm/s*

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spostamento SLV

200%

Test Number 4 - *Horizontal stiffness under a one side ramp loading*

The isolator has been deformed up to the design displacement under a defined applicant vertical load and keeping it constant during the test.

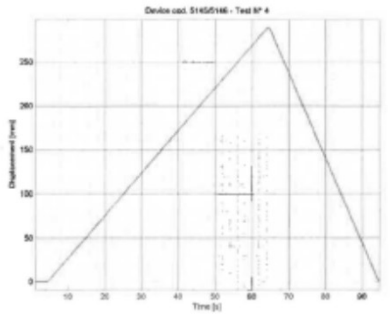

Fig. : Displacement – Time

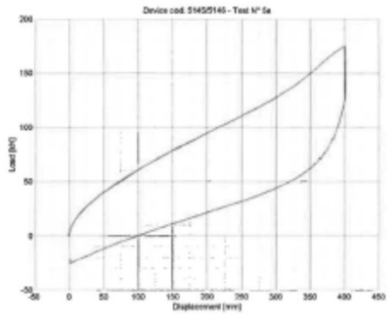

Fig. : Displacement – Load

Results

Maximum load	134.2	kN
Maximum displacement	289.8	mm
Effective stiffness	0.46	kN/mm
vertical load	1700.071	kN
F = f(d_57.7%)	54.9	kN
F = f(d_26.8%)	30.03	kN
d_57.7%	106.73	mm
d_26.8%	49.71	mm
rubber area	282743.3	mm2
tq value	184	mm
G modulus	0.28	MPa

OBSERVATIONS – The visual evidence has been fullfilled

Test Number 3g- *Horizontal characteristics under cyclic deformation test 200% of Tq*

The test has been carried out by applying on the device a vertical load corresponding to 6 MPa and keeping it constant during the test. After having fully applied the vertical load, three sinusoidal cycles characterized by amplitude equal to ±200% of the total thickness active during shear and frequency of 0.5 Hz have been performed. During the test, the horizontal load, the vertical load and the horizontal deflection have been recorded. The horizontal characteristics are expressed in terms of effective horizontal stiffness, K_{effb}, and equivalent damping factor, ξ_b.

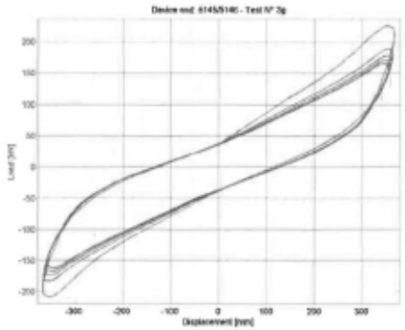

Fig. : Displacement – Load - Total Cycles

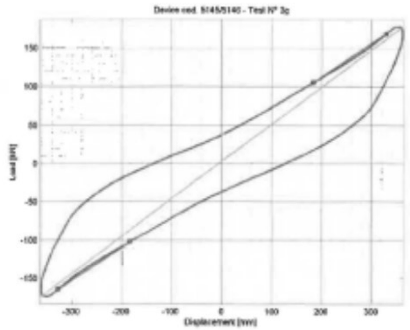

Fig. : Displacement – Load - Cycle n°3

Results	*Cycle 1*	*Cycle 2*	*Cycle 3*	*Cycle 4*	*Cycle 5*	
Maximum displacement	367.5	364	361.4	358	355.5	mm
Minimum displacement	-367.3	-365.4	-362.3	-359.1	-356.1	mm
Maximum load	225.8	188.8	177.7	170.2	165.3	kN
Minimum load	-208.6	-183.2	-173.6	-167	-162.1	kN
Effective stiffness k_{effb}	0.59	0.51	0.49	0.47	0.46	kN/mm
Dissipated energy	67619.2	59541.2	56609.7	54618.5	52896.7	J
Damping	13.48	13.97	14.17	14.38	14.45	%
Second branch stiffness k_2	0.6	0.47	0.43	0.42	0.41	kN/mm
Shear Modulus	0.38	0.33	0.32	0.31	0.3	
Load Q_d *(Average value)*	38.3	37.5	37.5	35.9	35.9	kN
Vertical Load	1668.3	1701.6	1706.5	1705.1	1703.4	kN
Maximum Velocity	884.6	875.2	864.6	842.8	827.7	mm/s

Isolatori elastomerici – TT EN15129

***Test Number 5a**- Lateral capacity under maximum seismic vertical load*

The horizontal displacement capacity of the isolator has been checked under the maximum seismic vertical load Ned,max
During and after the test the following checks have been performed.
- no signs of bond failure have been detected
- surface cracks or imperfections.

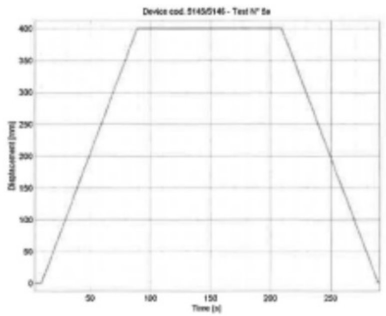

Fig. : Displacement – Time

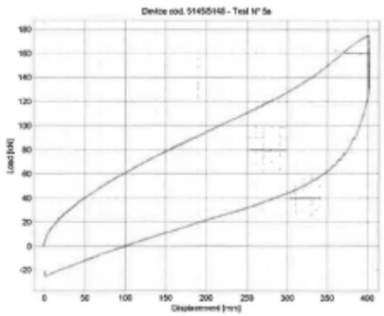

Fig. : Displacement – Load

Results

Maximum horizontal load	*175.8*	*kN*
Vertical load	*1082*	*kN*
Maximum displacement	*401.7*	*mm*

OBSERVATIONS

Signs of bond failure	*None*
Surface cracks or imperfections over 2 mm	*None*
Signs of failure or yielding in connections to the load platens	*None*

***Test Number 5b** - Lateral capacity under minimum seismic vertical load*

The horizontal displacement capacity of the isolator has been checked under the minimum seismic vertical load Ned,min
During and after the test the following checks have been performed.
- no signs of bond failure have been detected
- surface cracks or imperfections.

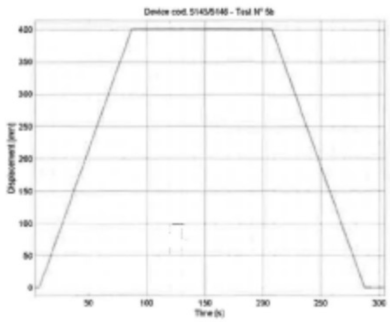

Fig. : Displacement – Time

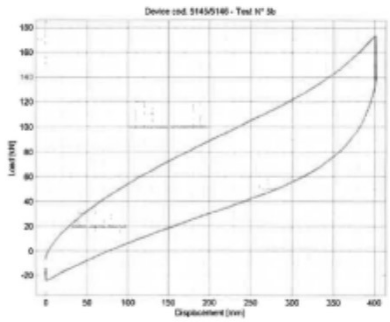

Fig. : Displacement – Load

Results

Maximum horizontal load	*172.8*	*kN*
Vertical load	*651.0*	*kN*
Maximum displacement	*402*	*mm*

OBSERVATIONS

Signs of bond failure	*None*
Surface cracks or imperfections over 2 mm	*None*
Signs of failure or yielding in connections to the load platens	*None*

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8.2.4.1.5.2 Combined compression and shear tests of horizontal characteristics

The equipment should preferably allow only one isolator to be tested at a time. The double-shear configuration may be used. The requirements for the testing-machine are given in Annex G.

The cyclic shear displacement should be applied at a frequency of 0,5 Hz or the isolation frequency. A lower frequency may be used with the agreement of the Structural Engineer. The test frequency shall be at least 0,01 Hz. The input waveform shall be sinusoidal or triangular; a sinusoidal waveform is preferred.

The isolator should be subjected to a compressive stress of 6 MPa. A different pressure may be used if requested by the Structural Engineer.

When isolators are tested at non-ambient temperature without using a temperature controlled enclosure, they shall be lagged with a system capable of maintaining the temperature at the required value. The isolator shall be maintained at the test temperature for sufficient time to ensure the interior has reached that temperature.

NOTE For a large isolator it may take several hours for the interior to reach the test temperature.

The stiffness, K_b, and damping, ξ_b, or second branch (or post-yield) stiffness, K_2, and characteristic strength, Q_d, shall be calculated using the expressions in G.5.

The test report shall conform to EN 1337-3:2005, H.8, items 1) to 3), and shall also include:

4) configuration of test - single or double shear, location and type of load-cells and displacement transducers, and confirmation (for example regarding any effect of friction on a load-cell reading) that the equipment requirements are satisfied;

5) applied compressive load and whether test conducted under constant compressive load or constant compressive displacement;

6) test temperature (s);

7) test frequency(ies);

8) list of test shear strain amplitudes in the order of the tests;

9) K_b and ξ_b (or K_2 and Q_d) for 3rd cycle at each shear strain amplitude;

10) copy of each 3rd cycle shear force-displacement loop and records of variation of compressive load and displacement with time during that cycle;

8.2.4.1.5.2 Combined compression and shear tests of horizontal characteristics

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NOTE For a large isolator i

The stiffness, K_b, and dampi
Q_d, shall be calculated using

8.2.4.1.5.3 Lateral capacity

The equipment should preferably allow only one isolator to be tested at a time. The double-shear configuration may be used; in this case the two isolators under test shall be within 15 % of each other in compression stiffness. The requirements for the testing-machine are given in Annex G. The two test equipment requirements in G.3 relating to the effect of hysteresis in the compressive load train need not apply. The test shall be performed under constant compressive load; fixed compressive displacement shall not be used.

The fixings used in the test shall be of the same design as those to be used in fixing the isolator to the protected structure and manufactured from similar materials.

NOTE The rate of loading does not significantly affect the result as the elastomer shear modulus is required not to be very sensitive to frequency. A ramp rate in the range corresponding to a rubber shear rate between 1 % s^{-1} and 100 % s^{-1} is recommended.

The maximum applied shear displacement shall be held for at least 2 min; during this period checks for visual signs of failure shall be carried out (with due regard to safety precautions). The checks shall also be made after removing the shear displacement, but while the compressive load is maintained.

The test report shall conform to EN 1337-3:2005, H.8, items 1) to 3), and shall also include:

4) configuration of test - single or double shear, location and type of load-cells and displacement transducers, and confirmation (for example regarding any effect of friction on a load-cell reading) that the equipment requirements are satisfied;

5) applied compressive load and whether test conducted under constant compressive load or constant compressive displacement;

6) test temperature (s);

7) test frequency(ies);

8) list of test shear strain amplitudes in the order of the tests;

9) K_b and ξ_b (or K_2 and Q_d) for 3rd cycle at each shear strain amplitude;

10) copy of each 3rd cycle shear force-displacement loop and records of variation of compressive load and displacement with time during that cycle;

PROVE DI QUALIFICA SULL'ELASTOMERO

8.2.1.2.3 Dependence of horizontal characteristics on frequency

The effect of frequency on horizontal characteristics K_b and ξ_b (or K_2 and Q_d) shall be determined by tests performed at a rubber shear strain amplitude of ± 100 %. The horizontal characteristics shall be measured at three frequencies. The recommended values are:

0,1 Hz   0,5 Hz   2,0 Hz

Other values spaced by the same ratios may be chosen in agreement with the structural engineer. The tests shall be in order of increasing frequency.

The values of K_b and ξ_b (or K_2 and Q_d) for the third cycle shall be reported for each test frequency. The values at the lowest and highest frequency shall not differ by more than 20 % from the value at the middle frequency.

For HDRB and LDRB, the tests may be performed on isolators scaled without restriction, or may be substituted by the tests required in 8.2.2.1.3.3 on the elastomer used in its manufacture.

8.2.1.2.4 Dependence of horizontal characteristics on temperature

The changes in horizontal characteristics K_b and ξ_b (or K_2 and Q_d) between the upper and lower service temperatures, T_U and T_L respectively, shall be determined by tests under the conditions and using the procedures given in the relevant parts of 8.2.4.1. The horizontal characteristics shall be measured at a rubber shear strain amplitude of ± 100 % over a range of temperatures extending from at least T_U to at least T_L. A test at 23 °C shall be included. The tests shall be performed in order of decreasing temperature. It is recommended that tests at the following temperatures are included if they are within the range of service conditions:

40 °C, 23 °C, 0 °C, - 10 °C, - 20 °C

The values of K_b and ξ_b (or K_2 and Q_d) for the third cycle shall be reported for each test temperature. The values at the lowest temperature shall not differ by more than + 80 % or – 20 % from the corresponding values at 23 °C, and the values at the highest temperature shall not differ by more than ± 20 % from those at 23 °C.

For HDRB and LDRB, the tests may be performed on isolators scaled without restriction, or may be substituted by the tests required in 8.2.2.1.3.4 on the elastomer used in its manufacture.

Isolatori elastomerici – TT EN15129

PROVE DI QUALIFICA SULL'ELASTOMERO

8.2.1.2.3 Dependence of horizo

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8.2.1.2.4 Dependence of horizo

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23 °C.

