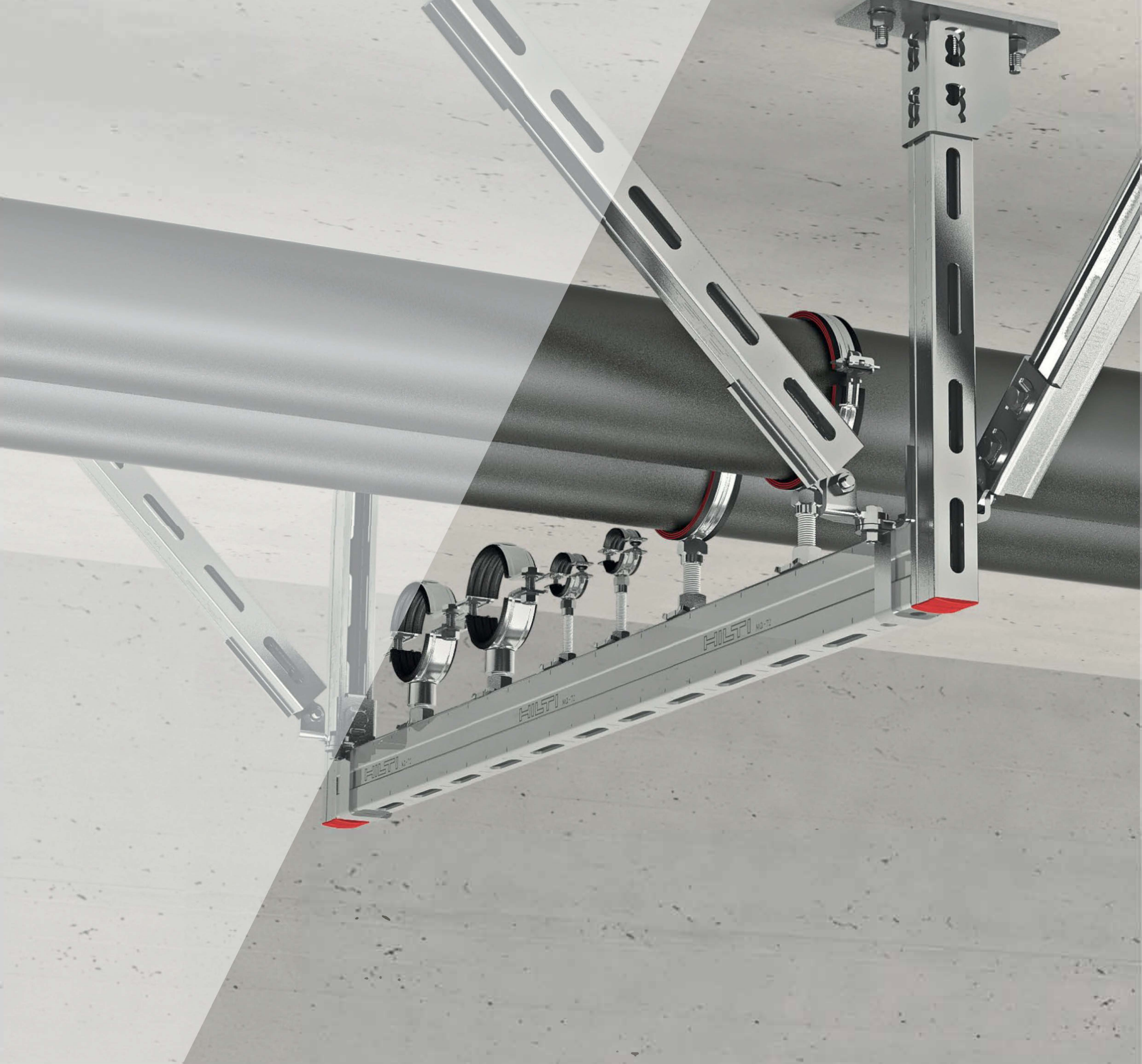
SEISMIK-HANDBUCH

Erdbebensicherheit von sekundären Bauteilen gemäss SIA 261

März 2021



Erdbebensicherheit von sekundären Bauteilen gemäss SIA 261

Planung und Berechnung von Erdbebensicheren Befestigungen von nicht tragenden Bauteilen und Installationen

Wichtiger Hinweis:
Wir empfehlen Ihnen bei der Ausarbeitung und Berechnungen Kontakt mit uns aufzunehmen, um eine Normengerechte Ausführung sicherzustellen. Bitte kontaktieren sie unser Engineering Team unter: ch-technik@hilti.com

oder alternativ unter:

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Ausgangslage

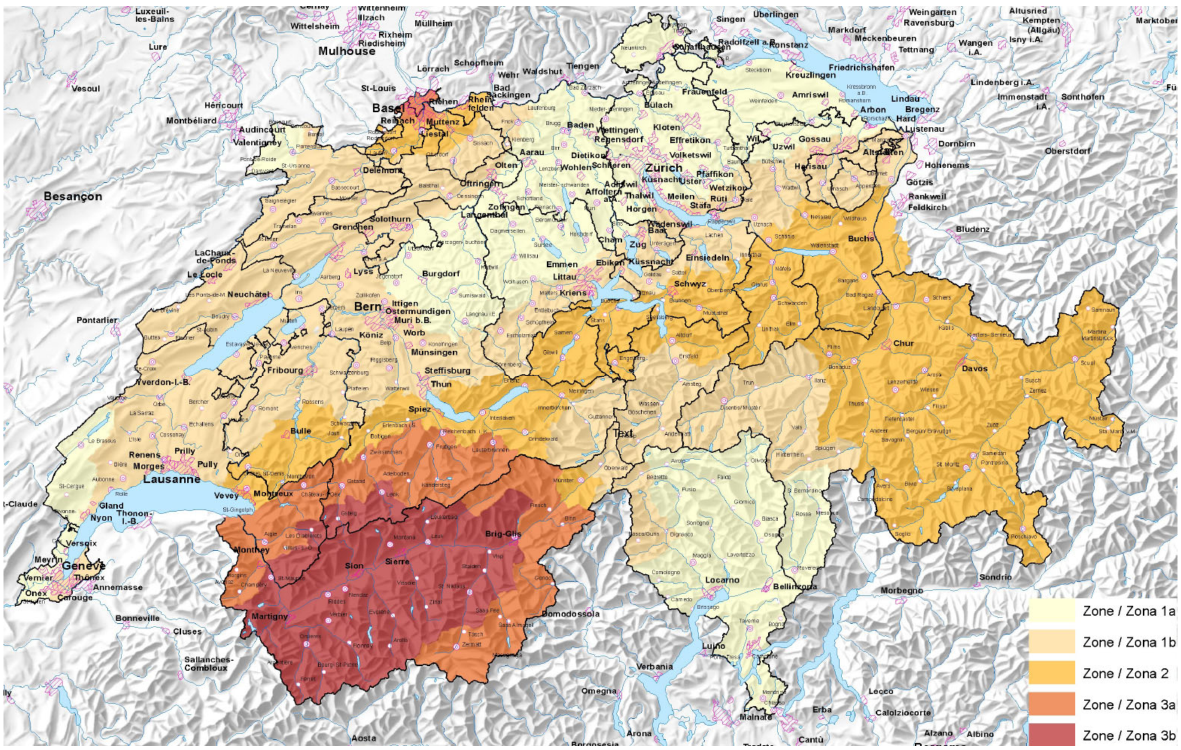
Erdbeben können überall in der Schweiz auftreten und weisen das bedeutendste Schadenpotential unter den Naturgefahren auf.

Bestehende Bauten weisen oft eine unbekannte und zum Teil ungenügende Erdbebensicherheit auf. Eine Überprüfung zeigt auf, ob verhältnismässige Massnahmen zielführend sind.

Die Berücksichtigung der Erdbebeneinwirkung bereits im Vorprojekt gemäss den geltenden SIA Tragwerksnormen für Neubauten (SIA 260 ff.) und für bestehende Bauten (SIA 269 ff.) bietet dank Bemessung und baulichen Massnahmen einen effizienten Schutz.

Gemäss Baugesetz sind Bauten und Anlagen nach den Anforderungen an die Erdbebensicherheit der anerkannten Regeln der Technik zu erstellen und zu unterhalten.

Erdbebengerechtes Bauen ist bei Neubauten kostengünstig.

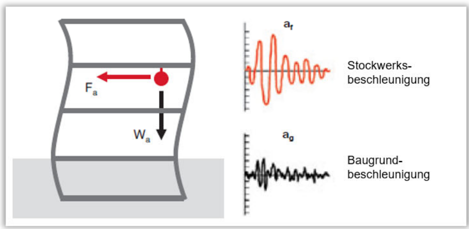


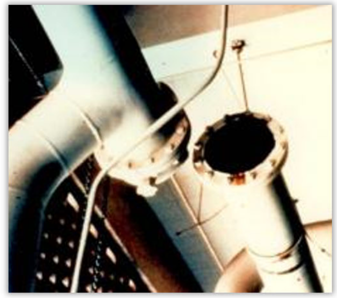
Hauptziel

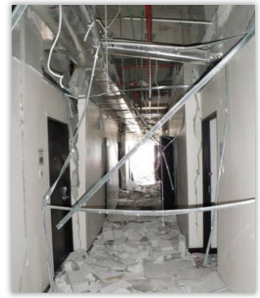
Das Schutzziel der erdbebengerechten Installation von Produktions- und Infrastrukturanlagen besteht grundsätzlich im Personenschutz, sowie je nach Anforderungen im Schutz der Umwelt vor schweren Schädigungen und der Schadensbegrenzung wichtiger Produktions- und Infrastrukturanlagen. Bei Life-Line Gebäuden wird darüber hinaus ein Funktionserhalt gefordert.

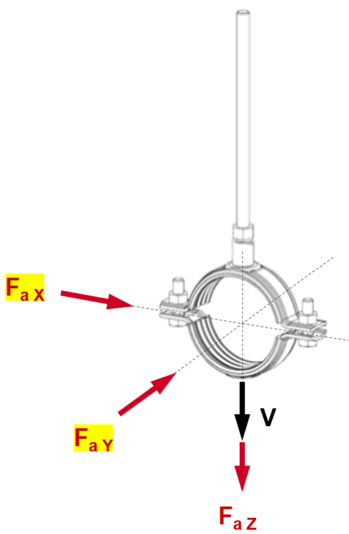
Technische Herausforderung

Ein **Erdbeben** verursacht **Vibrationen im Boden**, die sich auf das Gebäudetragwerk und auch **nicht-tragende Bauteile übertragen.**









- Ohne seismische Einwirkung, Bemessung der Halterung auf ständige Last **V**.
- Ein Erdbeben verursacht **zusätzliche Kräfte in allen Richtungen** auf die Rohrleitungen**.**
- Gemäss SIA 261 und EC8 können die zusätzlich vertikalen seismischen Einwirkungen $F_{a\,Z}$ vernachlässigt werden.
- Lasten in horizontaler Richtung $F_{a\,X}$ und $F_{a\,Y}$ sind in der Regel am kritischsten für die Rohrkonstruktion zu sehen.

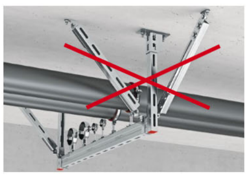
V = ständige Last

F_a = seismische Einwirkungen

Verantwortung

Werkeigentümer/innen sind für die Sicherheit verantwortlich und haften für Schäden an Personen und Güter (Art. 58 OR). Bestehende Gebäude sind somit periodisch dem neusten Stand der Sicherheit anzupassen.