For HDRB and LDRB, the tests m
substituted by the tests required in 8.2

8.2.1.2.5 Dependence of horizontal characteristics on repeated cycling

The horizontal characteristics K_b and ξ_b (or K_2 and Q_d) of the isolator shall be constant under repeated cyclic loading. The stability of the characteristics shall be verified by tests. The rubber shear strain amplitude shall be 100 % or the design shear strain if requested by the structural engineer. The other test conditions and procedures shall conform to those given in the relevant parts of 8.2.4.1. The requirement for constant characteristics K_b and ξ_b (or K_2 and Q_d) is met when:

— the ratio between the minimum and maximum value of K_b (or K_2) measured in the cycles between the second and the tenth shall not be less than 0,7;

— the ratio between the minimum and maximum value of ξ_b (or Q_d) measured in the cycles between the second and the tenth shall not be less than 0,7;

— the ratio between the minimum and maximum value of K_b (or K_2) measured in the cycles between the first and the tenth shall not be less than 0,6.

For HDRB and LDRB, the tests may be performed on isolators scaled without restriction, or may be substituted by the tests on the elastomer used in its manufacture as required in 8.2.2.1.3.6.

The requirements may refer to more than the tenth cycle if requested by the Structural Engineer.

8.2.1.2.9 Effect of ageing

The changes in the horizontal characteristics K_b and ξ_b of the isolator (or K_2 only for LRB manufactured using low damping elastomer) shall be estimated to be less than 20 % over the expected service life of the isolator. The estimated change shall be determined by accelerated ageing tests on the elastomer material of the isolator (see 8.2.2.1.3.5), and by reference to any available directly relevant service life data on devices fabricated from similar materials. For PPRB, ageing tests on the polymer plug material shall also be performed according to 8.2.2.1.3.5 so that its contribution to the change in K_b and ξ_b can be estimated. Unless requested otherwise by the Structural Engineer, the requirement in this subclause is deemed to be met if the elastomer material (and polymer plug material if applicable) satisfies the requirement in 8.2.2.1.3.5 under the standard ageing conditions (14 days at 70 °C) given there.

NOTE The service life of anti-seismic devices is discussed in Annex B. For elastomeric isolators, it can be expected to be 60 years.

Isolatori elastomerici – TT EN15129

Politecnico di Milano - Dipartimento di Ingegneria Strutturale Cod.Cliente Rapporto di prova n. 2011/541/1 pag.2 di 21

POLITECNICO DI MILANO
DIPARTIMENTO DI INGEGNERIA STRUTTURALE
LABORATORIO PROVE MATERIALI
20133 MILANO - P.ZA LEONARDO DA VINCI, 32

Sede di Milano
accettazione materiale: Via Celoria, 3 Tel.: 02-2399.4210 Fax :02-2399.4211

Cod. Fiscale 80057930150
P. IVA 04376620151

Sede di Lecco
C.so Promessi Sposi,29
23900 Lecco
Tel.: 0341-48.8793
Fax : 0341-48.8771

Applicant: XXXXXX SRL - Zanè, Italy
Report no.: 2011/541

Certificate of Type Testing according to **hEN** 15129:2009

Type Testing of elastomer for isolators

compound XXXXXX 40 HDRB

Applicant: XXXXXX SRL
Test Report n°: 2011/541
Scope: Type testing of elastomer for Elastomeric Isolators, compound XXXXXX 40 HDRB
Reference: EN 15129:2009 "Antiseismic Devices", clause 8.2
Procedure: LPM.POP.05.106 and Letter dated 18 January 2011
Date of tests: from 21st of April 2011 to 06th of October 2011
Date of issue: 10th November 2011

The Inspector
Virginio Quaglini, PhD

Contents

2. MATERIALS

The type tests were performed on the high damping elastomeric compound identified by the applicant XXXXXX SRL as

compound	**XXXXXX 40 HDRB**
raw material	**NR + SBR blend**
G modulus*	**0.4 MPa**
damping*	**15%**
Upper bound temperature	**40°C**
Lower bound temperature	**-10°C**
batch	**601 of 03/03/2011**

* nominal values at 100% shear strain

Slitte multidirezionali - qualifica

Apparecchi di appoggio stradali

Descrizione

Lo scopo di questo sistema d'appoggio è consentire la trasmissione delle sollecitazioni dalla sovrastruttura (travi, soletta) alle strutture di sostegno (spalle, pile), permettendo, ove richiesto, gli spostamenti secondo le direzioni del piano dell'appoggio. Il dispositivo ha inoltre la funzione di compensare le tolleranze di fabbricazione e di montaggio degli elementi prefabbricati al fine di consentire una corretta trasmissione delle sollecitazioni nelle zone di contatto specialmente quando si opera con calcestruzzo e/o cemento armato precompresso.
Dal punto di vista statico, tutti gli apparecchi d'appoggio si oppongono alla forza generata lungo la direttrice del carico verticale e il disco in gomma incapsulato nella base consente rotazioni intorno ad un asse qualsiasi del piano di appoggio assorbendo flessioni o cedimenti.
Qualora occorresse assicurare la possibilità di spostamento in tutte le direzioni del piano di appoggio, si adotterà un appoggio del tipo mobile multidirezionale.
In questo caso l'apparecchio d'appoggio è composto da una piastra di base realizzata dal pieno in un unico pezzo, in cui la superficie a contatto con la sottostruttura presenta due scarichi circolari per migliorarne l'incollaggio. Il disco in elastomero è protetto da due anelli antiestrusione e da una guarnizione parapolvere che non consente penetrazione di detriti nel vano del disco. Sul piano superiore del pistone è posto un disco in PTFE lubrificato che, in accoppiamento con la superficie inox della slitta, garantisce gli scorrimenti. La slitta presenta sulla superficie superiore una tacchettatura per migliorare l'incollaggio con la trave. A protezione di tutti i componenti in movimento, l'appoggio è circondato da un gonnellino esterno in gomma, fissato alla slitta. Gli elementi di bloccaggio tra slitta e basamento sono stati realizzati in maniera da consentire la preregolazione e sono presenti indicatori di scorrimento graduati per visualizzare gli spostamenti durante la vita di esercizio del dispositivo. Inoltre, per assicurare la precisione di installazione, sono presenti due bolle di livello incassate lungo i due lati della slitta. A differenza di quanto è possibile riscontrare in altre realizzazioni presenti sul mercato, la TEC Group non prevede l'utilizzo di elettrosaldatura per nessun elemento costituente il dispositivo, ciò a garanzia di massima affidabilità nel tempo.
Gli appoggi sono realizzati in conformità alla norma europea EN1337:2005 e provvisti di marcatura CE.

Normativa di riferimento

La progettazione e la realizzazione del dispositivo è stata eseguita in conformità alle seguenti normative ed istruzioni:

- D.M. 14/01/2008 "Normativa Tecnica sulle Costruzioni".
- UNI EN 1337:2005 "Appoggi strutturali".

Slitte multidirezionali - qualifica

Tabella riassuntiva

Tipo	*Carico vert. (kN)*	*Rotazione α (+/- gradi)*	*Diametro base (mm)*	*Altezza (mm)*
TD-ML 25	250	0.85	130	75
TD-ML 50	500	0.85	170	80
TD-ML 75	750	0.85	220	80
TD-ML100	1000	0.85	220	90
TD-ML 125	1250	0.85	240	90
TD-ML 150	1500	0.85	290	90
TD-ML 175	1750	0.85	310	90
TD-ML 200	2000	0.85	340	95
TD-ML 250	2500	0.85	370	95
TD-ML 300	3000	0.85	400	105
TD-ML 350	3500	0.85	440	110
TD-ML 400	4000	0.85	470	110
TD-ML 450	4500	0.85	500	125
TD-ML 500	5000	0.85	530	125
TD-ML 600	6000	0.85	600	130
TD-ML 700	7000	0.85	650	135
TD-ML 800	8000	0.85	680	145
TD-ML 900	9000	0.85	720	165
TD-ML 1000	10000	0.85	780	165
TD-ML 1250	12500	0.85	880	175
TD-ML 1500	15000	0.85	950	200
TD-ML 1750	17500	0.85	1050	200
TD-ML 2000	20000	0.85	1100	230

N.B. Le dimensioni sopra riportate sono indicative in quanto l'appoggio viene progettato per ogni specifico insieme di combinazioni di carico/spostamento fornite dal progettista dell'opera.

Indicazioni sui materiali

Acciaio laminato a caldo S355J2 UNI EN 10025 (Fe510)

COEFFICIENTE DI POISSON	0.3
MODULO DI ELASTICITÀ	206000 N/mm^2
DENSITÀ DI MASSA	7850 Kg/m^3
MODULO DI TAGLIO	79230 N/mm^2
CARICO UNITARIO DI ROTTURA	510 N/mm^2
ALLUNGAMENTO % A ROTTURA	23%
CARICO UNITARIO DI SNERVAMENTO	355 N/mm^2
CARICO UNITARIO AMMISSIBILE	210 N/mm^2

Gomma naturale (ISO 6446)

DUREZZA NOMINALE	63 +/-5 Shore A3
RESISTENZA A ROTTURA (Istruzione FF.SS. 44E)	>15.5 N/mm^2
DENSITÀ DI MASSA	1200 Kg/m^3
MODULO G	1 N/mm^2
ALLUNGAMENTO A ROTTURA	> 400%

Acciaio X5NiCrMo 1712 (AISI 316)

COEFFICIENTE DI POISSON	0.3
MODULO DI ELASTICITÀ	206000 N/mm^2
DENSITÀ DI MASSA	7850 Kg/m^3
MODULO DI TAGLIO	79230 N/mm^2
CARICO UNITARIO DI ROTTURA	490-685 N/mm^2
CARICO UNITARIO DI SCOSTAMENTO DALLA PROPORZIONALITA'	205 N/mm^2
CARICO UNITARIO AMMISSIBILE	136 N/mm^2

Politetrafluoroetilene PTFE (EN 1337-2)

DUREZZA (UNI 4916-74)	55 Shore D3
RESISTENZA A TRAZIONE (23°)	>24 N/mm^2
DENSITÀ DI MASSA	2170 Kg/m^3
CARICO MASSIMO	50 N/mm2
ALLUNGAMENTO A ROTTURA (23°)	> 300%

Nessuna indicazione sul coefficiente d'attrito

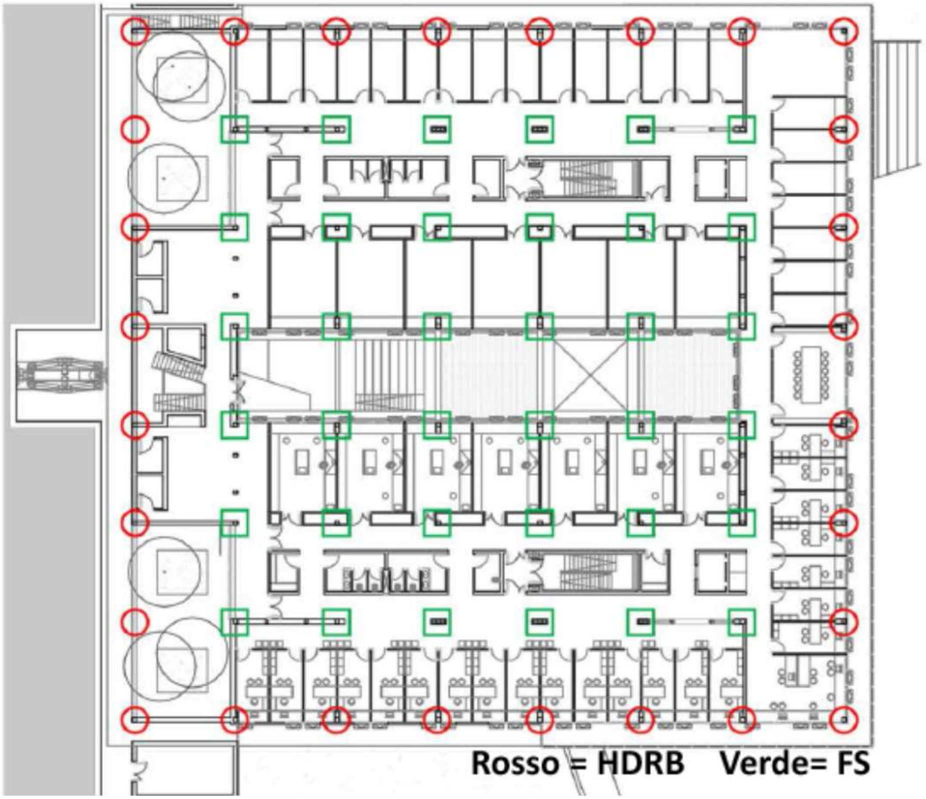
Misura dell'attrito in fase di accettazione

Prove di accettazione dei dispositivi

Isolatori elastomerici – FPCT EN15129

8.2.4.1.4 Sampling frequency

For each type of isolator, the factory production control compression test and compression and shear test (see Table 11) shall be carried out on the first production isolator. Subsequently, at least 20 % of the production isolators of each type, chosen randomly, shall be subjected to both factory production control tests. For projects involving a structure supported by four or fewer isolators, all the production isolators for that structure shall be tested unless otherwise agreed with the Structural Engineer.



28 isolatori elastomerici SI-S 600/182

6 isolatori elastomerici testati

+

4 slitte multidirezionali

Isolatori elastomerici - FCT EN15129

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TEST REPORT

FPC Test – Reference EN 15129 – NTC2008

DEVICE	Tec IG 600-184-S
CLIENT	Tec Group
PROJECT	Comune di Camerino – CRU Centro Ricerca Universitaria

CLIENT ORDER	---------------
TEST REPORT NUMBER	233/2019
TEST REPORT CODE	TR_233_19_LAB_124_19
SISMALAB ORDER	124_2019
TEST PERFORMER	CARAMIA CIRO

Rev	00	01	02	03	04	05	06
Data	14/11/2019						

CONTENT

Isolatori elastomerici - FCT EN15129

Non può essere superata la deformazione di progetto

SECTION 3 TESTING PROTOCOL

N	TEST	DISPLACEMENT - mm	V.LOAD - kN	F - Hz	S. FUNCTION	CYCLE
1	C.S.	-	2100	-	ramp	1
2a	H.C.C 5%	9.2	1696	0.5	sinusoidal	5
2b	H.C.C 10%	18.4	1696	0.5	sinusoidal	5
2c	H.C.C 20%	36.8	1696	05.	sinusoidal	5
2d	H.C.C 50%	92	1696	0.5	sinusoidal	5
2e	H.C.C 100%	184	1696	0.5	sinusoidal	5
2f	H.C.C 150%	276	1696	0.5	sinusoidal	5

Details

Test Number 1 *- Compression Stiffness – device 5277*

The test has been performed by applying a vertical load up to N_{SD} and keeping it constant for at least 2 minutes. The secant compression stiffness K_v of the isolator has been determined between (1/3) N_{SD} and N_{SD}. At the maximum load the isolator has been examined to look for signs of failure. The requirements have been fulfilled and the load-displacement relation has increased monotonically up to N_{sd} and the isolator has shown no visual evidence of manufacturing imperfections or failure.
The visual evidence has included :
-signs of bond failure
-laterally misaligned or vertically misplaced reinforcing plates
-surface cracks or imperfections over 2 mm wide or deep.

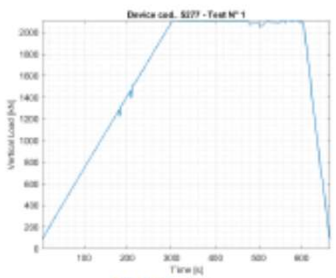


Fig. Load - Time

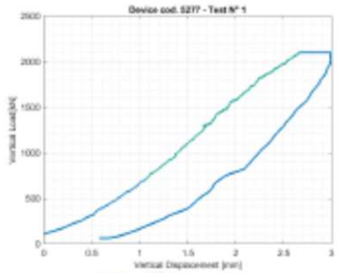


Fig. Load - Displacement

Results

Displacement corresponding to the maximum load reached	2.7	*mm*
Displacement corresponding to the 33% of the max. load	1.1	*mm*
Maximum Force reached	2100	*kN*
33% of the Maximum load reached	700.6	*kN*
Vertical Stiffness k_v	872.35	*kN/mm*

Test Number 1 *- Compression Stiffness – device 5278*

The test has been performed by applying a vertical load up to N_{SD} and keeping it constant for at least 2 minutes. The secant compression stiffness K_v of the isolator has been determined between (1/3) N_{SD} and N_{SD}. At the maximum load the isolator has been examined to look for signs of failure. The requirements have been fulfilled and the load-displacement relation has increased monotonically up to N_{sd} and the isolator has shown no visual evidence of manufacturing imperfections or failure.
The visual evidence has included :
-signs of bond failure
-laterally misaligned or vertically misplaced reinforcing plates
-surface cracks or imperfections over 2 mm wide or deep.

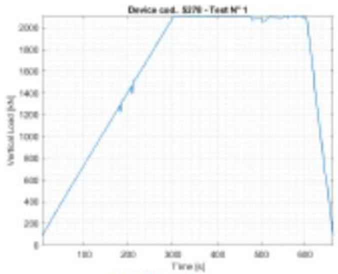


Fig. Load - Time

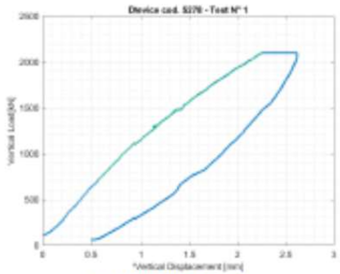


Fig. Load - Displacement

Results

Displacement corresponding to the maximum load reached	2.3	*mm*
Displacement corresponding to the 33% of the max. load	0.6	*mm*
Maximum Force reached	2100	*kN*
33% of the Maximum load reached	700.6	*kN*
Vertical Stiffness k_v	825.92	*kN/mm*

Isolatori elastomerici - FCT EN15129

5%

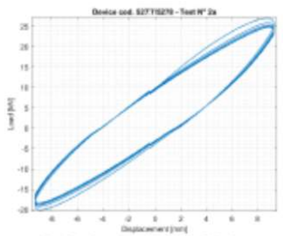


Fig. : Displacement – Load - Total Cycles

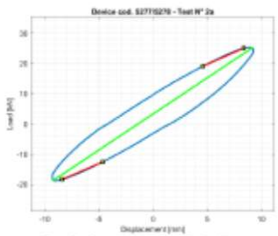


Fig. : Displacement – Load - Cycle n°3

Results	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	
Maximum displacement	9.3	9.2	9.2	9.2	9.2	mm
Minimum displacement	-9.3	-9.3	-9.3	-9.3	-9.3	mm
Maximum load	27	25.8	25.3	25.1	24.9	kN
Minimum load	-20	-19.2	-18.9	-18.5	-18.4	kN
Effective stiffness $keff_b$	2.54	2.43	2.39	2.35	2.34	kN/mm
Dissipated energy	216.3	200.1	194	190.1	187.1	J
Damping	15.8	15.25	15.08	15	14.85	%
Second branch stiffness k_2	1.55	1.59	1.58	1.57	1.56	kN/mm
Shear Modulus	1.65	1.58	1.55	1.53	1.52	
Load Q_d (Average value)	6.7	6.6	6.4	6.3	6.2	kN
Vertical Load	1700.4	1700.3	1700	1701.5	1701.7	kN
Maximum Velocity	32.2	32.3	32.2	32.1	32.2	mm/s

10%

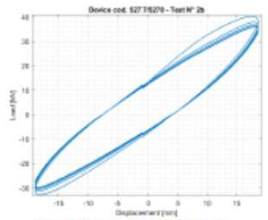


Fig. : Displacement – Load - Total Cycles

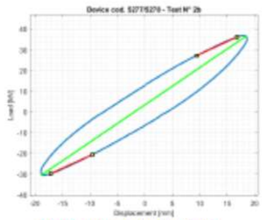


Fig. : Displacement – Load - Cycle n°3

Results	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	
Maximum displacement	18.6	18.6	18.6	18.6	18.6	mm
Minimum displacement	-18.9	-18.9	-18.9	-18.9	-18.9	mm
Maximum load	40.3	37.9	36.9	36.3	36	kN
Minimum load	-32.7	-31.1	-30.5	-29.9	-29.6	kN
Effective stiffness $keff_b$	1.94	1.84	1.8	1.77	1.75	kN/mm
Dissipated energy	668	606.3	584.3	572.1	562.6	J
Damping	15.53	14.9	14.7	14.64	14.54	%
Second branch stiffness k_2	1.19	1.23	1.22	1.21	1.2	kN/mm
Shear Modulus	1.26	1.2	1.17	1.15	1.14	
Load Q_d (Average value)	10.3	10.1	9.7	9.5	9.4	kN
Vertical Load	1696.6	1694.4	1690.7	1693.7	1697.2	kN
Maximum Velocity	64.1	64.1	63.9	64.4	64.1	mm/s

20%

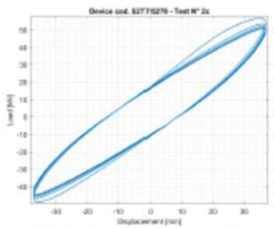


Fig. : Displacement – Load - Total Cycles

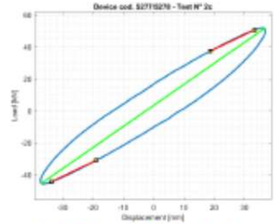


Fig. : Displacement – Load - Cycle n°3

Results	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	
Maximum displacement	36.9	36.9	36.9	36.9	36.9	mm
Minimum displacement	-37.3	-37.3	-37.3	-37.3	-37.3	mm
Maximum load	56.7	53.4	52.1	51.3	50.7	kN
Minimum load	-48.8	-46.5	-45.5	-44.9	-44.4	kN
Effective stiffness $keff_b$	1.42	1.35	1.32	1.3	1.28	kN/mm
Dissipated energy	1826.4	1668.6	1616.8	1588.2	1566.2	J
Damping	14.85	14.33	14.22	14.17	14.13	%
Second branch stiffness k_2	0.92	0.92	0.91	0.9	0.89	kN/mm
Shear Modulus	0.93	0.88	0.86	0.84	0.84	
Load Q_d (Average value)	14.1	13.9	13.6	13.3	13.2	kN
Vertical Load	1689.5	1695.9	1689.2	1698.5	1693.2	kN
Maximum Velocity	125.5	125.9	126.1	125.4	125.7	mm/s

50%

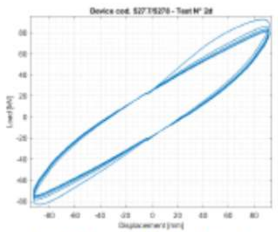


Fig. : Displacement – Load - Total Cycles

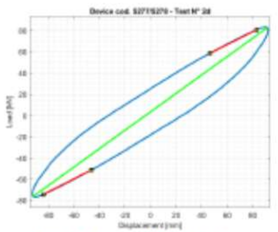


Fig. : Displacement – Load - Cycle n°3

Results	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	
Maximum displacement	91.9	91.9	91.9	91.9	91.9	mm
Minimum displacement	-92.4	-92.4	-92.4	-92.4	-92.4	mm
Maximum load	92.6	85.9	83.4	81.9	80.9	kN
Minimum load	-83.2	-78.6	-76.6	-75.4	-74.5	kN
Effective stiffness $keff_b$	0.95	0.89	0.87	0.85	0.84	kN/mm
Dissipated energy	7624.9	6864.7	6671.6	6564.3	6483.8	J
Damping	14.98	14.42	14.4	14.42	14.42	%
Second branch stiffness k_2	0.62	0.62	0.61	0.6	0.6	kN/mm
Shear Modulus	0.62	0.58	0.56	0.56	0.55	
Load Q_d (Average value)	22.1	21.9	21.7	21.5	21.3	kN
Vertical Load	1702.2	1705.8	1705.2	1704	1694.1	kN
Maximum Velocity	300.5	300.7	300.3	298.5	298.3	mm/s

100%

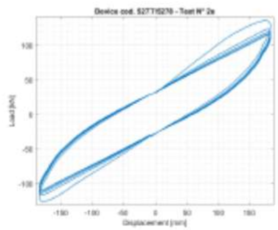


Fig. : Displacement – Load - Total Cycles

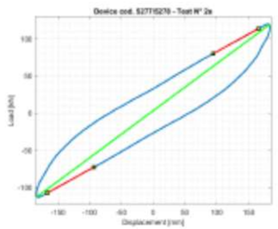


Fig. : Displacement – Load - Cycle n°3

Results	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	
Maximum displacement	184	183.9	184	183.9	183.9	mm
Minimum displacement	-184.4	-184.4	-184.3	-184.3	-184.2	mm
Maximum load	136.1	123.7	119.5	117	115.3	kN
Minimum load	-125.2	-116.4	-113	-110.8	-109.2	kN
Effective stiffness $keff_b$	0.71	0.65	0.63	0.62	0.61	kN/mm
Dissipated energy	22171.4	20067	19451.4	19145.2	18940.7	J
Damping	14.67	14.44	14.46	14.53	14.59	%
Second branch stiffness k_2	0.54	0.49	0.47	0.46	0.46	kN/mm
Shear Modulus	0.46	0.42	0.41	0.4	0.4	
Load Q_d (Average value)	29.2	29.7	30.2	30	29.8	kN
Vertical Load	1690.7	1693.6	1697.3	1694.4	1692.8	kN
Maximum Velocity	588.9	590.2	589.4	590.2	586.9	mm/s

150%

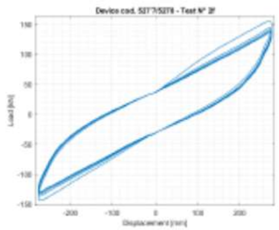


Fig. : Displacement – Load - Total Cycles

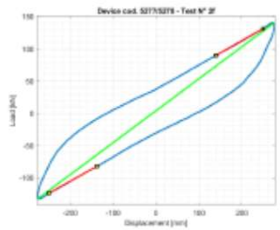


Fig. : Displacement – Load - Cycle n°3

Results	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	
Maximum displacement	276.3	276.3	276.4	276.3	276.3	mm
Minimum displacement	-276.3	-276.2	-276.2	-276.2	-276.2	mm
Maximum load	155.6	144.4	140.8	138.4	136.8	kN
Minimum load	-143.2	-135.8	-132.6	-130.5	-129	kN
Effective stiffness $keff_b$	0.54	0.51	0.49	0.49	0.48	kN/mm
Dissipated energy	39146.3	36329.6	35777.4	35190.7	34957.9	J
Damping	15.09	14.94	15.08	15.08	15.15	%
Second branch stiffness k_2	0.41	0.38	0.37	0.37	0.37	kN/mm
Shear Modulus	0.35	0.33	0.32	0.32	0.31	
Load Q_d (Average value)	33.2	34.6	33.8	33.9	33.8	kN
Vertical Load	1679.3	1698.7	1697.6	1697	1697	kN
Maximum Velocity	830	832.5	818.4	818	806.7	mm/s

EN 15129 – slitte piane

8.4 Flat Surface Sliders

8.4.1 Requirements

The sliding elements of Flat Surface Sliders shall conform to EN 1337-2 or be covered by an ETA

The sliding elements shall be combined with a rotating element in accordance with EN 1337-1.