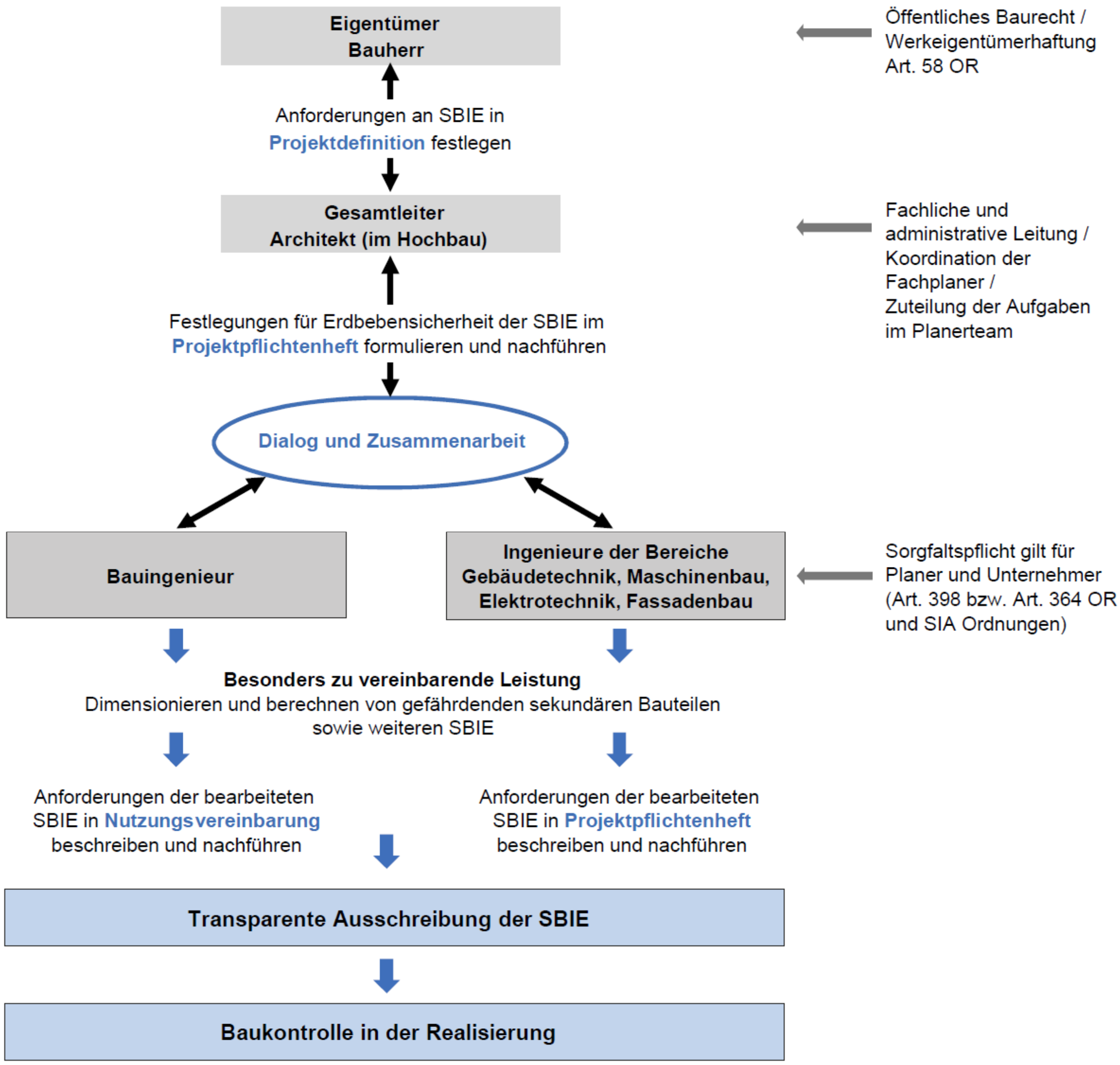
Planer/innen verpflichten sich, die anerkannten Regeln der Baukunde einzuhalten, welche durch die SIA-Normen vorgegeben werden (Art. 398 OR und SIA-Ordnungen).



Der Bauherr will keine erforderliche Erdbebenertüchtigung.
→ Der Planer muss in jedem Fall **abmahnen und zwar schriftlich**.
→ Allenfalls muss der Planer **vom Vertrag zurücktreten**.
→ Eine Haftung des Planers gegenüber dem Bauherrn entfällt. Nicht ausgeschlossen ist jedoch eine **ausservertragliche Haftung des Planers gegenüber Dritten** im Falle eines Erdbebenschadens. (Literatur: Institut für Schweizerisches und Internationales Baurecht Universität Freiburg)

Verantwortungen und Zuständigkeiten

Die Verantwortungen und Zuständigkeiten sind in der Empfehlung des Bundesamtes für Umwelt BAFU 'Erdbebensicherheit sekundärer Bauteile und weiterer Installationen und Einrichtungen', Abb. 3.1 aufgeführt.



SBIE (Sekundäre Bauteile und weitere Installationen und Einrichtungen)

Normative Anforderungen

SIA Normen

<u>SIA 261-2020 16.1.2 Allgemeines</u>

- Das mit der erdbebengerechten Projektierung angestrebte Schutzziel besteht im **Personenschutz**, der **Schadensbegrenzung** und der **Gewährleistung der Funktionstüchtigkeit** wichtiger Bauwerke unter der Einwirkung des Bemessungsbebens.

<u>SIA 261-2020 16.7.1 Sekundäre Bauteile</u>

- Für sekundäre Bauteile von Bauwerken der Bauwerksklassen I, II und III, die im Falle des Versagens **Personen gefährden**, das **Tragwerk beschädigen** können, ist sowohl für das Bauteil als auch für dessen <u>Verbindungen</u> und <u>Befestigungen</u> oder <u>Verankerungen</u> der Nachweis der Tragsicherheit zu erbringen.
- Gleiches gilt für sekundäre Bauteile von Bauwerken der Bauwerksklassen II und III, die eine **bedeutende Infrastrukturfunktion beeinträchtigen**, besonders **wertvolle Einrichtungen beschädigen** oder die **Umwelt gefährden** können.

(Hinweis: Unterkonstruktionen und Befestigungen für SBIE sind nach Auskunft des SIA gemäss den Tragwerksnormen SIA 260 bis 266 zu bemessen. Aus diesem Grund fehlen die entsprechenden Hinweise und Bemessungsregeln in den Normen, welche die SBIE direkt betreffen. Gerne unterstützen wir, falls Wissen bzw. das Bewusstsein für die Erdbebenproblematik fehlt)

> Die SIA Normen sind nicht in allen Schweizer Kantonen als verbindlich deklariert, gelten jedoch als aktueller Stand der Technik und sind - sofern nicht andere Normen, wie z.B. die SN EN Normen verwendet werden - somit als verbindlich anzusehen.

ETAG

Die ETA Richtlinie ETAG 001, Anhang E von 2013 definiert die seismische Zulassung von Befestigungen im Beton.

SN EN-Normen

Die sog. Eurocodes definieren den Umgang mit sekundären Bauteilen analog den SIA-Normen. Relevant ist dabei insbesondere EN 1998-1_2006-04, Art. 4.3.5.

SIA 261: Nicht tragende Bauteile

Im Massenschwerpunkt des Bauteils ist folgende Horizontalkraft in beiden horizontalen Richtungen aufzubringen:

$$F_a = \frac{\gamma_f \, a_{gd} \, S \, G_a}{g \, q_a} \left[\frac{3\left(1 + \frac{z_a}{h}\right)}{1 + \left(1 - \frac{T_a}{T_1}\right)^2} - 0{,}5 \right] \geq \frac{\gamma_f \, a_{gd} \, S \, G_a}{g \, q_a} \qquad (49)$$

Gebäudeklassifizierungen

G_a	Eigenlast des Bauteils *(gemäss Hilti PROFIS Installation)*	
a_{gd}	Bodenbeschleunigung / Erdbebenzone Z1a (SIA 261: 16.2.1.2)	0.60 m/s²
g	Erdbeschleunigung: 1m/s²=0.1g / 1g=9.81 m/s²	9.81 m/s²
S	Baugrundklasse C (SIA 261: 16.2.2.4 Tabelle 24)	1.45 ---
z_a	Höhe eines nicht tragenden Bauteils über dem Fundament *(gemäss Planvorgabe)*	5.00 m
h	Gesamthöhe des Gebäudes *(gemäss Planvorgabe)*	20.00 m
T_1	Grundschwingzeit Bau-/Tragwerk (Angabe Bauingenieur)	0.631 s
T_a	Grundschwingzeit eines nicht tragenden Bauteils (Rohre)	0.631 s
T_a	Grundschwingzeit eines nicht tragenden Bauteils (Elektro & Lüftung)	0.000 s
y_f	Bedeutungsbeiwert / Bauwerksklasse BWK II (SIA 261: 16.3.1.2 Tabelle 25)	1.2 ---
q_a	Verhaltensbeiwert (SIA 261: 16.7.3)	1.5 ---

Benötigte Unterlagen – Anfrageformular

Installationstechnik Erdbebenberechnung nach SIA 261 – für sekundäre Bauteile

Kundendaten:		**Objektdaten:**	
Firma:	....	Objekt:	....
Adresse:	....	Bauteil:	....
Kunden Nr.:	....	Adresse:	....
Ansprechperson:	....		....
Telefon:	....		
E-Mail:	....		

Erdbebenzonen a_{gd} SIA 261 – 16.2.1.2

☐ Zone Z1a (a_{gd} 0.6 m/s) ☐ Zone Z1b (a_{gd} 0.8 m/s) ☐ Zone Z2 (a_{gd} 1.0 m/s) ☐ Zone Z3a (a_{gd} 1.3 m/s) ☐ Zone 3b (a_{gd} 1.6 m/s)

Baugrundklasse S SIA 261 – 16.2.2.4 Tabelle 24

☐ A (S 1.00, Harter Fels od. weicher Fels unter max. 5m Lockergest.) ☐ B (S 1.20, zementierter Kies/Sand, Lockergesteine über 30 m)

☐ C (S 1.45, unzementierter Kies/Sand über 30m) ☐ D (S 1.70, Feinsand/Silt/Ton über 30m)

☐ E (S 1.70, C + D zw. 5-30 m über steiferen Schicht A + B) ☐ F1 (organische Ablagerungen, Torf/Seekreide)

Bauwerksklasse BWK γ_f SIA 261 – 16.3 Tabelle 25

☐ I (γ_f 1.0, Wohn-, Büro- und Gewerbegeb.) ☐ II (γ_f 1.2, Spitäler, Sportanlagen, öff. Verw.) ☐ III (γ_f 1.5, Akutspitäler, Katastrophenschutz)

Verhaltensbeiwert / Tragwerkverhalten (für sekundäre Bauteile) q_a SIA 261 – 16.7.3

☐ q_a 1.5, Bem. des sekundären Bauteils und der zugehörigen Verankerungen und Befestigungen ☐ q_a 1.0 Nachweis für die Grenzzustände Abheben und Kippen des sekundären Bauteils

Grundschwingzeit T_1 SIA 261 – 16.5.2.3

.... s T_1 Grundschwingzeit des Bauwerks (Tragwerk)

Gebäudehöhe / Höhe des Bauteils Gemäss Planvorgabe (Gebäudeschnitt)

.... m z_a Höhe eines nicht tragenden Bauteils über dem Fundament .... m h Gesamthöhe des Gebäudes

Seismische Leistungskategorie Dübel

☐ C1 oder… ☐ C2

Wo/Welche Bereiche sind gegen Erdbeben zu sichern?

....

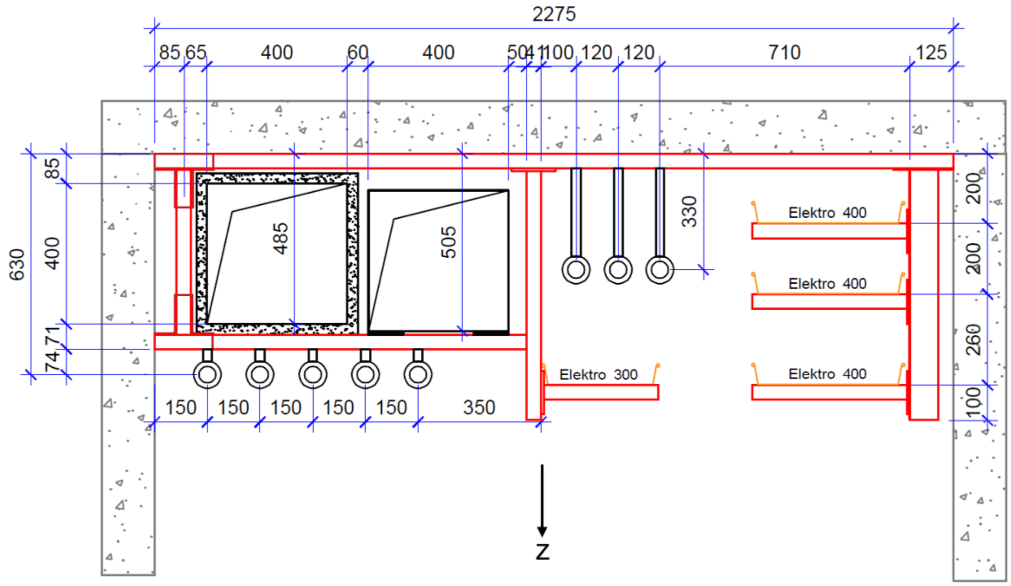
....