NOTE 1 Flat Surface Sliders can be considered as the limiting case for Curved Surface Sliders with curvature, $R = \infty$.

When Flat Surface Sliders are used to dissipate energy, in addition to transmit vertical loads lateral flexibility, their sliding elements shall conform to 8.3.1 of this European Standard.

NOTE 2 In Curved Surface Sliders restoring force is provided by gravity due to their geometry, while with flat sliding surface do not possess any re-centring capability.

Flat Surface Sliders shall be used in combination with appropriate devices that provide adequ capability to the seismic isolation system.

8.4.2 Materials

Materials shall conform to 8.3.2 of this European Standard.

8.4.3 Design

Design shall conform to 8.3.3 of this European Standard.

8.4.4 Testing

Testing shall conform to 8.3.4 of this European Standard.

Richiesta la prova E della tabella 15

8.4.5 Manufacturing, Assembly and Tolerances

Manufacturing, Assembly and Tolerances shall conform to 8.3.5 of this European Standard.

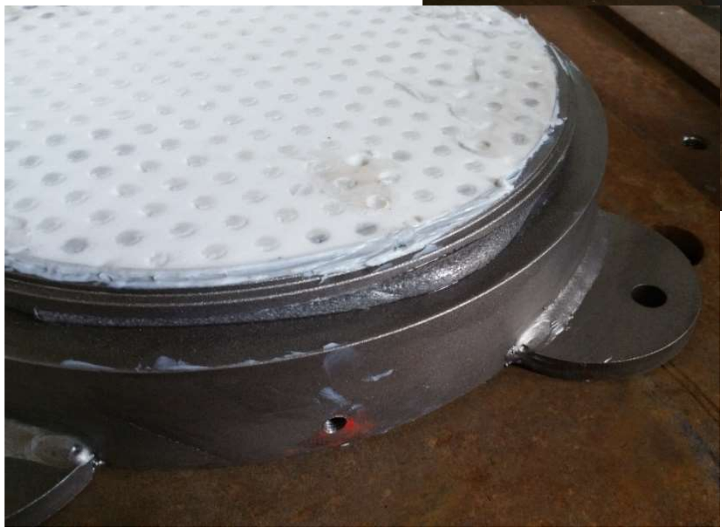
Slitte multidirezionali - FCT EN15129

Table 15 — Test Matrix to verify the sliding isolation behaviour

Type of Test	Test run	Compression Load N_S [kN]	Displacement d_X [m]	Peak velocity v_o [mm/s]	Number of complete cycles
Service	S	N_{Sd}	maximum non seismic movement	5	20
Benchmark	P1	N_{Sd}	$1{,}0 \cdot d_{bd}$	50	3
Dynamic 1	D1	N_{Sd}	$0{,}25 \cdot d_{bd}$	v_{Ed}	3
Dynamic 2	D2		$0{,}5 \cdot d_{bd}$	v_{Ed}	3
Dynamic 3	D3		$1{,}0 \cdot d_{bd}$	v_{Ed}	3
Integrity of overlay	O	N_{Sd}	$1{,}0 \cdot d_{bd}$	v_{Ed}	3
Seismic	E	$N_{Ed,max}$ and $N_{Ed,min}$	c d_{bd}	v_{Ed}	3
Bi-directional	B	N_{Sd}	$1{,}0 \cdot d_{bd}$	v_{Ed}	3
Property verification	P2	N_{Sd}	$1{,}0 \cdot d_{bd}$	v_{Ed}	3
Ageing	P3	N_{Sd}	$1{,}0 \cdot d_{bd}$	50	3

Slitte multidirezionali - FCT EN15129

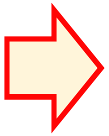
Importante assumere in fase di progetto un margine di sicurezza rispetto allo spostamento massimo (comportamento fragile)



Slitte multidirezionali - FCT EN15129

Configurazione singola difficile misurare forze orizzontali minori dell'1% del carico verticale

Slitte multidirezionali - FCT EN15129



Configurazione «doble shear» con 3+3 slitte testate contemporaneamente:
con attrito macchina annullato e stabile nei confronti del carico verticale

Slitte multidirezionali - FCT EN15129

SISMALAB
>>Soluzioni Ingegneristiche Sperimentali Antisismiche

TEST REPORT

Reference EN 15129

DEVICE	*Appoggio a disco elastomerico confinato multidirezionale Tec disc 1575-600-600*
PROJECT	*Comune di Camerino – CRU CENTRO RICERCA UNIVERSITARIA*
CLIENT	*Tec Group*

CLIENT ORDER	
TEST REPORT NUMBER	0236/2019
TEST REPORT CODE	TR_236_19_LAB_124_18
SISMALAB ORDER	000124_2018
TEST PERFORMER	CARAMIA CIRO

Rev	00	01	02	03	04	05	06
Data	20/11/2019						

THIS TEST REPORT CONSISTS OF 24 PAGES

THIS TEST REPORT CAN BE REPRODUCED ONLY INTEGRALLY AND SHALL BE SUBJECTED TO DUTY STAMP FOR USE ACCORDING TO ITALIAN LAW D.P.R. 642/72

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TEL	*099 8110037*
P. IVA E C.F.	*02775290733*
INTERNET	*www.sismalab.it*
MAIL	*prove@sismalab.it*

DEVICE CHARACTERISTICS - *Ref. Tec_disc_2500_800_800_pr_fpc*

MAXIMUM VERTICAL LOAD U.L.S.	*Nslu*	*2500*	*kN*
MAXIMUM SEISMIC VERTICAL LOAD	*Ned,max*	*1700*	*kN*
MINIMUM SEISMIC VERTICAL LOAD	*Ned,min*	*300*	*Kn*
MAXIMUM DISPLACEMENT S.L.V.	d_{SLV}	*290*	*Mm*
MAXIMUM DISPLACEMENT S.L.C.	d_{SLC}	*350*	*Mm*

SECTION 2 TEST IN PROTOCOL

N	TEST	DISPL. - mm	V.LOAD - kN	Velocity	SHAPE OF FUNCTION	CYCLE
1	Friction Test	290	1700	520 mm/s	Sinusoidal	3
2	Friction Test	290	1100	520 mm/s	Sinusoidal	3

SECTION 3 DATA ANALYSIS

FIRST FRICTION COEFFICIENT

$$\mu = F_{MAX} / V_{load}$$

F_{MAX} : *Maximum Load*
V_{load} : *Vertical load*

FRICTION COEFFICIENT

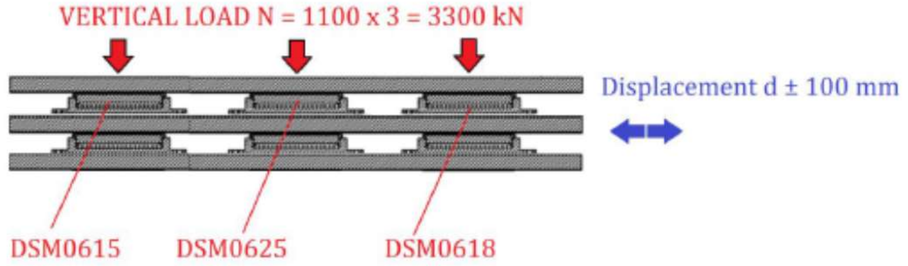
$$\mu = H / [2(d^{+} + |d^{-}|)V_{load}]$$

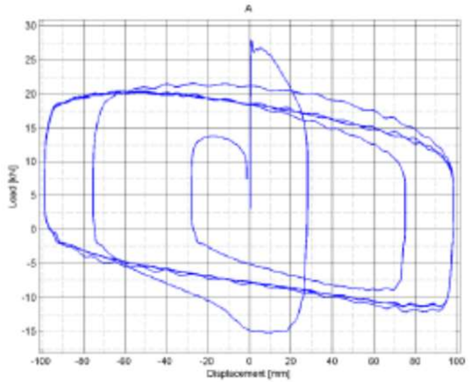
H : Hysteresis loop area
d+ : Maximum displacement
d- : Minimum displacement
V_{load} : *Vertical load*

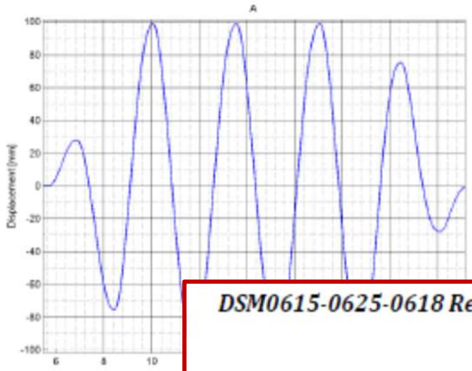
Slitte multidirezionali - FCT EN15129

SECTION 12 SIX DEVICES TESTED SIMULTANEOUSLY

*The test has been carried out by applying a vertical load equal to 3*1100 kN and keeping it constant during the test. After having fully applied the vertical load, three sinusoidal cycles characterized by amplitude equal to ±100 mm have been performed.*
This test aims to evaluate the friction coefficient of the devices without the uncertainty due to the friction of the test machine slide.







DSM0615-0625-0618 Results :

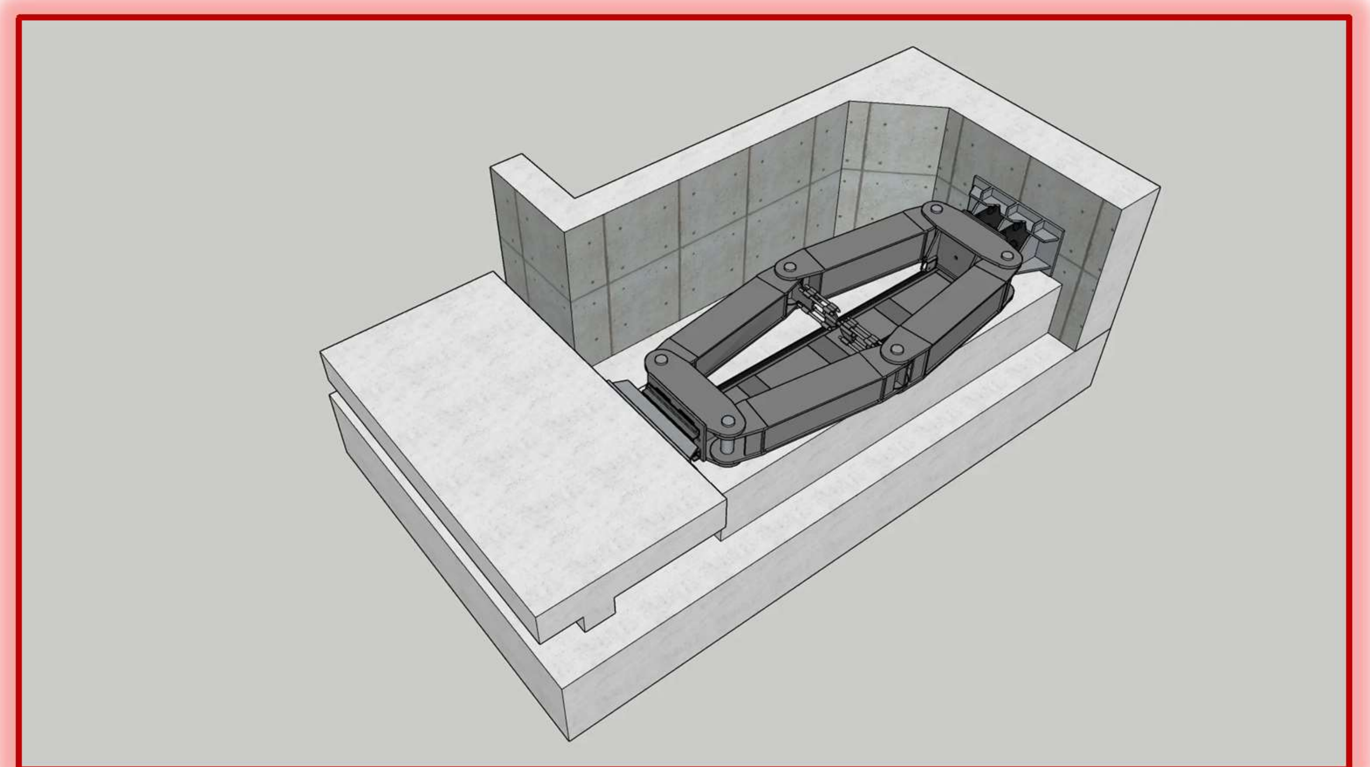
	Pre-Cycle	Cycle 1	Cycle 2	Cycle 3	Average	
Maximum displacement	-	98.4	98.4	98.4		mm
Minimum displacement	-	-98.7	-98.7	-98.7		mm
Maximum load	28	21.2	20.4	20.4		kN
Dissipated energy	-	5163.9	4866.4	4846.1	**4958.8**	J
Friction coefficient	0.85	0.4	0.37	0.37	**0.38**	%
Vertical load	3298.3	3299.1	3300.6	3300.3		kN