Nichttragende Bauteile		
Beschleunigung (a_g·S)	Gebäudeklasse BWK I & II	Gebäudeklasse BWK III
< 0.05 g	seismisch nicht relevant	
0.05 g to 0.1 g	ETA C1	ETA C2
> 0.1 g	ETA C2	

Formel gemäss SIA 261:2020, 16.7.2

$$F_a = \frac{\gamma_f\, a_{gd}\, S\, G_a}{g\, q_a}\left[\frac{3\left(1+\frac{z_a}{h}\right)}{1+\left(1-\frac{T_a}{T_1}\right)^2} - 0{,}5\right] \geq \frac{\gamma_f\, a_{gd}\, S\, G_a}{g\, q_a}$$

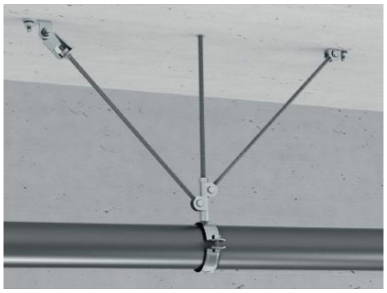
Benötigte Unterlagen – Schnitt / Typ



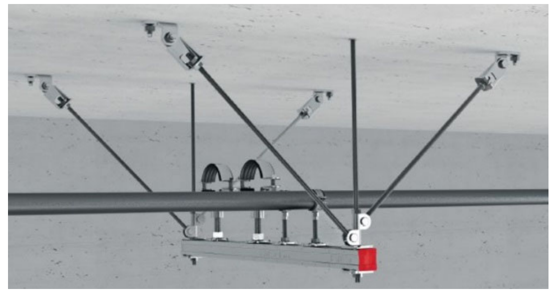
Angaben:
Befestigungsabstand, Medium, Durchmesser, Isolations-Material & -Stärke → Ergibt Last z
Gesamthöhne des Gebäudes, Höhe des Bauteils

Mögliche Lösungsvorschläge

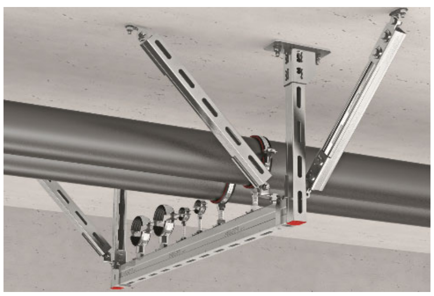
Einzelpunktbefestigung



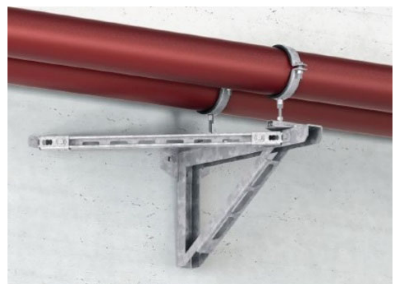
Abgehängte Schiene mit Gewindestange



U-Joch mit Schienen



Wandkonsolen

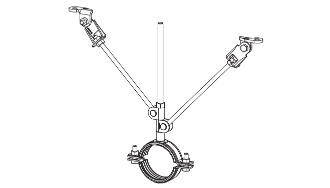
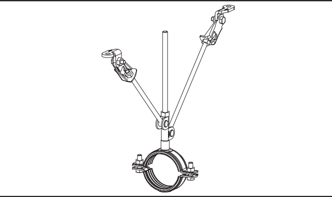


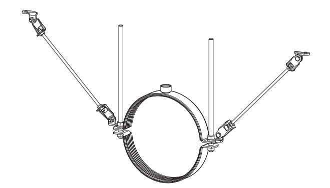
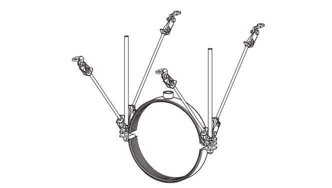
Literaturverzeichnis

- SIA 261:2020 Bauwesen (SN 505 261)
- Erdbebensicherheit sekundärer Bauteile und weiterer Installationen und Einrichtungen (BAFU)
- ETAG 001, Anhang E (1. Juli 2013)
- ETA-11/0006
- SN EN 1998-1_2006-04

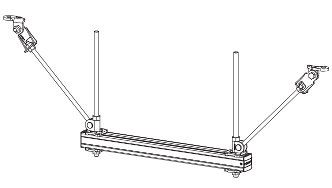
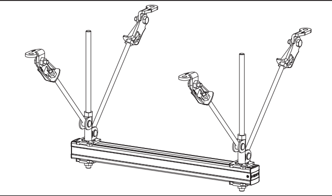
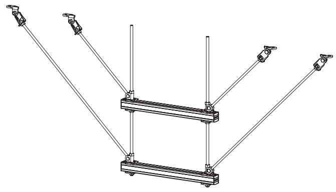
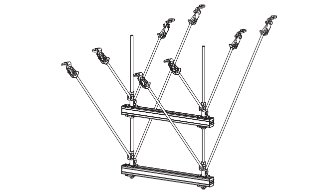
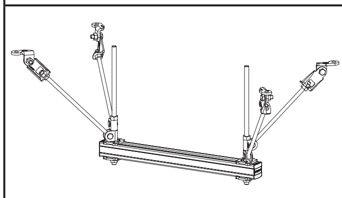
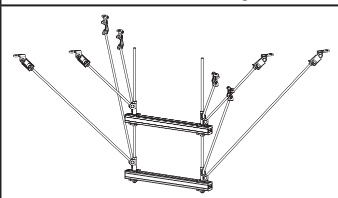
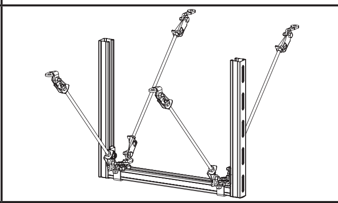
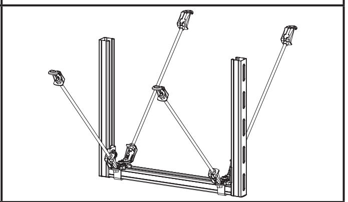
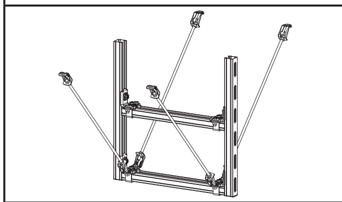
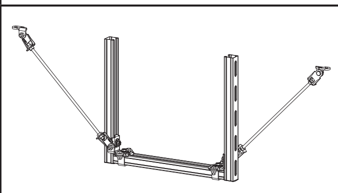
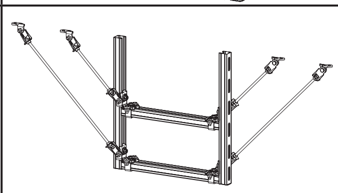
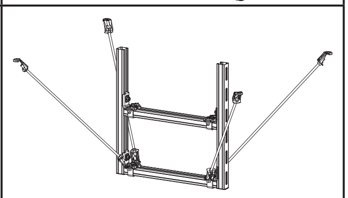
3.3 Collection of typical applications

Single pipe

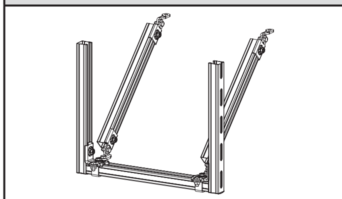
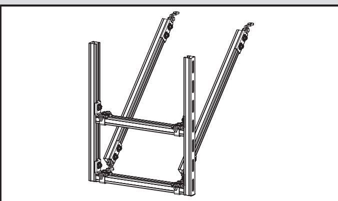
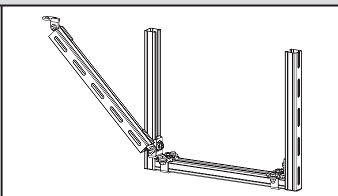
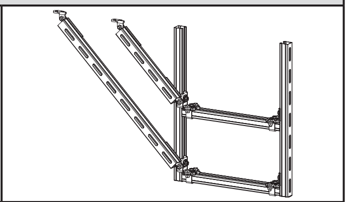
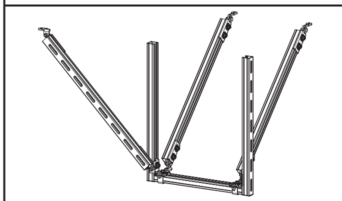
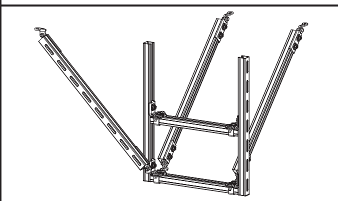
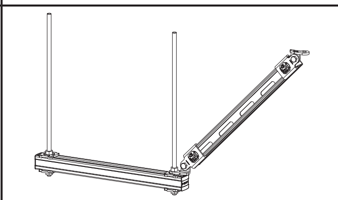



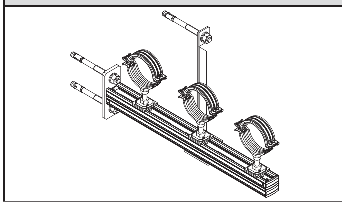
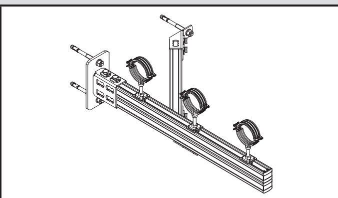
Trapeze – seismic bracing with rods

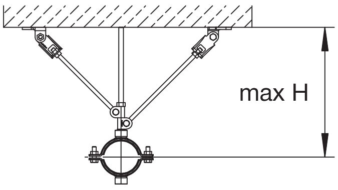
Trapeze – seismic bracing with channels

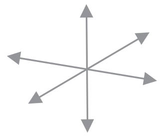








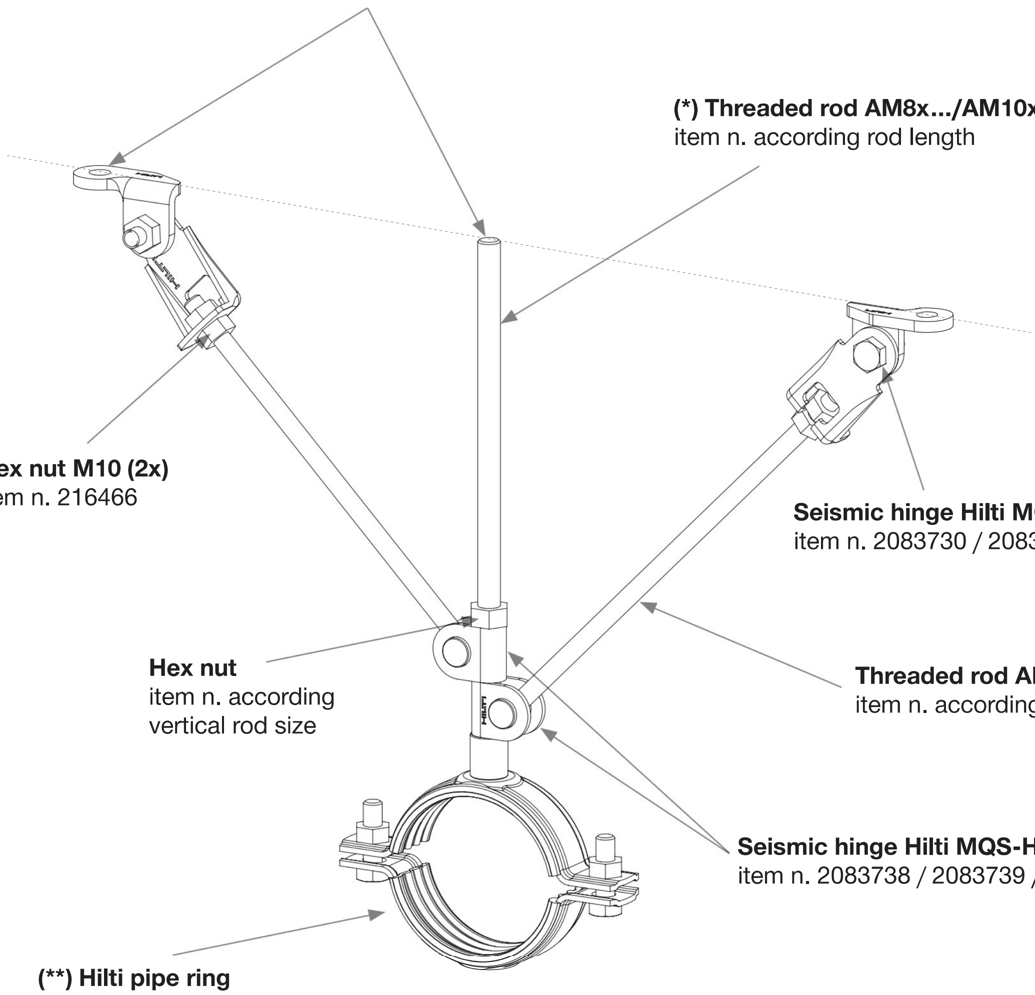
Wall bracket

Single pipe Transversal bracing	Max. design load (seismic horizontal) in [N]	
	Longitudinal [Y]	Transversal [X]
	- 0 -	- 800 -



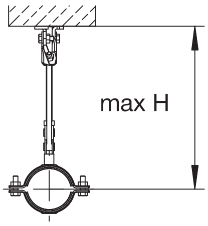




General Design Notes
Design loads are stated in this paper are depending on following conditions:
- (*) using M10 or M12 rods; for applications with M8 vertical rod, please contact the Hilti Technical Service
- (**) for relevant pipe rings – see Annex D
- max. height H – top of ceiling to center of pipe: 800 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C

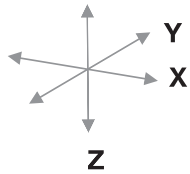
MQS System
Seismic Designed Solutions

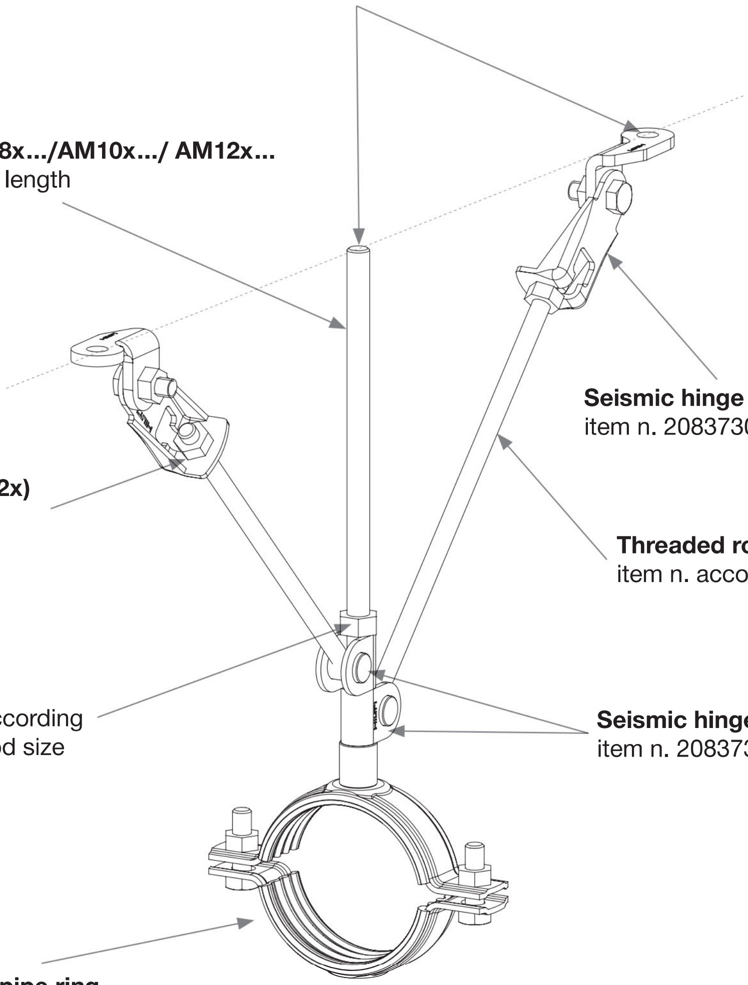
Single pipe Longitudinal bracing	Max. design load (seismic horizontal) in [N]	
	Longitudinal [Y]	Transversal [X]
	- 800 -	- 0 -



⌀ pipe ≤ 4”

SEISMIC LOAD ORIENTATION





General Design Notes

Design loads are stated in this paper are depending on following conditions:

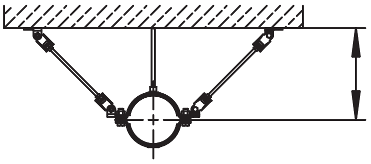
- (*) using M10 or M12 rods; for applications with M8 vertical rod, please contact the Hilti Technical Service
- (**) for relevant pipe rings – see Annex D
- max. height H – top of ceiling to center of pipe: 800 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C

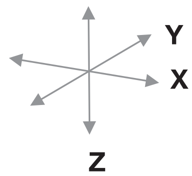
MQS System

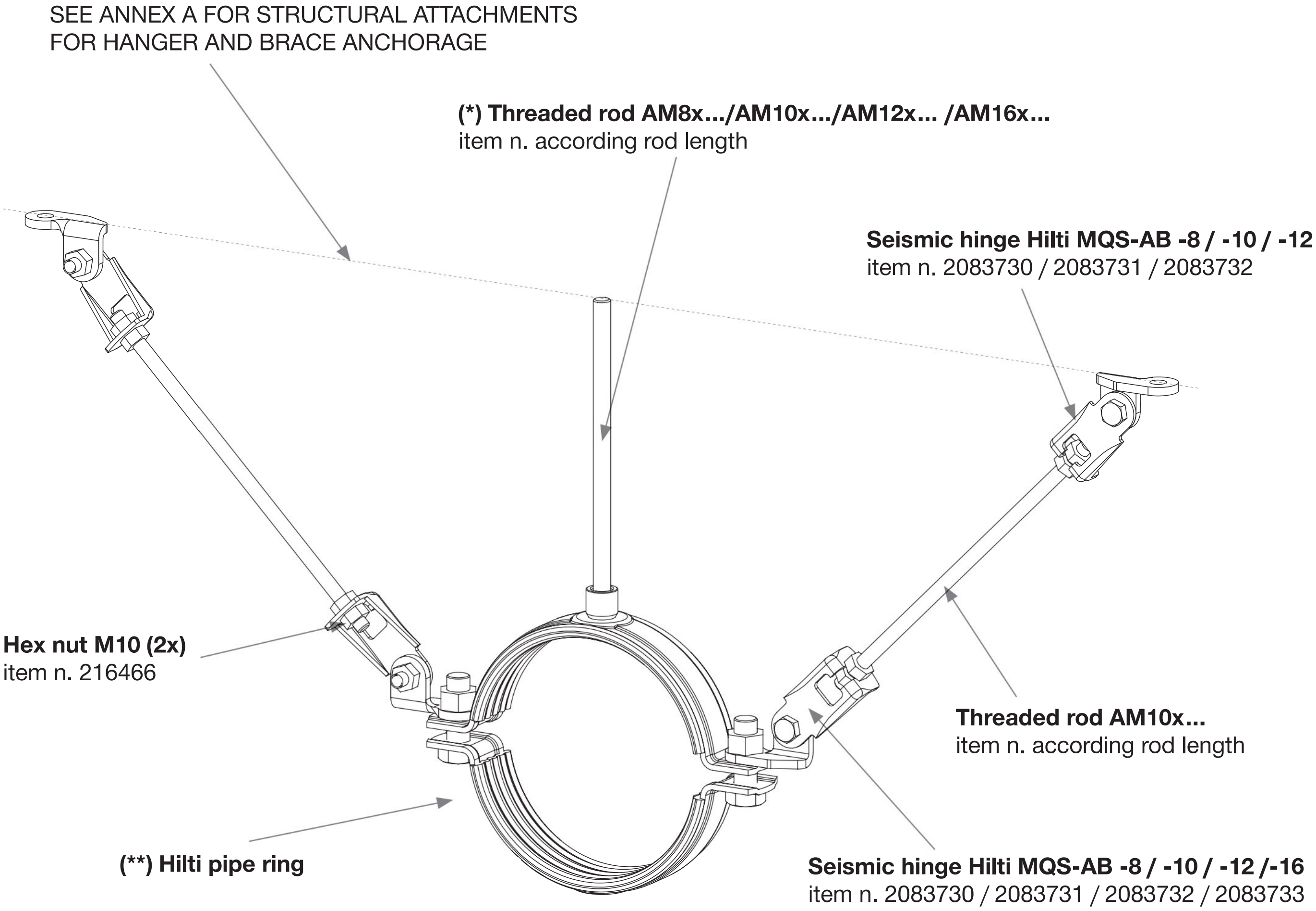
Seismic Designed Solutions

Single pipe Transversal bracing

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
- 0 -	- 1500 -



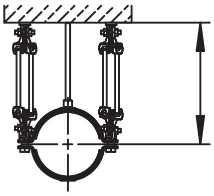




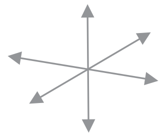
General Design Notes
Design loads are stated in this paper are depending on following conditions:
- (*) using M10, M12 or M16 rods; for applications with M8 vertical rod, please contact the Hilti Technical Service
- (**) for relevant pipe rings – see Annex D
- max. height H – top of ceiling to center of pipe: 800 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C

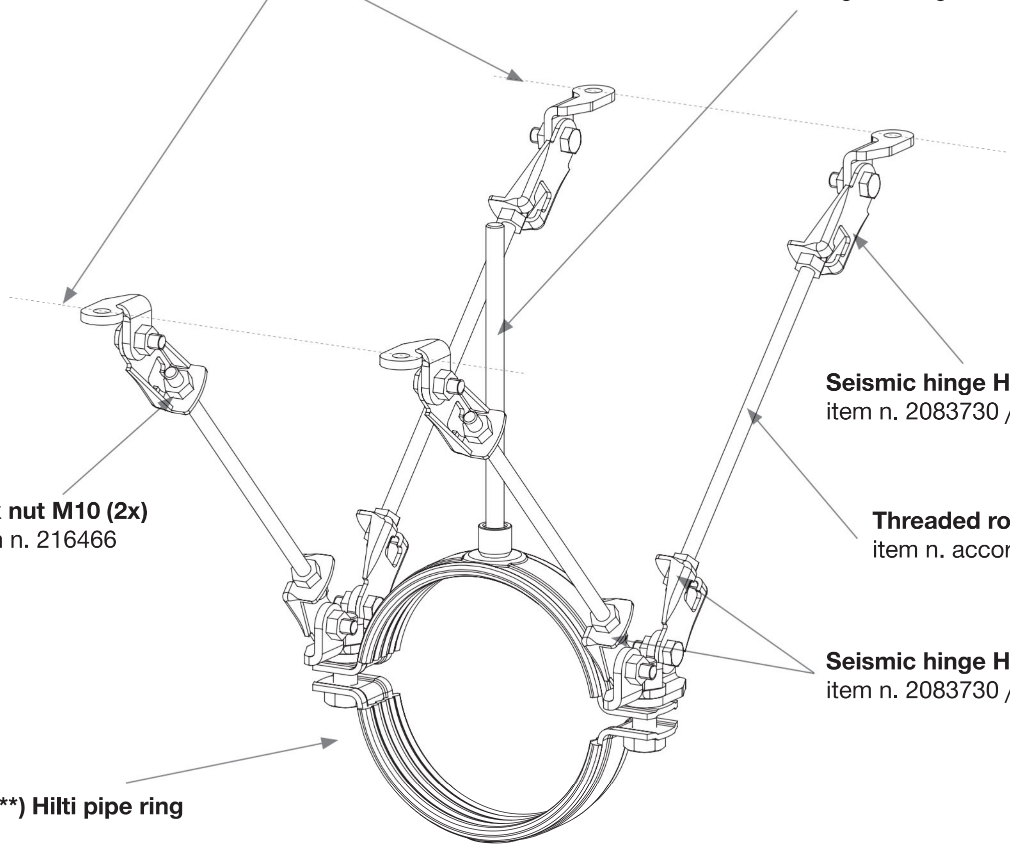
MQS System
Seismic Designed Solutions

Single pipe Longitudinal bracing	Max. design load (seismic horizontal) in [N]	
	Longitudinal [Y]	Transversal [X]
	- 1500 -	- 0 -



4” ≤ ø pipe ≤ 324 mm



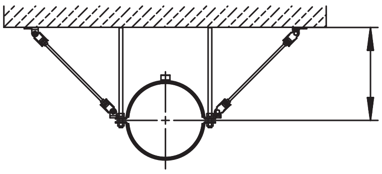


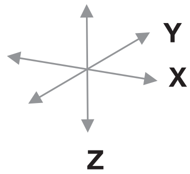
General Design Notes
Design loads are stated in this paper are depending on following conditions:
- (*) using M10, M12 or M16 rods; for applications with M8 vertical rod, please contact the Hilti Technical Service
- (**) for relevant pipe rings – see Annex D
- max. height H – top of ceiling to center of pipe: 800 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C