$E_{AV\_GROUOP} = E_{DSM0615}+E_{DSM0625}+E_{DSM0618}$ = **4958.8** J
μ_{AV_GROUOP} = **0.38%**

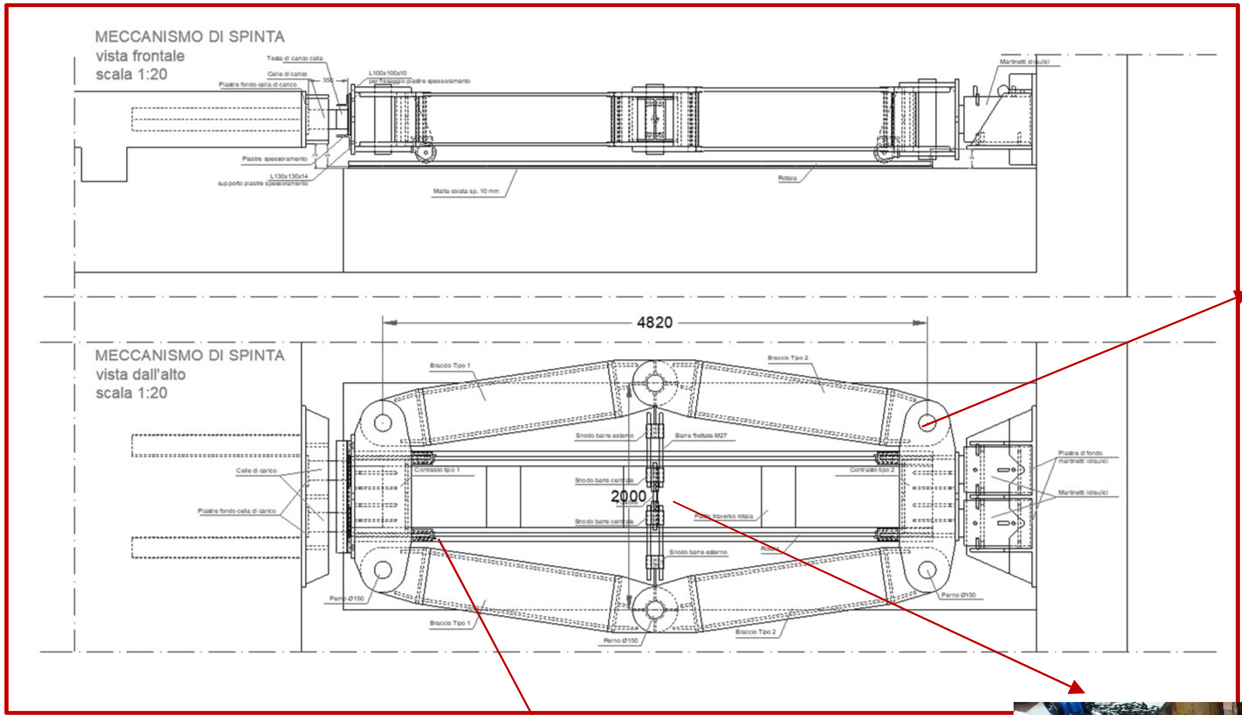
Prove di spinta

Prova di spinta – meccanismo di spinta

Dalla concezione e predisposizione in fase di progetto del meccanismo di spinta, della struttura di contrasto e della trave di spinta dell'edificio alla realizzazione della prova

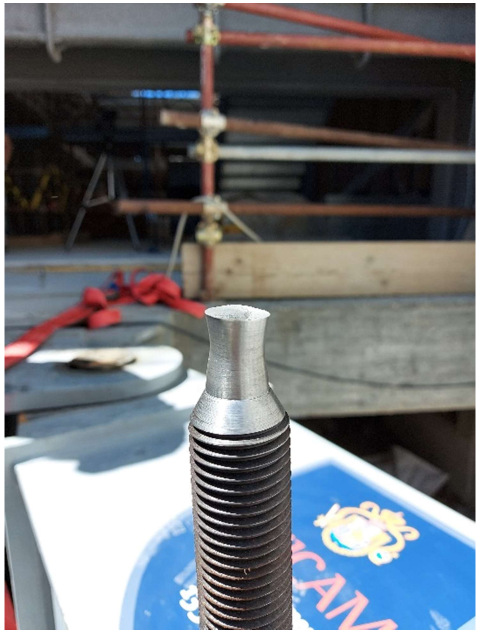


Prova di spinta – meccanismo di spinta

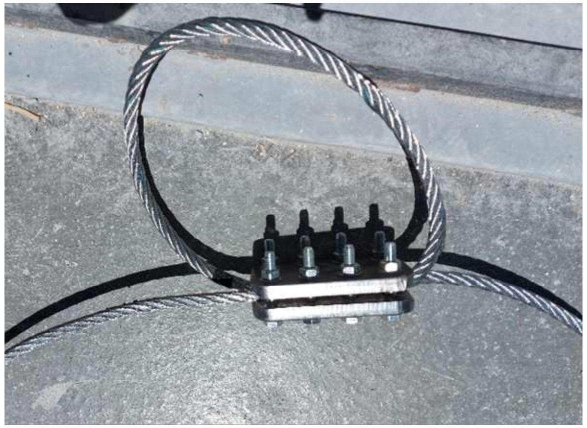


Prova di spinta – meccanismo di spinta

Fusibili M40 10.9 con tornitura calibrate nella zona rottura a diversi diametri

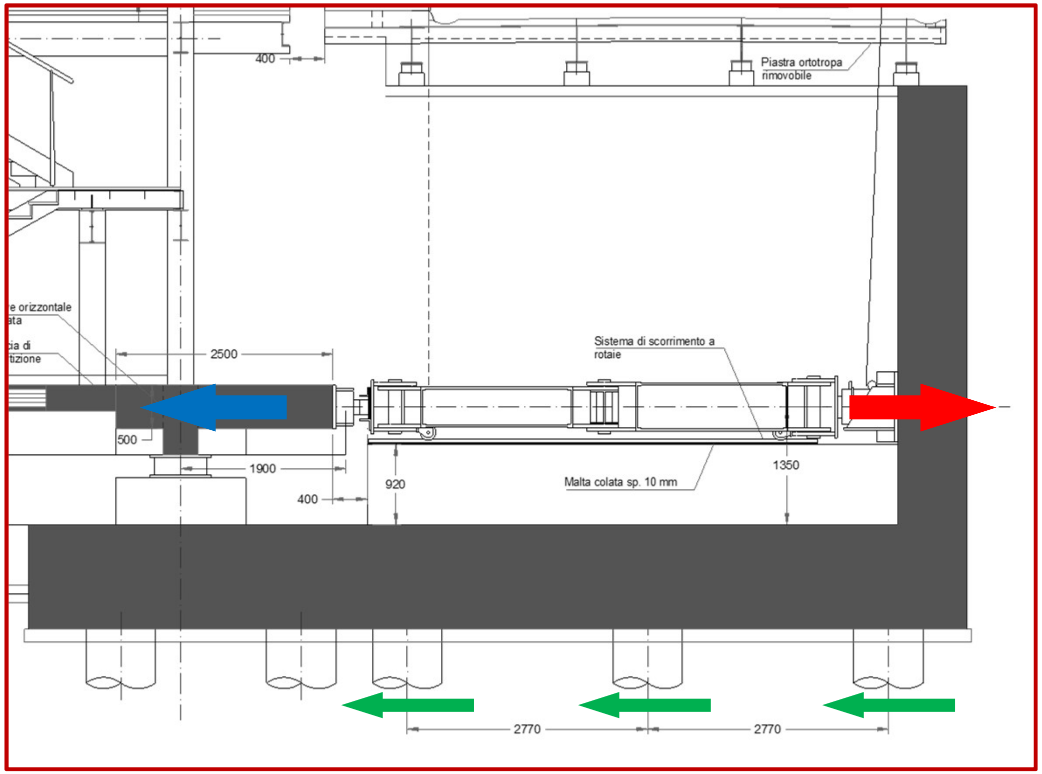


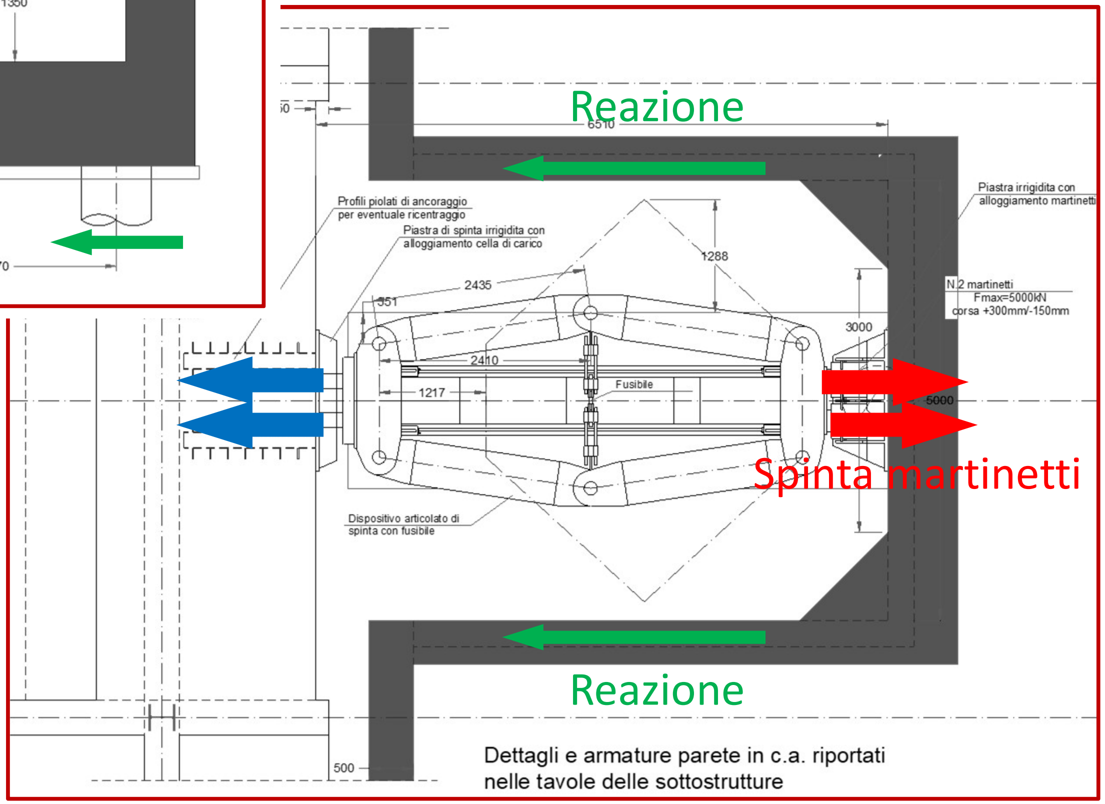
Rottura del fusibile testato il lboratorio



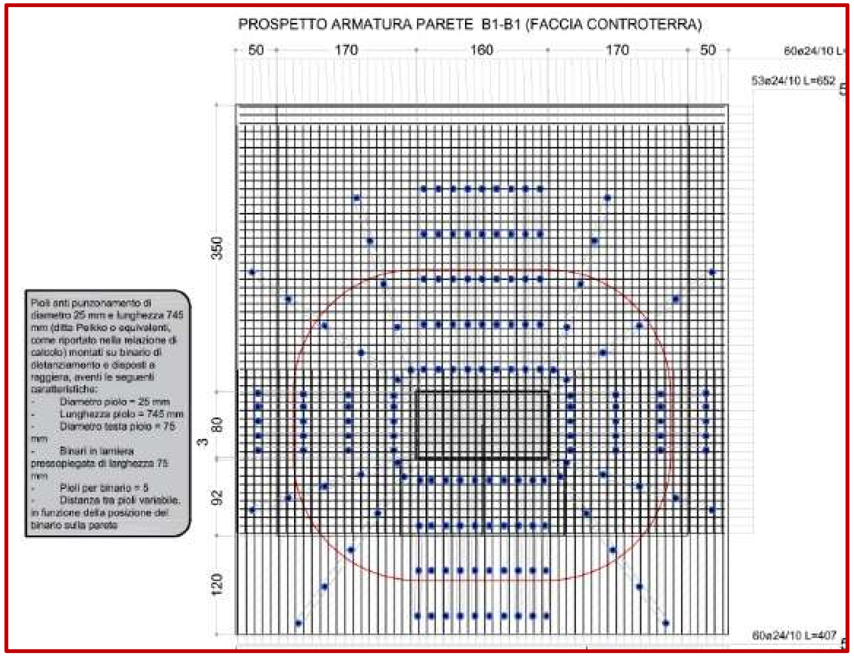
Cappio dissipatore (tipo reti paramassi) realizzato con due piastre accoppiate con bulloni e rondelle troncoconiche per controllo della compressione.

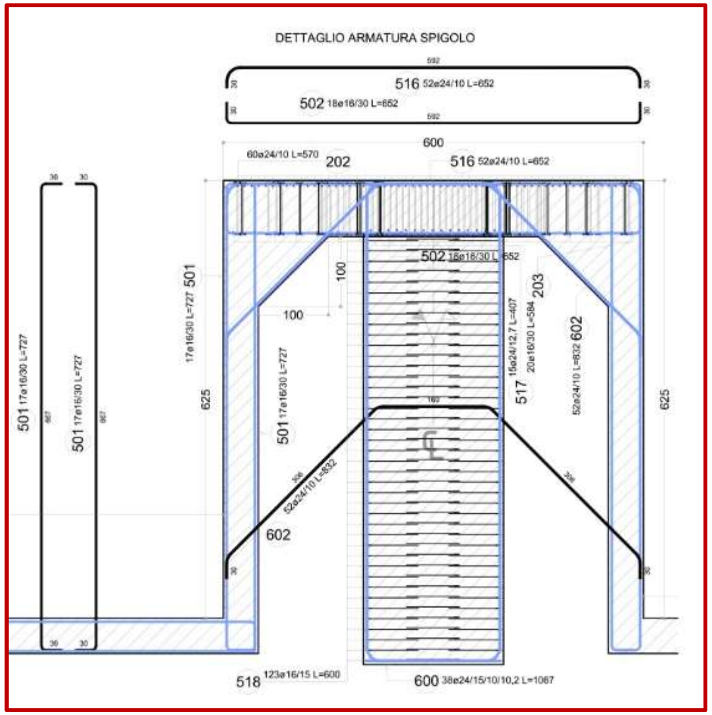
Prova di spinta – meccanismo di spinta



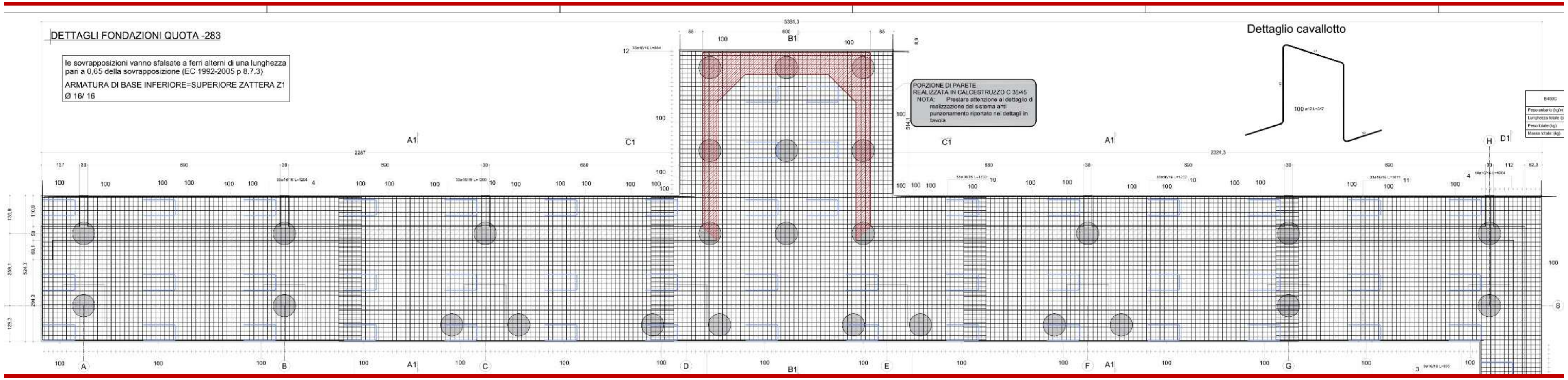


Prova di spinta – meccanismo di spinta

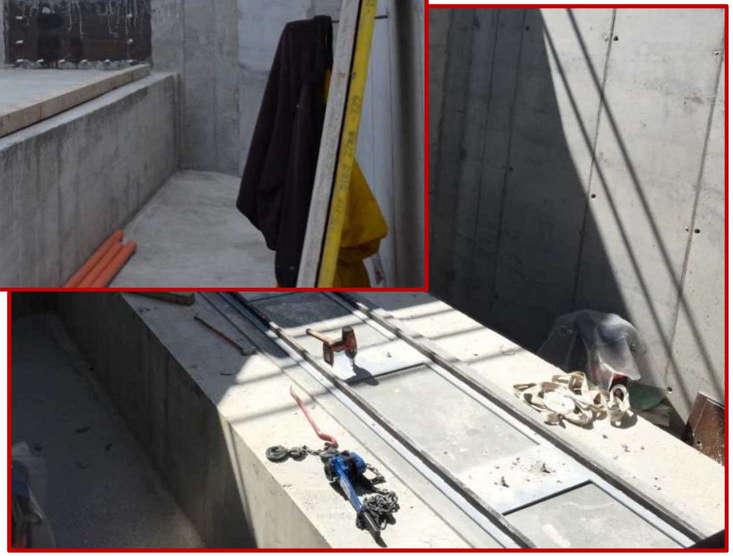




Vano di spinta su nove pali per la redistribuzione della reazione:



Prova di spinta – meccanismo di spinta



Prova di spinta – meccanismo di spinta

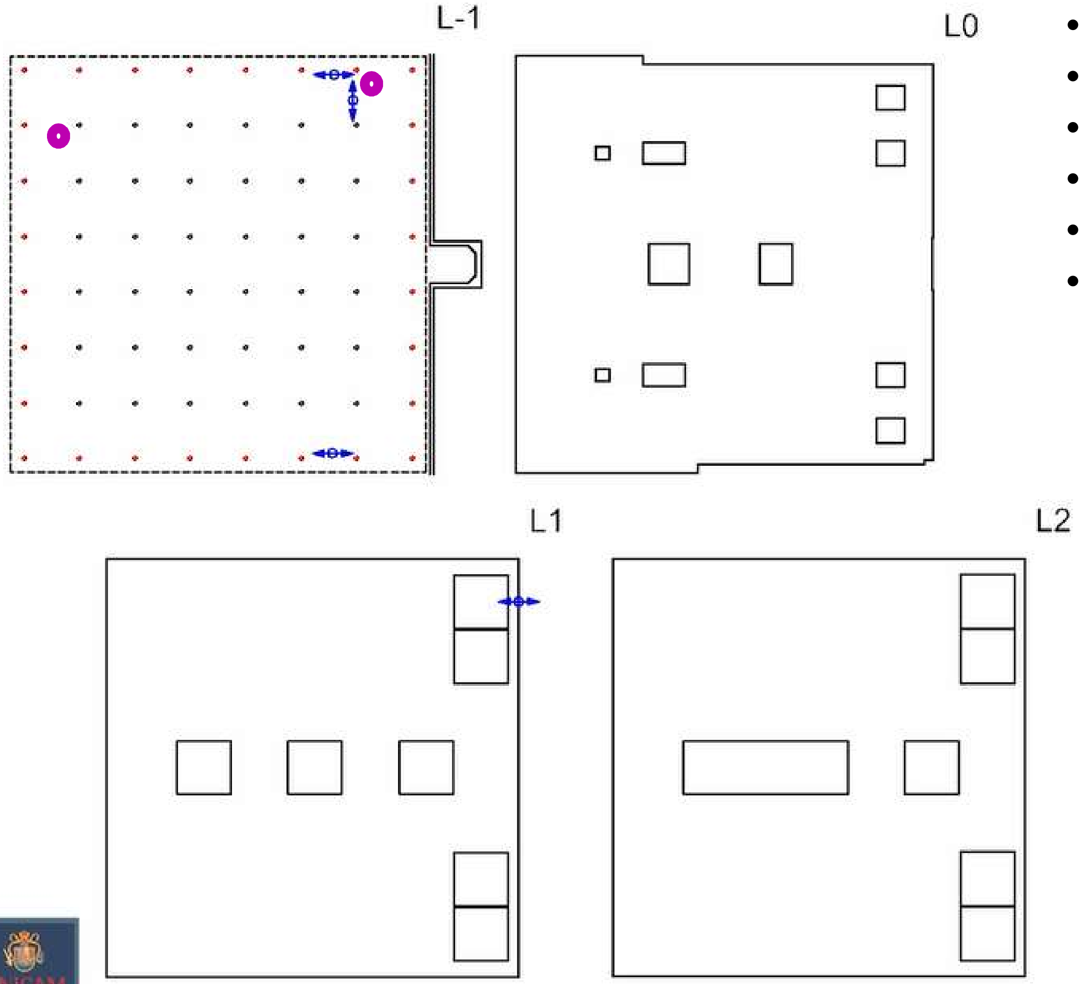
Prova di spinta – meccanismo di spinta

Prova di spinta – sistema di spinta

2 martinetti idraulici da 5000 kN
(corsa massima 300mm)

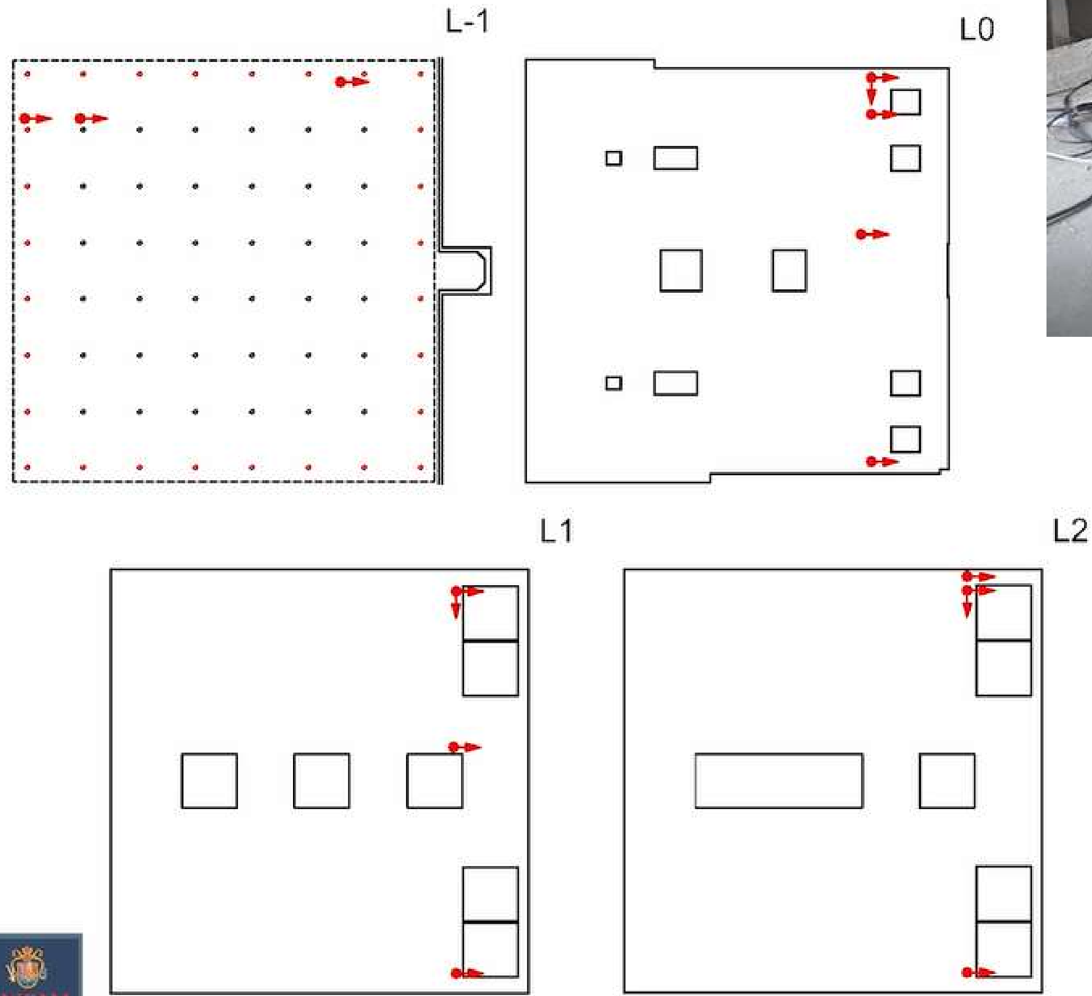
1 pompa manuale da 700 bar
(portata 1.8 - 4.5 l/m)