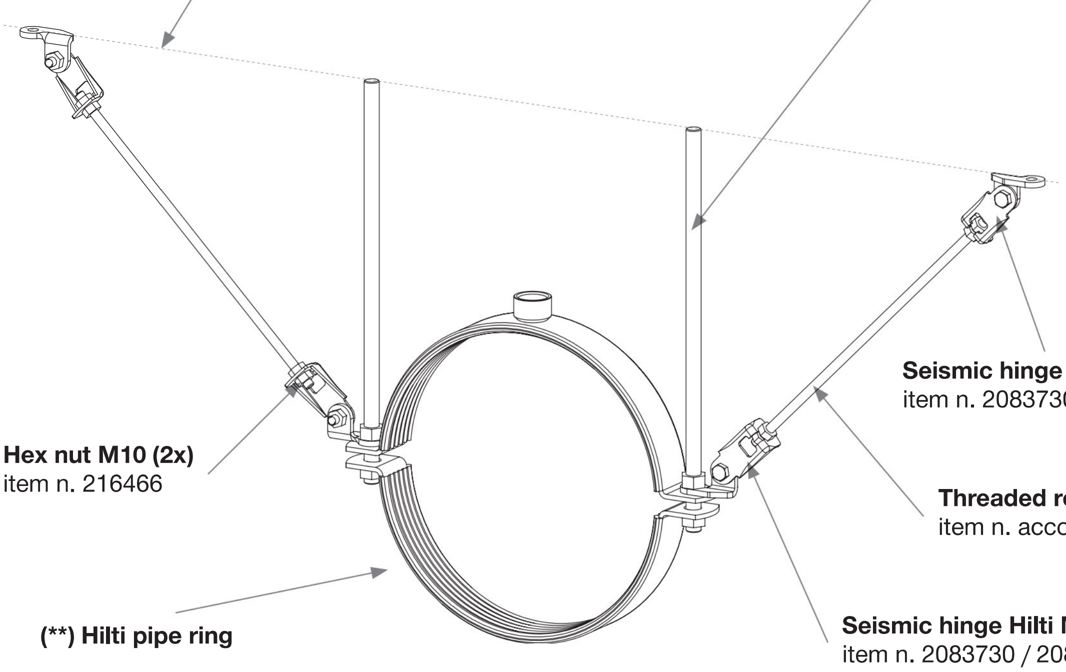
MQS System
Seismic Designed Solutions

Single pipe Transversal bracing

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
- 0 -	- 2800 -







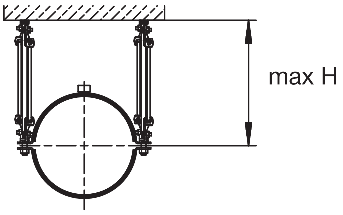
General Design Notes

Design loads are stated in this paper are depending on following conditions:

- (*) using M10, M12 or M16 rods; for applications with M8 vertical rod, please contact the Hilti Technical Service
- (**) for relevant pipe rings – see Annex D
- max. height H – top of ceiling to center of pipe: 800 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C

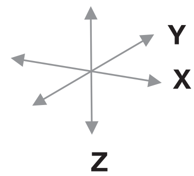
MQS System
Seismic Designed Solutions

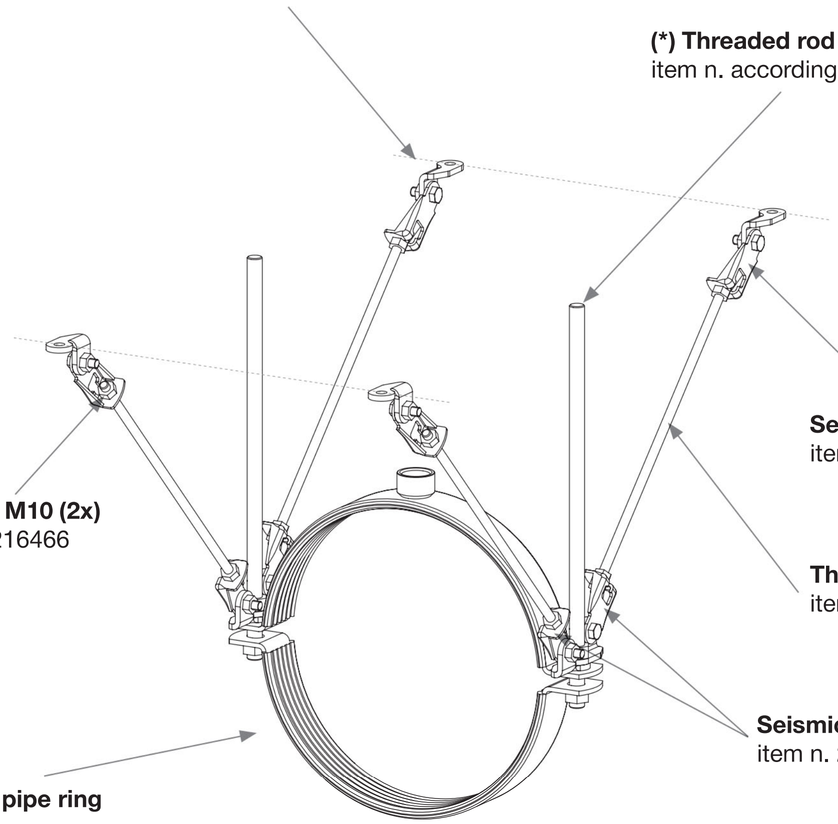
Single pipe Longitudinal bracing	Max. design load (seismic horizontal) in [N]	
	Longitudinal [Y]	Transversal [X]
	- 2800 -	- 0 -



∅ pipe ≥ 324 mm

SEISMIC LOAD ORIENTATION



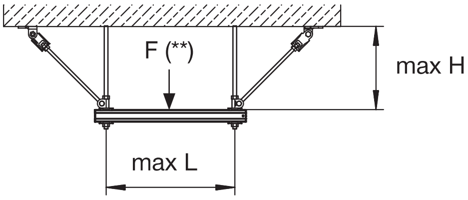


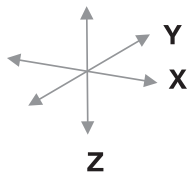
General Design Notes
Design loads are stated in this paper are depending on following conditions:
- (*) using M10, M12 or M16 rods; for applications with M8 vertical rod, please contact the Hilti Technical Service
- (**) for relevant pipe rings – see Annex D
- max. height H – top of ceiling to center of pipe: 800 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C

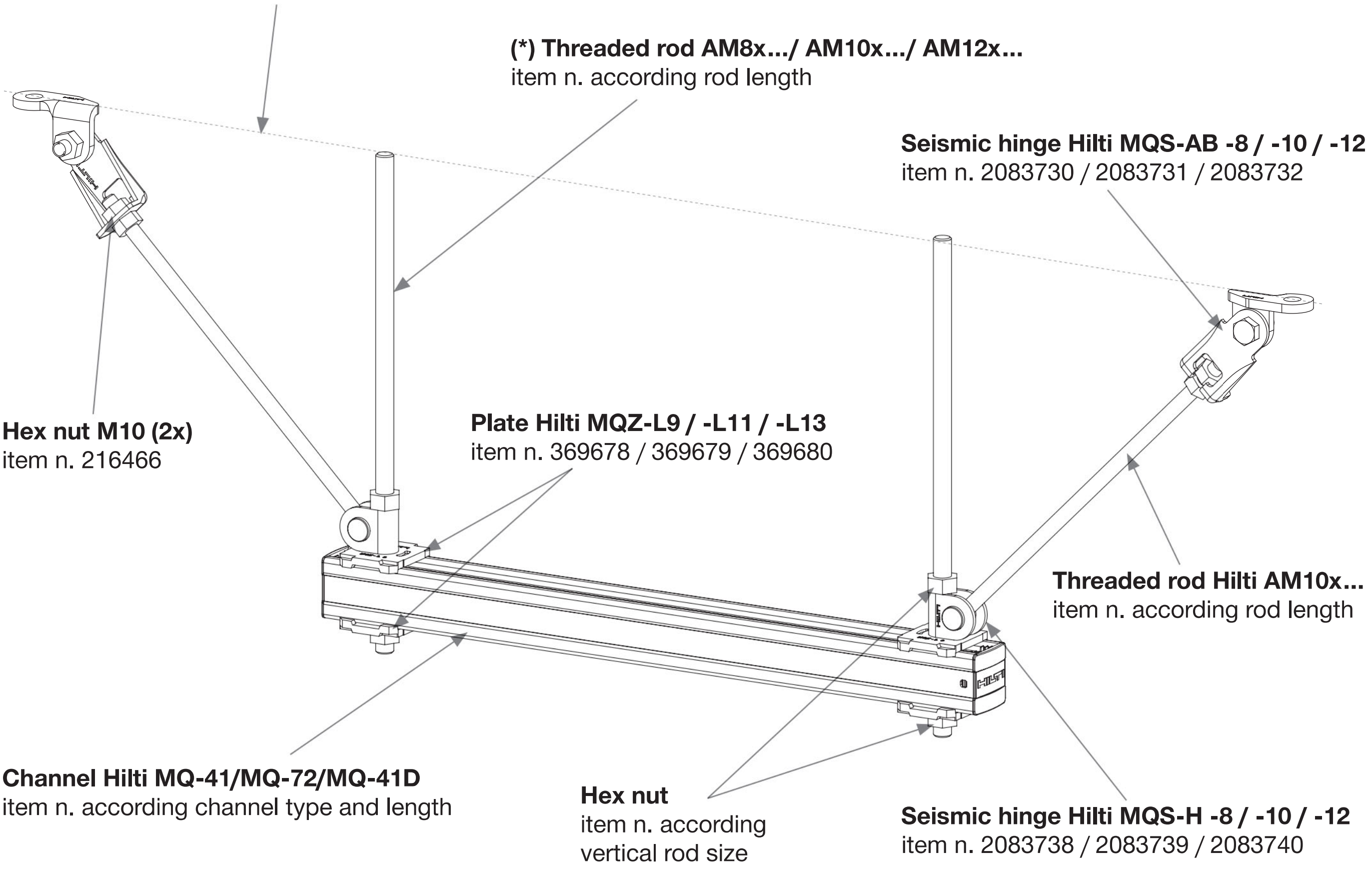
MQS System
Seismic Designed Solutions

Trapeze with rod bracing Transversal

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
- 0 -	- 2500 -







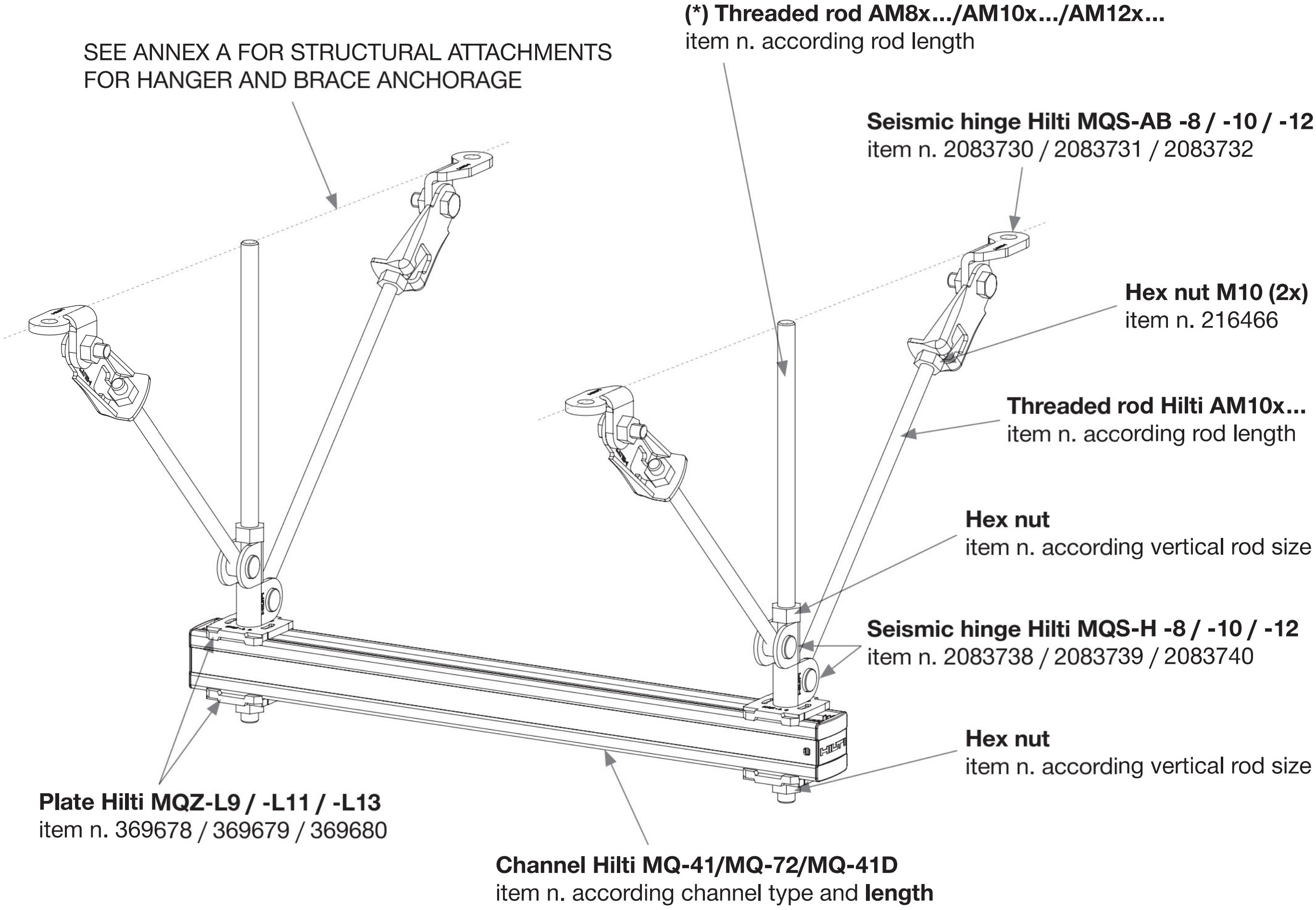
General Design Notes

Design loads are stated in this paper are depending on following conditions:

- (*) using M10 or M12 rods; for applications with M8 vertical rods, please contact the Hilti Technical Service
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(**): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

MQS System
Seismic Designed Solutions

# Trapeze with rod bracing Longitudinal	Max. design load (seismic horizontal) in [N]	
	Longitudinal [Y]	**Transversal [X]**
	- 2800 -	- 0 -



General Design Notes

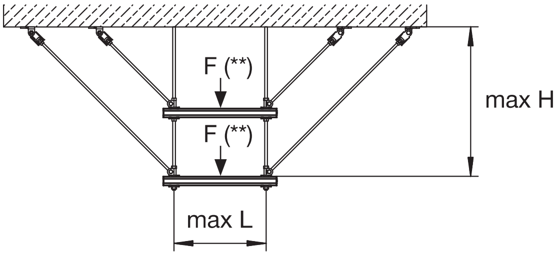
Design loads are stated in this paper are depending on following conditions:

- (*) using M10 or M12 rods; for applications with M8 vertical rods, please contact the Hilti Technical Service
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(**): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

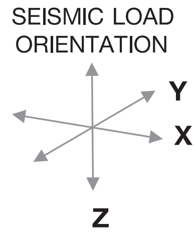
MQS System
Seismic Designed Solutions

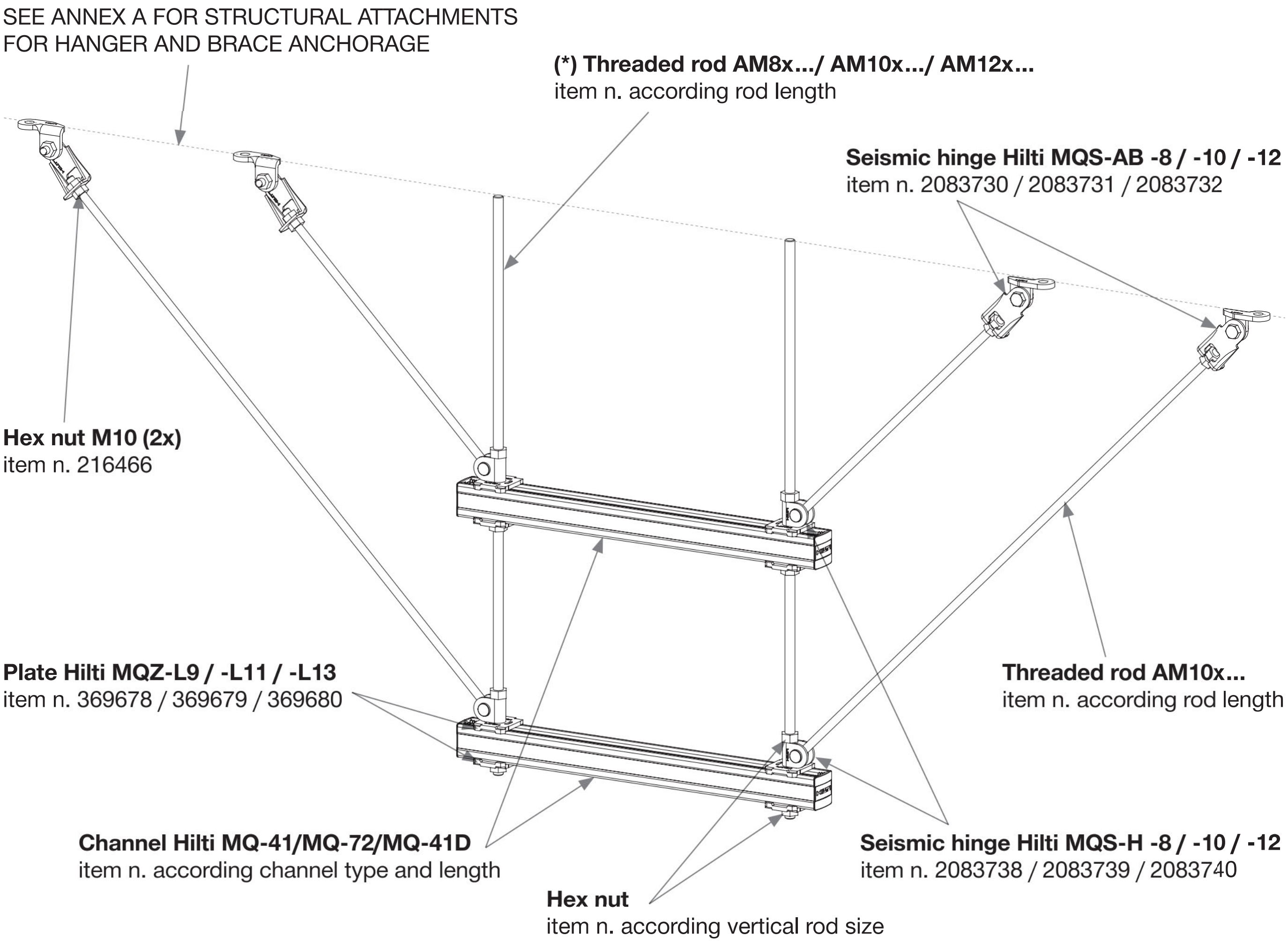
Trapeze with rod bracing Transversal – Multilevel

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
- 0 -	- 2500 - **(1)**



(1) max desing load for each channel level





General Design Notes

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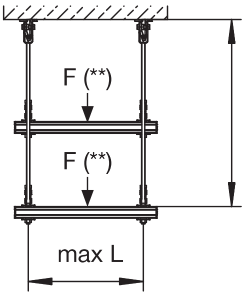
- (*) using M10 or M12 rods; for applications with M8 vertical rods, please contact the Hilti Technical Service
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B "Selection Tables" or use PROFIS Installation
- F(**): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

MQS System
Seismic Designed Solutions

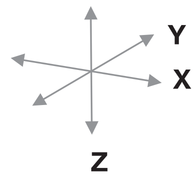
Hilti strongly advises the Customer to verify the respective application by consultation and calculation of an structural engineer for the compliance of the product with applicable norms and standards. The non-involvement of a structure engineer will lead to a release of Hilti's liability. It is required that the Product is used strictly according to the applicable Hilti Instruction For Use and within the application limits specified in the Hilti Technical Data Sheets, the technical specifications and supporting Product literature, and the relevant application limits were not exceeded at any time.

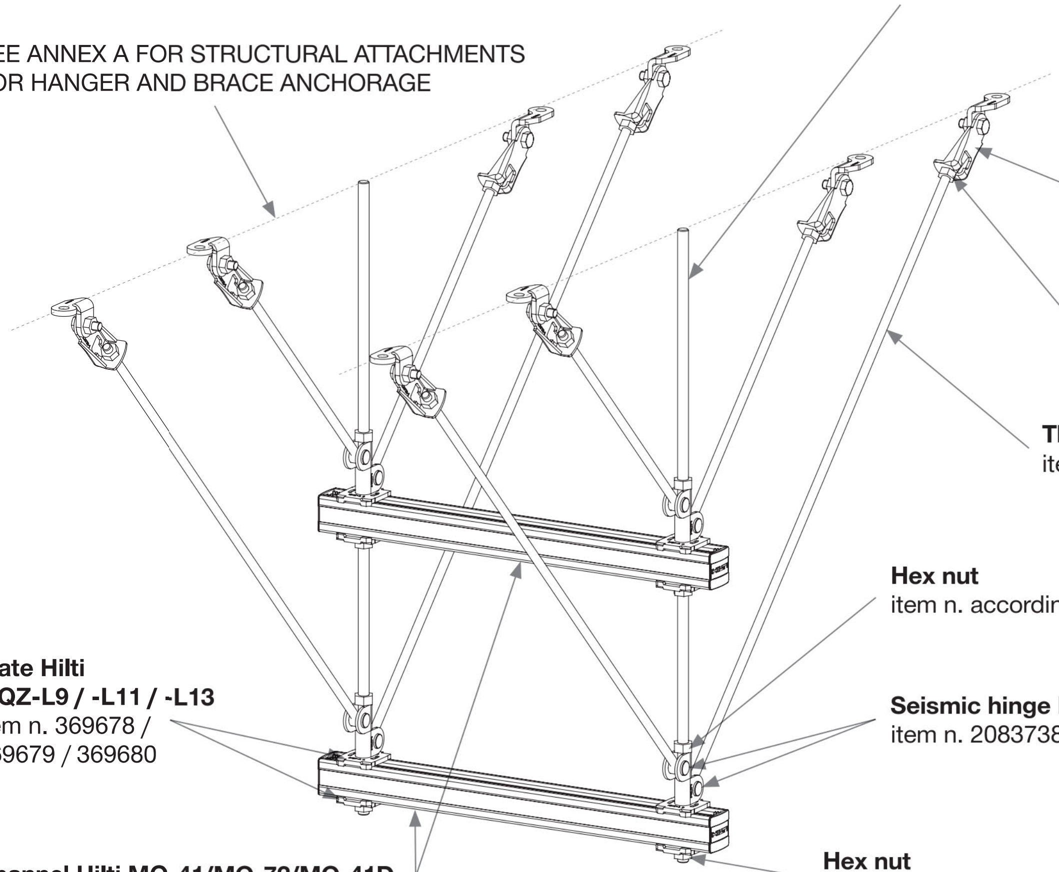
Trapeze with rod bracing Longitudinal – Multilevel

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	**Transversal [X]**
- 2800 - **(1)**	- 0 -



(1) max design load for each channel level





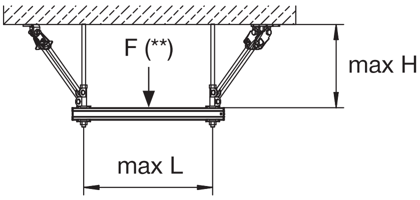
General Design Notes

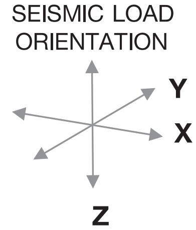
Design loads are stated in this paper are depending on following conditions:

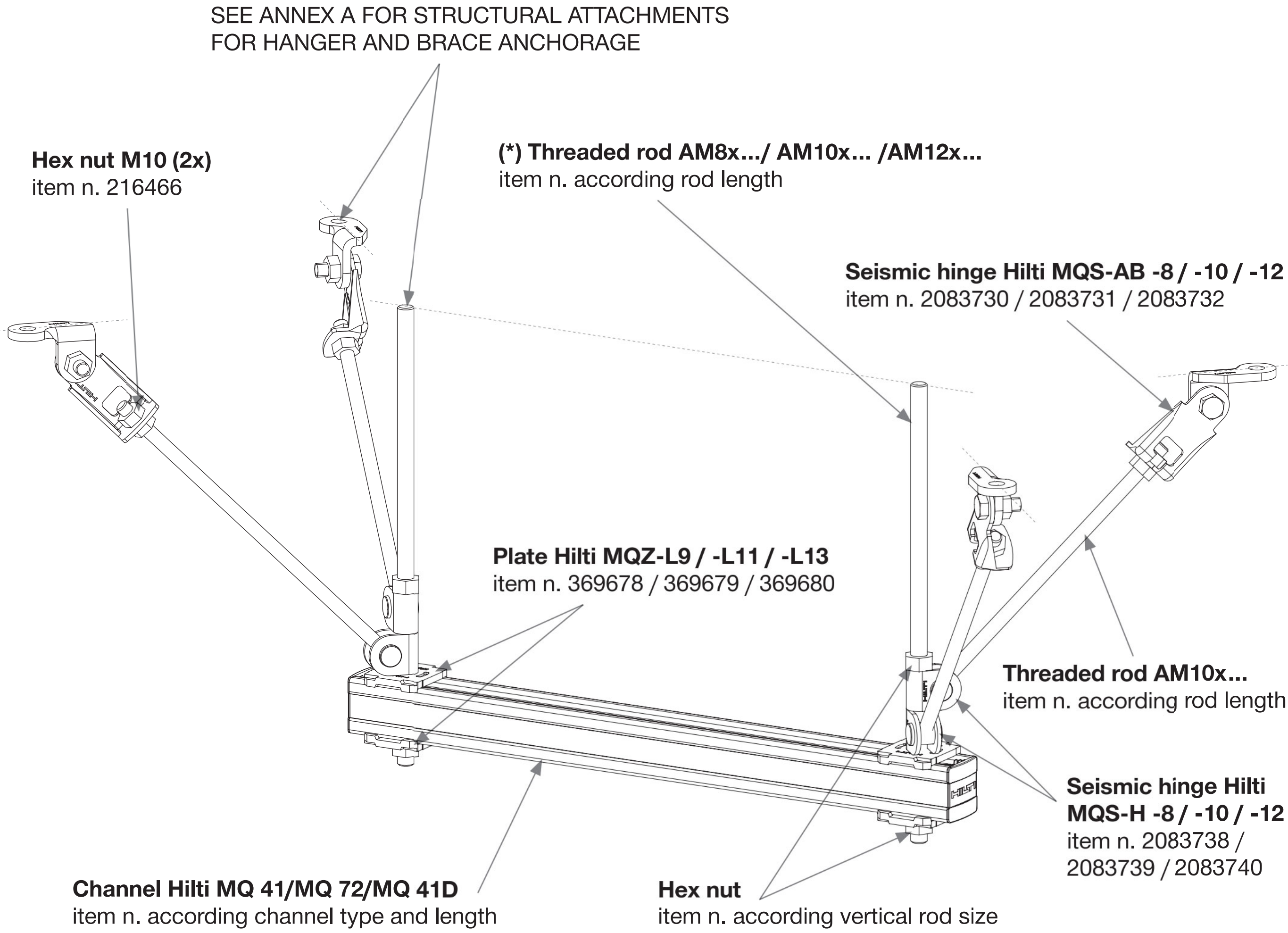
- (*) using M10 or M12 rods; for applications with M8 vertical rods, please contact the Hilti Technical Service
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(**): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

MQS System
Seismic Designed Solutions

Trapeze with rod bracing 4-way bracing	Max. design load (seismic horizontal) in [N]	
	Longitudinal [Y]	Transversal [X]
	Calculation with PROFIS is needed	





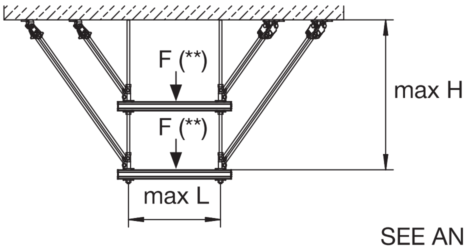


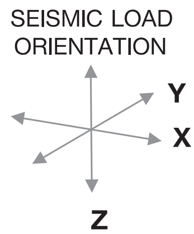
General Design Notes

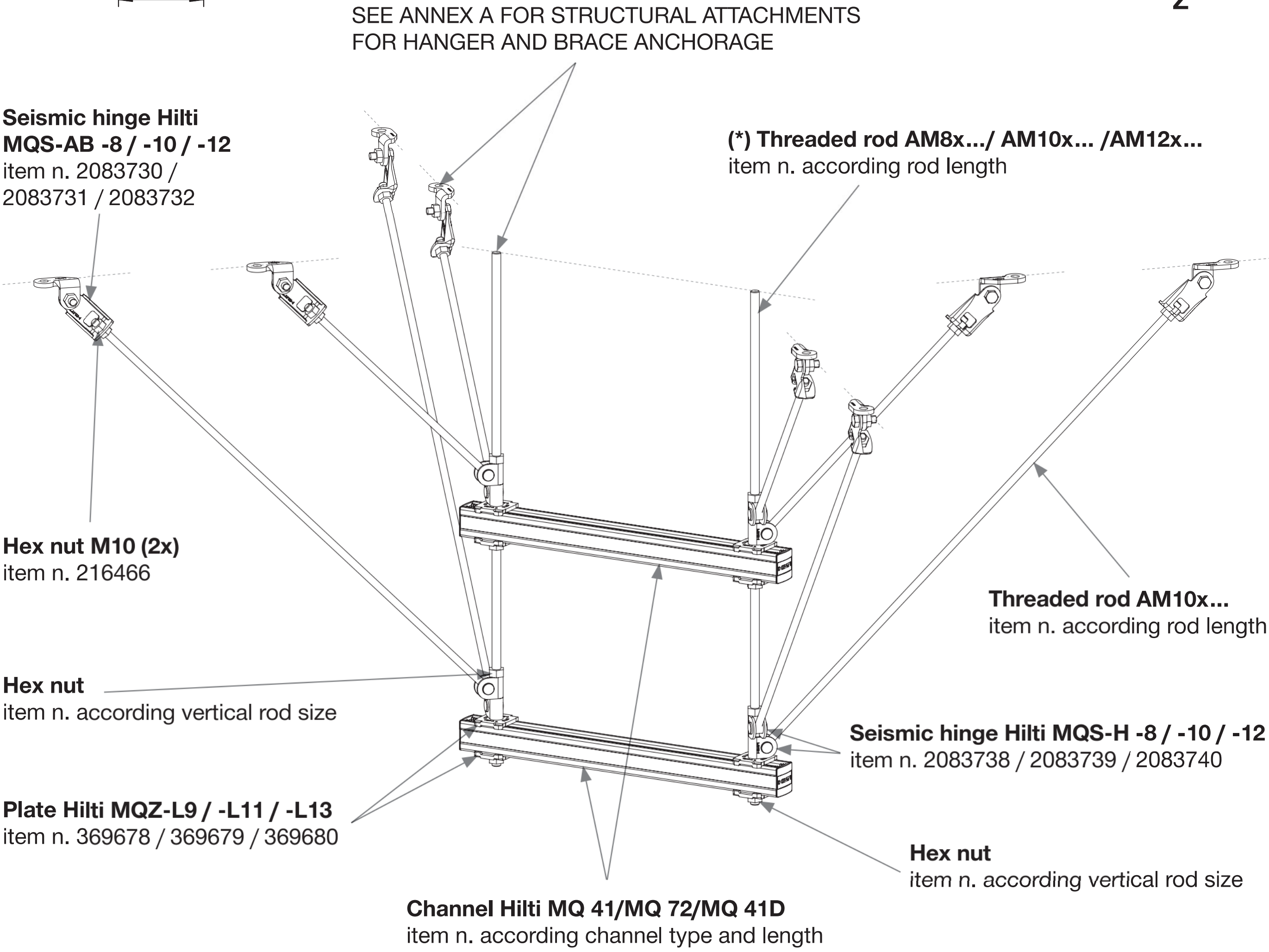
Design loads are stated in this paper are depending on following conditions:
- (*) using M10 or M12 rods; for applications with M8 vertical rods, please contact the Hilti Technical Service
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(**): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

MQS System
Seismic Designed Solutions

Trapeze with rod bracing 4-way bracing – Multilevel	Max. design load (seismic horizontal) in [N]	
	Longitudinal [Y]	**Transversal [X]**
	Calculation with PROFIS is needed	







General Design Notes

Design loads are stated in this paper are depending on following conditions:

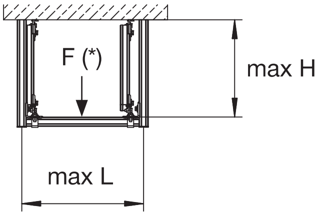
- (*) using M10 or M12 rods; for applications with M8 vertical rods, please contact the Hilti Technical Service
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(**): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

MQS System

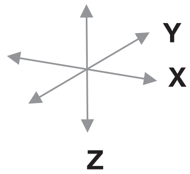
Seismic Designed Solutions

Trapeze with channel bracing Longitudinal

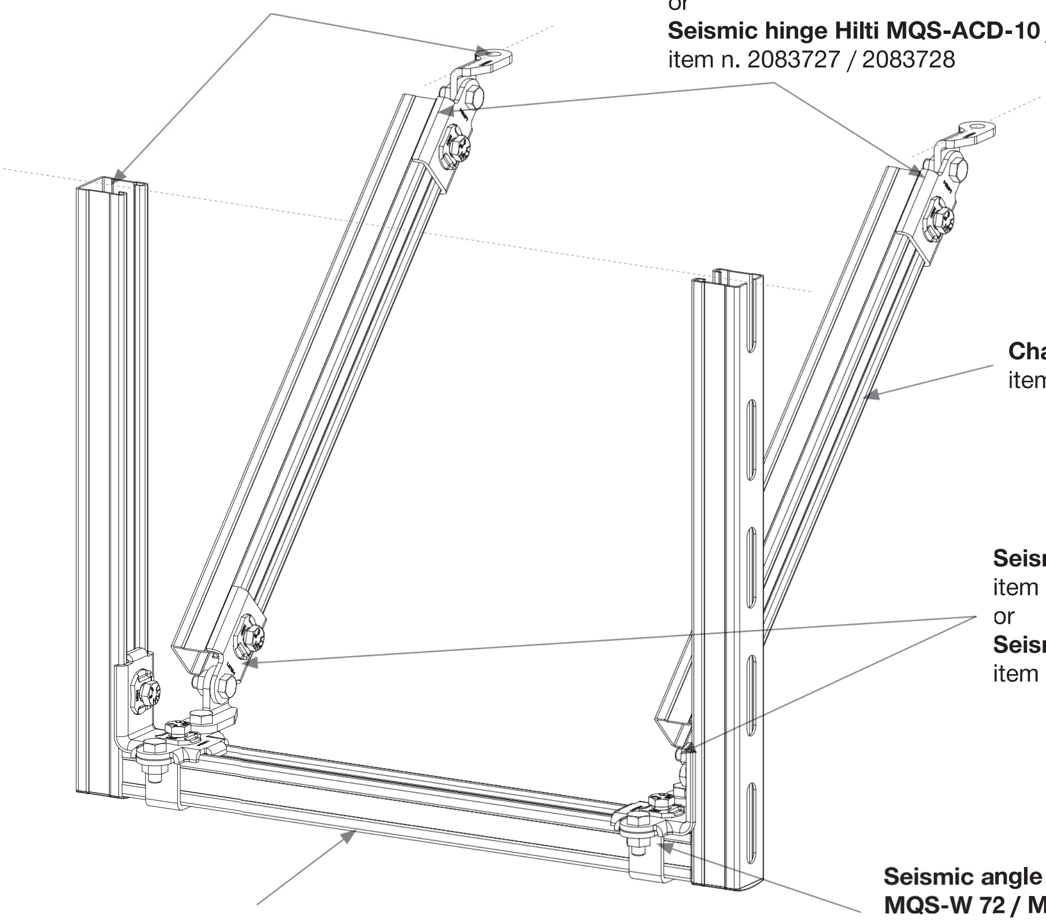
Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
See Annex E - Selection Tables	



SEISMIC LOAD ORIENTATION



SEE ANNEX A FOR STRUCTURAL ATTACHMENTS FOR HANGER AND BRACE ANCHORAGE



General Design Notes

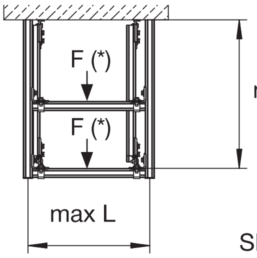
Design loads are stated in this paper are depending on following conditions:

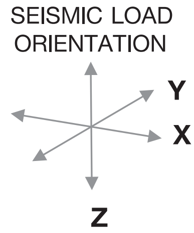
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