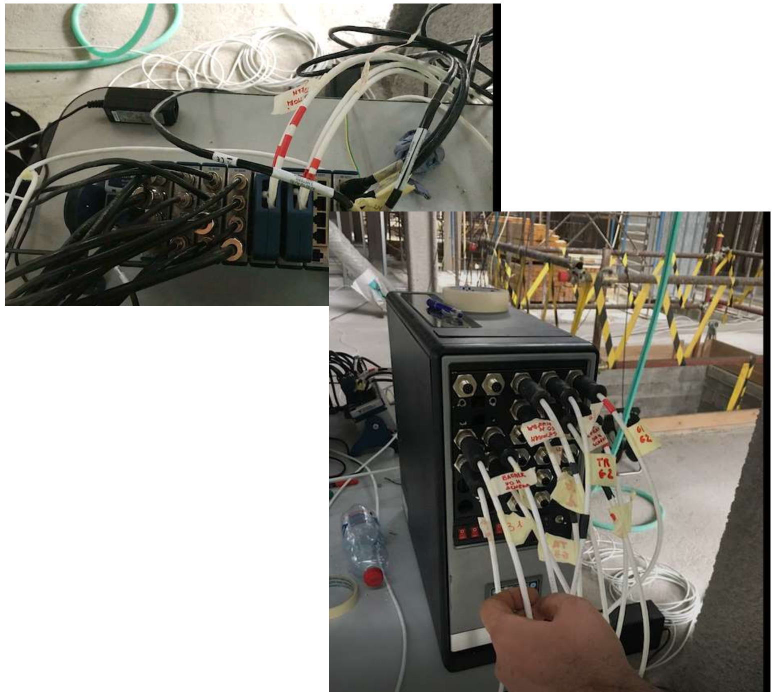
Prova di spinta – strumentazione e sistema di acquisizione



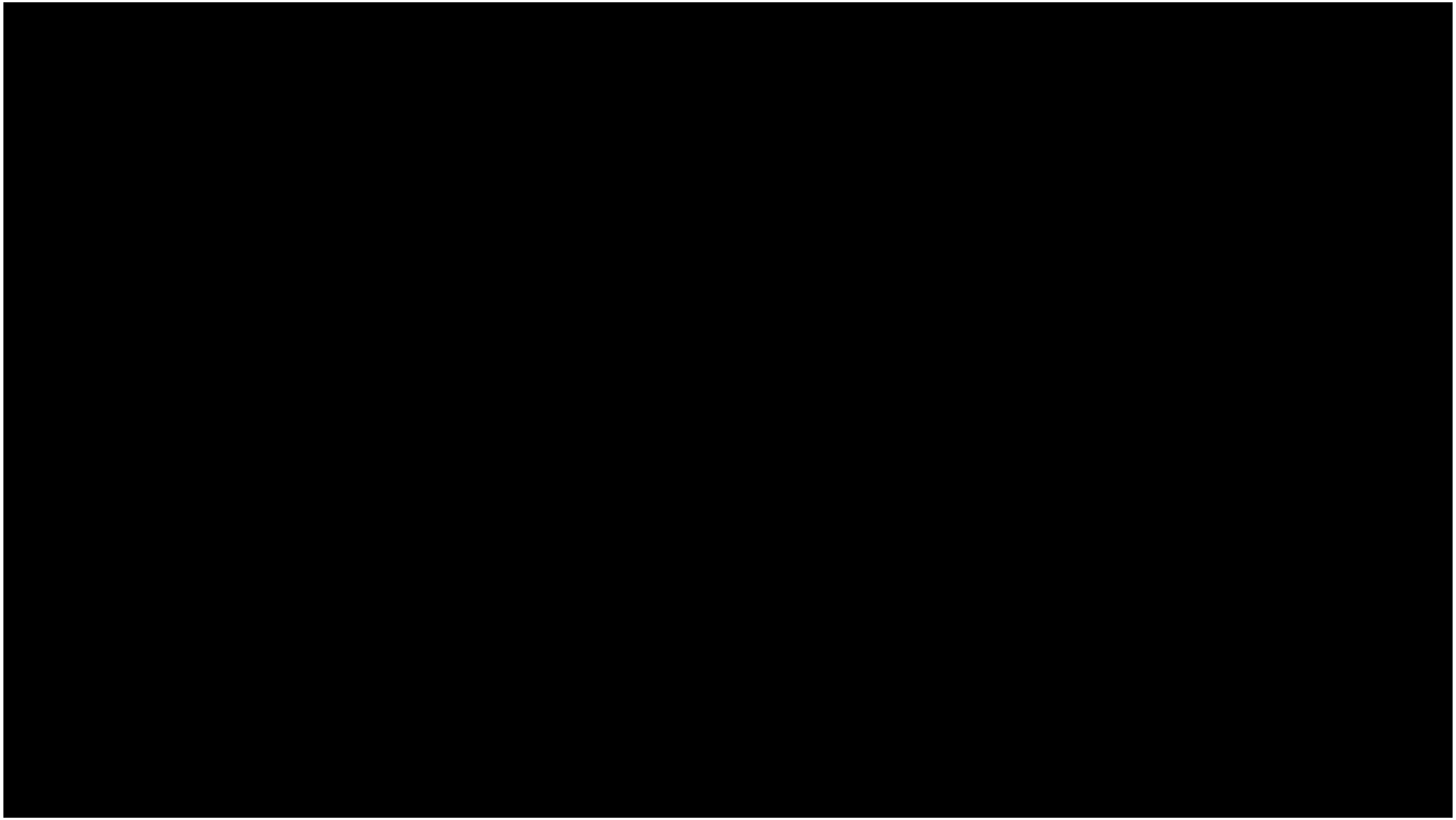
- 4 trasduttori di spostamento orizzontali
- 2 sensori di spostamento verticali
- 16 accelerometri
- 4 estensimetri sui controventi
- 36 estensimetri sui pali di fondazione
- 4 termometri digitali

Prova di spinta – strumentazione e sistema di acquisizione





Prova di spinta



Prova di spinta

The Tests

Objective: evaluate dynamic behavior
under extreme seismic events

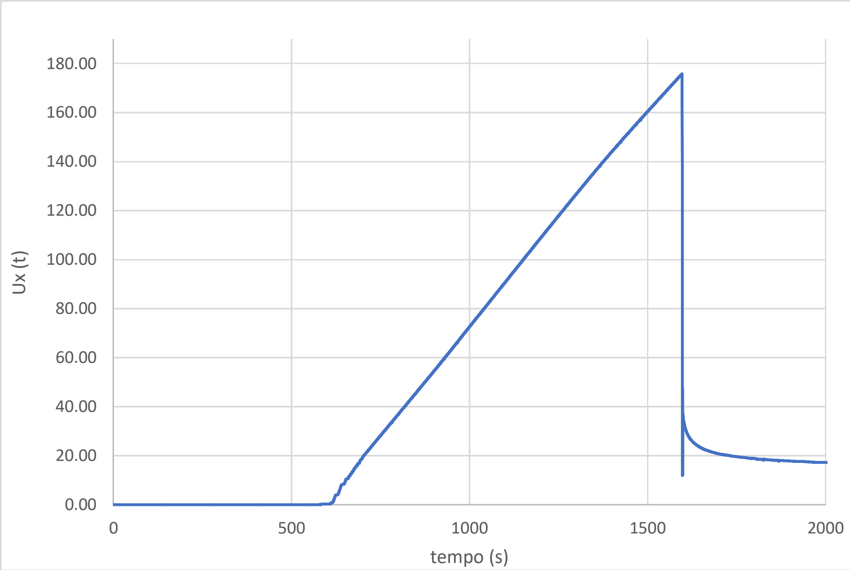
5 Dynamic tests
2 Static tests

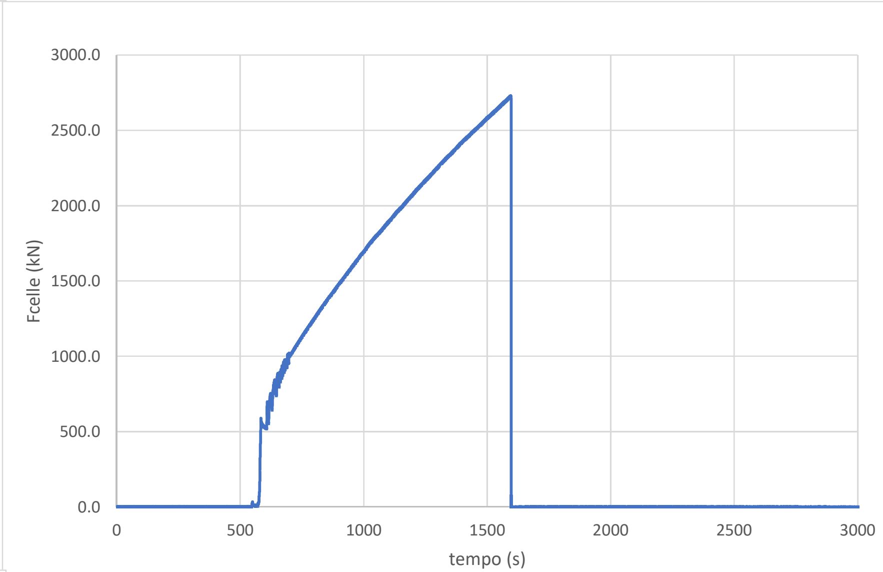
Prova di spinta – prove effettuate

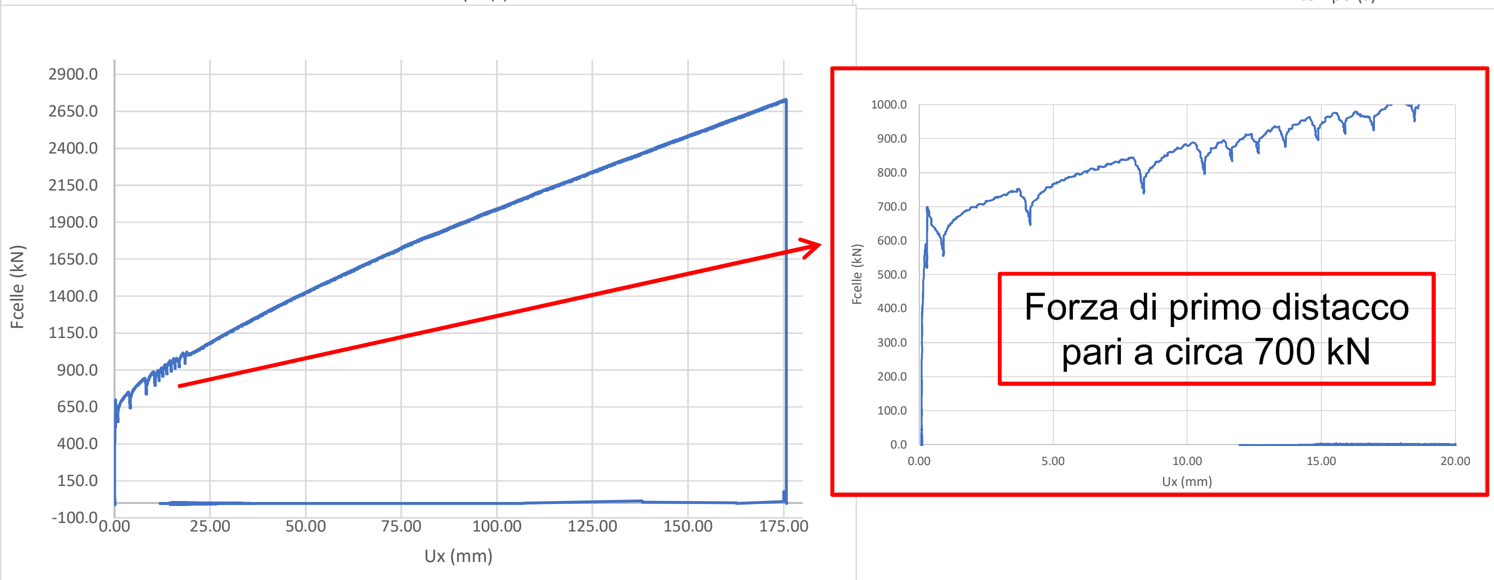
3 Luglio 2020	**1° prova**	**Prova di spinta preliminare per il collaudo** del sistema di spinta eseguita con un fusibile di diametro 10mm.
	2° prova	**Prova dinamica** con rottura del fusibile, di diametro 21mm, ottenendo uno spostamento massimo del sistema di isolamento pari a **175.7 mm**. La forza misurata dalle celle di carico è pari a **2753 kN**.
	3° prova	**Prova statica** fino a fine corsa dei martinetti corrispondente ad uno spostamento di **230 mm** e una forza massima delle celle di cario pari a **3228 kN** (e scarico)
6 Luglio 2020	**4° prova**	**Prova dinamica** con fusibile di 17mm e un tirante pari a 2000mm. Al momento della rottura lo spostamento misurato è di **88.1 mm** e la forza sulle celle pari a **1791.8 kN**.
	5° prova	**Prova dinamica** con fusibile di 22.5mm e tirante di 2000mm. Il massimo spostamento misurato è di **205.8 mm** e la forza misurata sulle celle pari a **3156.8 kN**.
	6° prova	**Prova dinamica** con fusibile di 17.2mm e tirante di 2000mm. Spostamento misurato a livello del sistema di isolamento pari a **100.7 mm** e forza sulle celle pari a **1829.5 kN**.
	7° prova	**Prova statica** fino ad uno spostamento massimo di **285 mm** e una forza massima delle celle di cario pari a **3868 kN** (e scarico)

Prova di spinta

Prova dinamica (prova n.2)

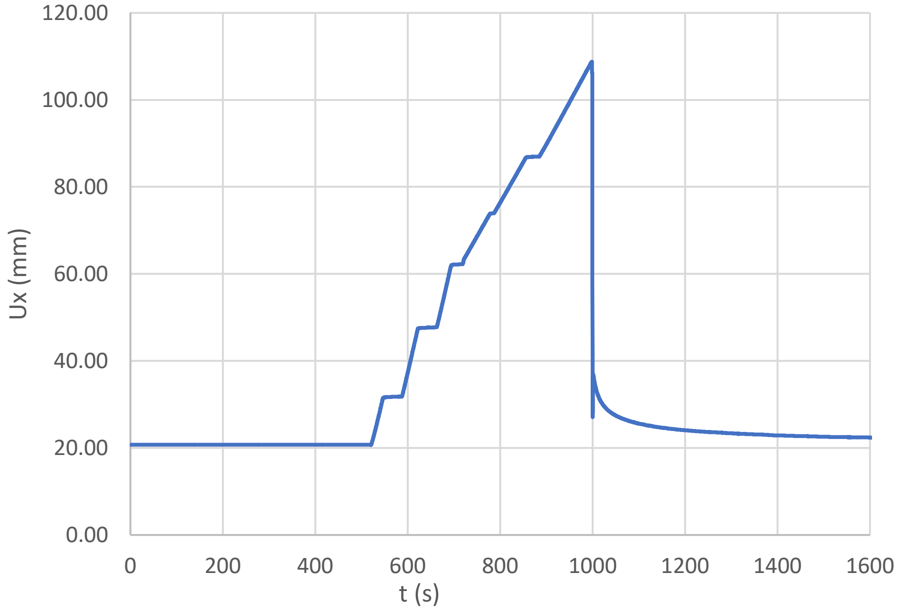


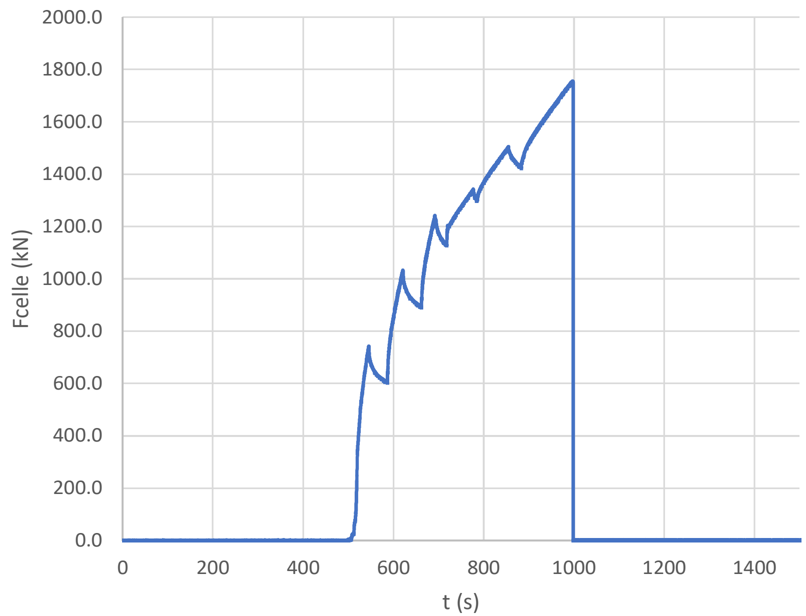


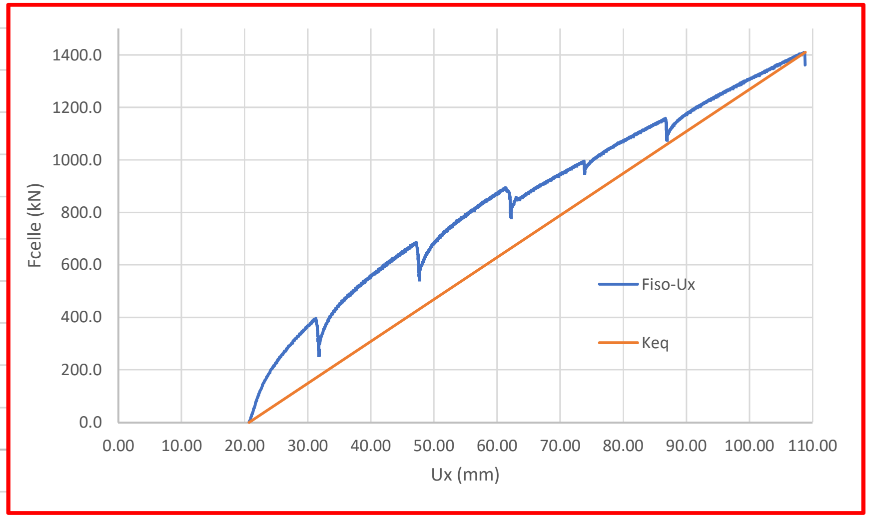


Prova di spinta

Prova dinamica (prova n.4)

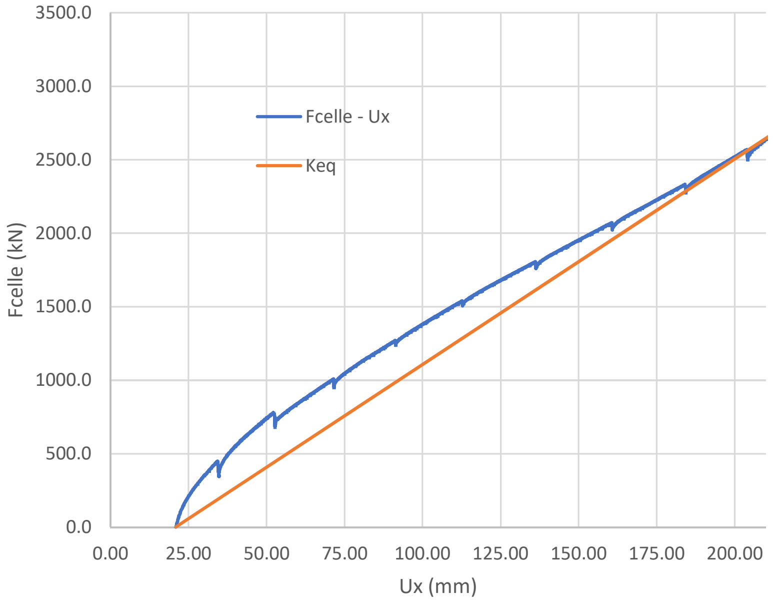


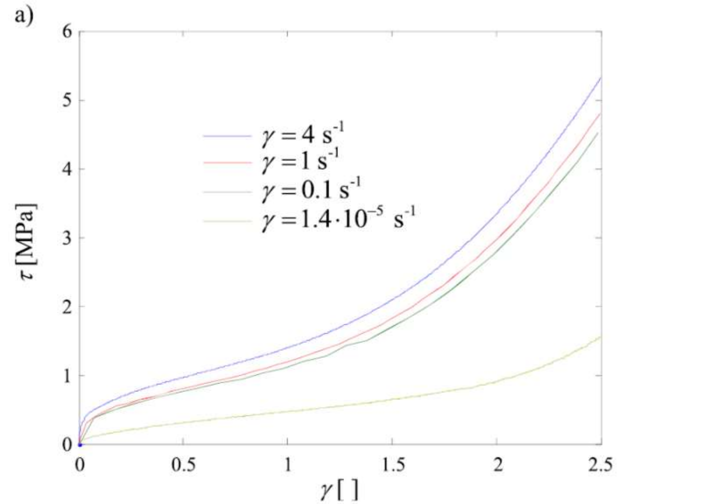




Prova di spinta

Prova dinamica (prova n.5)



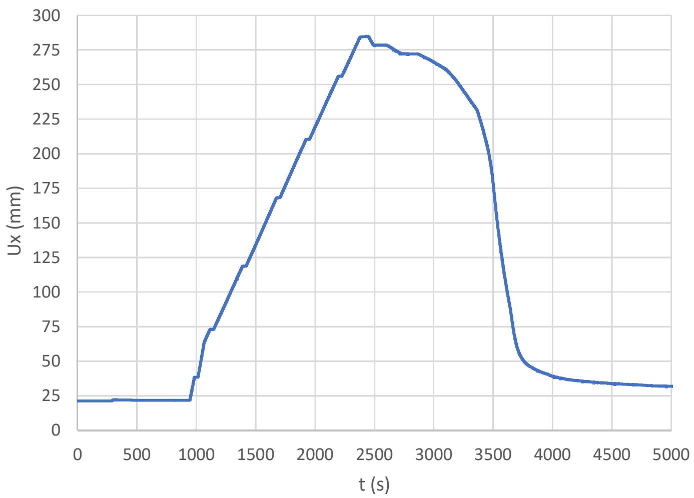


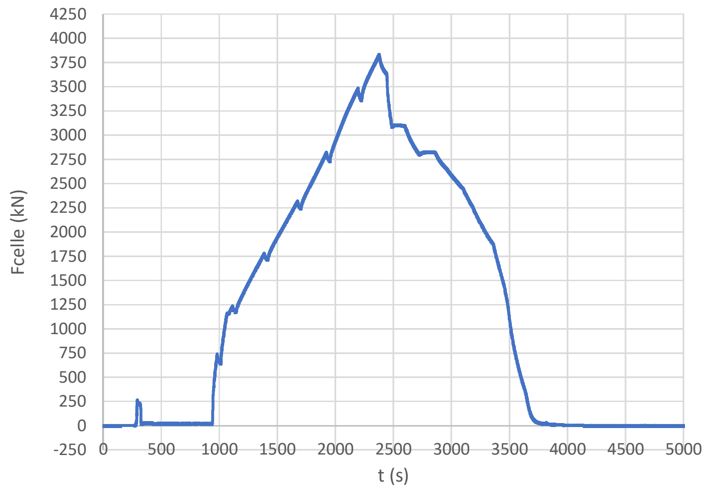
Stress softening behaviour of HDNR bearings: modelling and influence on the seismic response of isolated structures

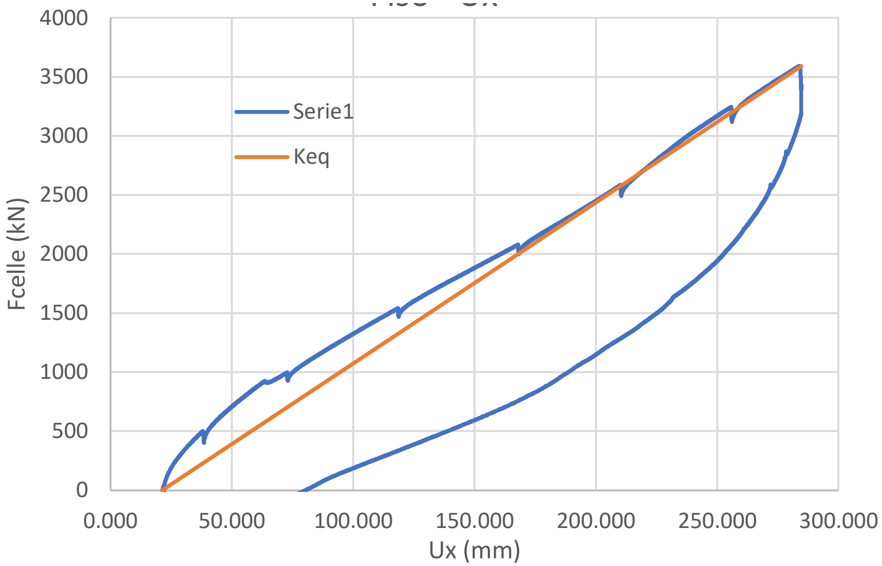
Enrico Tubaldi[1,*,†], Laura Ragni[2], Andrea Dall'Asta[3], Hamid Ahmadi[4] and Alan Muhr[4]

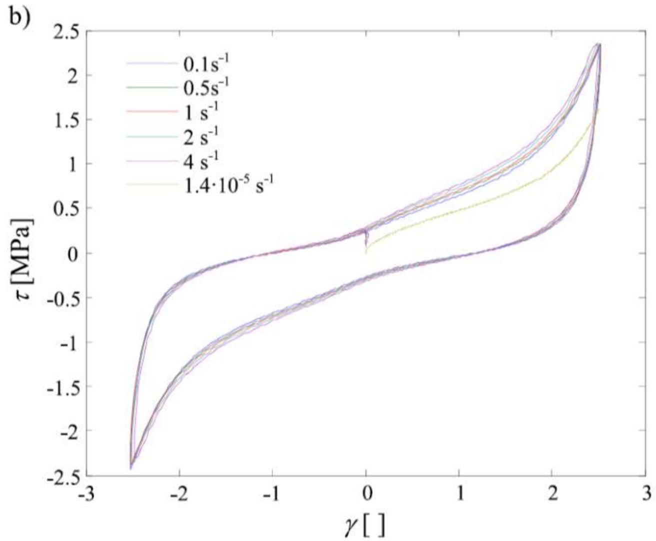
Prova di spinta

Prova statica (prova n.7)









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Progetto ed esecuzione di strutture isolate: Centro ricerche UniCAM (CHIP)

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https://youtu.be/Ou95s6_Jcws

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Ordine degli Ingegneri della Provincia di Macerata 29/01/2021