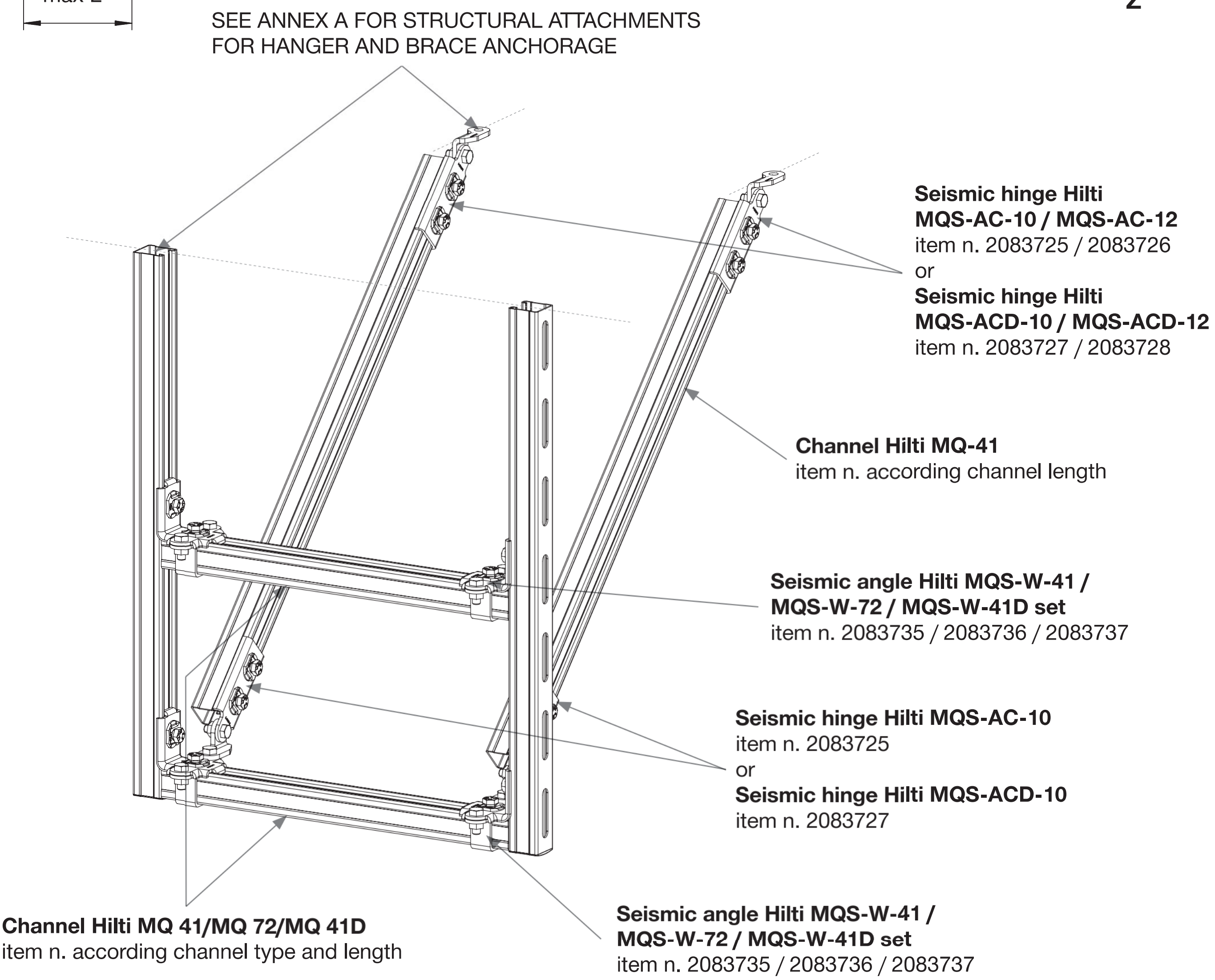
MQS System
Seismic Designed Solutions

Trapeze with channel bracing Longitudinal – Multilevel

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	**Transversal [X]**
Calculation with PROFIS is needed	



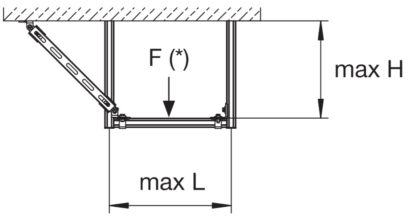


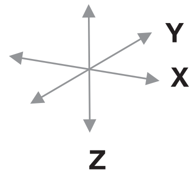


General Design Notes
Design loads are stated in this paper are depending on following conditions:
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

MQS System
Seismic Designed Solutions

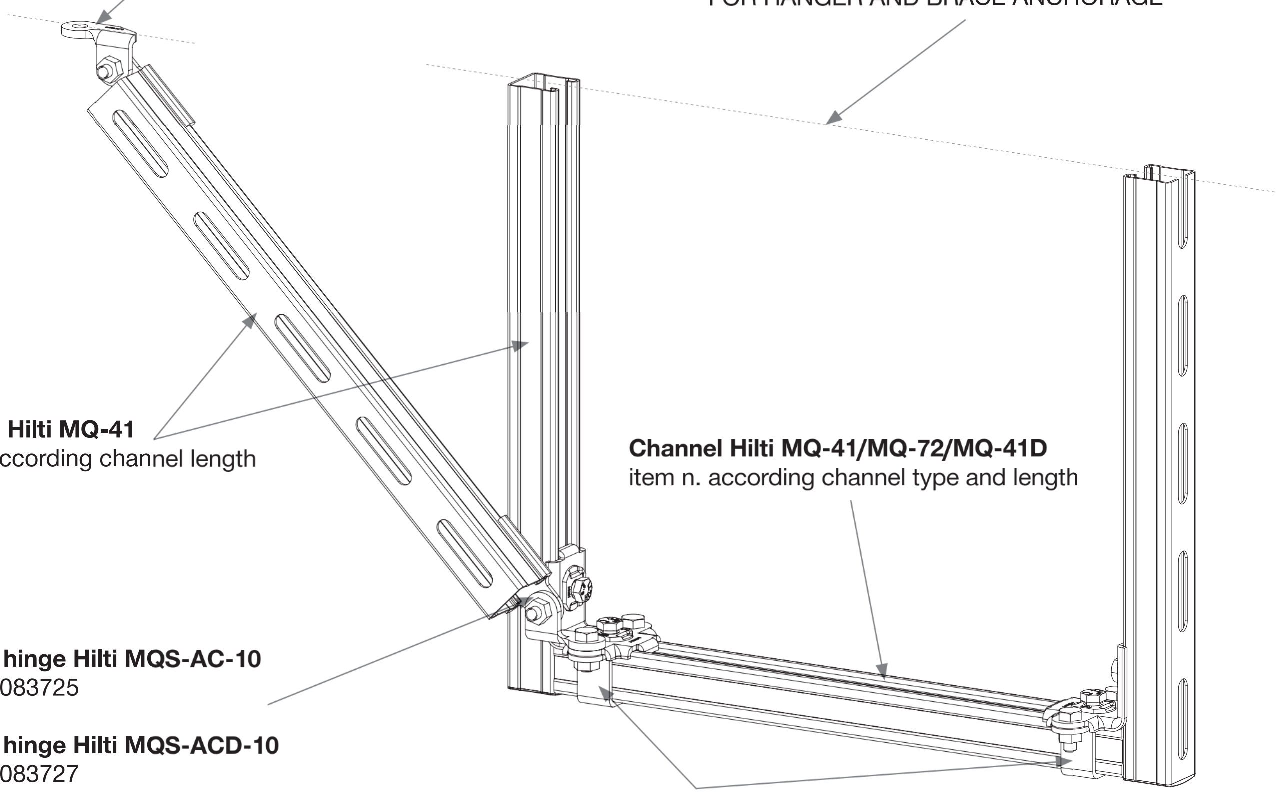
# Trapeze with channel bracing Transversal	Max. design load (seismic horizontal) in [N]	
	Longitudinal [Y]	**Transversal [X]**
	See Annex E - Selection Tables	





Seismic hinge Hilti MQS-AC-10 / MQS-AC-12
item n. 2083725 / 2083726
or
Seismic hinge Hilti MQS-ACD-10 / MQS-ACD-12
item n. 2083727 / 2083728

SEE ANNEX A FOR STRUCTURAL ATTACHMENTS FOR HANGER AND BRACE ANCHORAGE



Channel Hilti MQ-41
item n. according channel length

Channel Hilti MQ-41/MQ-72/MQ-41D
item n. according channel type and length

Seismic hinge Hilti MQS-AC-10
item n. 2083725
or
Seismic hinge Hilti MQS-ACD-10
item n. 2083727

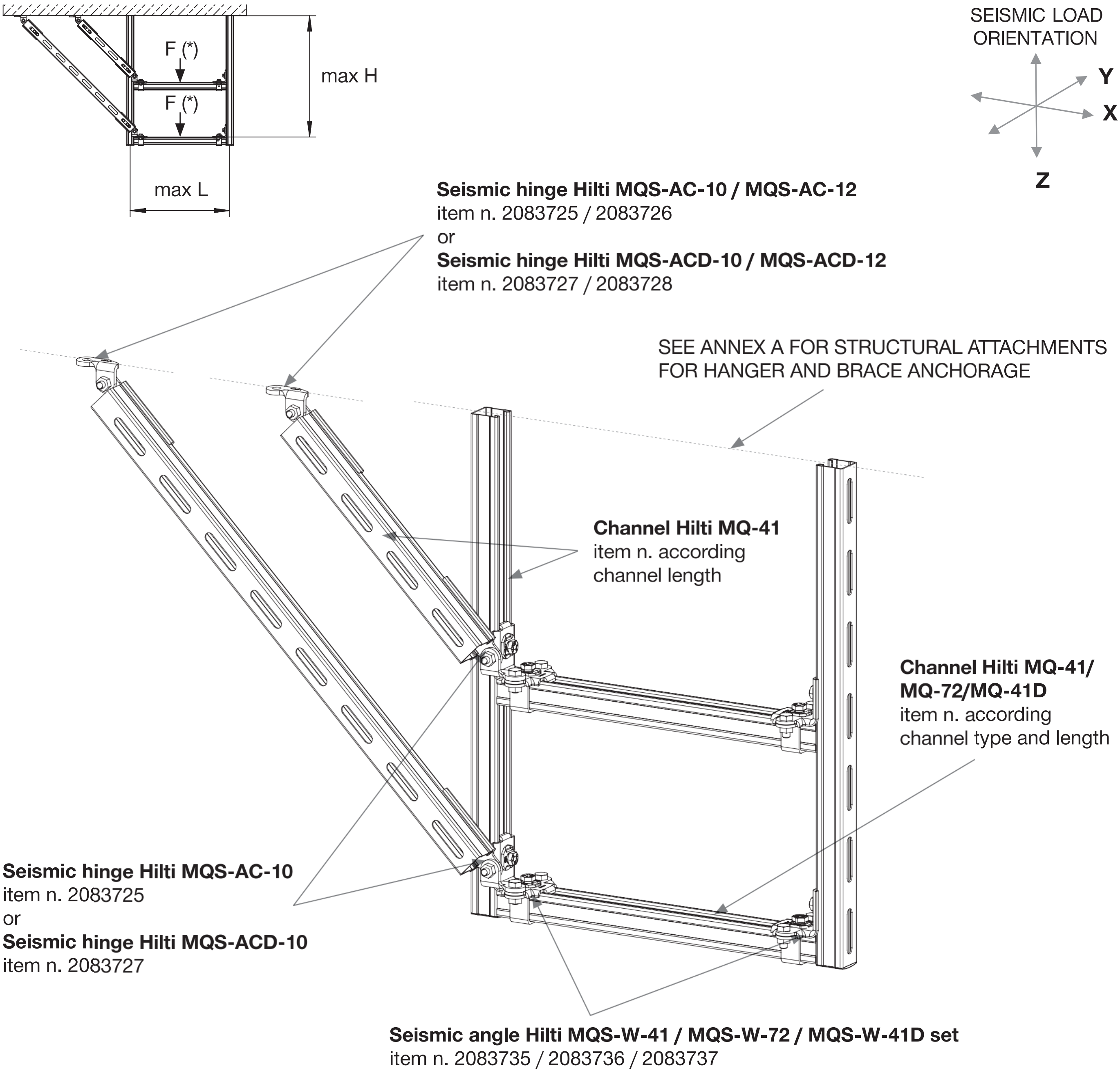
Seismic angle Hilti MQS-W-41 / MQS-W-72 / MQS-W-41D set
item n. 2083735 / 2083736 / 2083737

General Design Notes
Design loads are stated in this paper are depending on following conditions:
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

MQS System
Seismic Designed Solutions

Trapeze with channel bracing Transversal – Multilevel

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
Calculation with PROFIS is needed	



General Design Notes

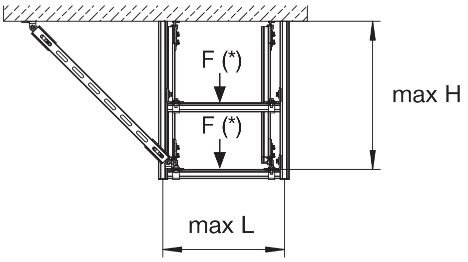
Design loads are stated in this paper are depending on following conditions:

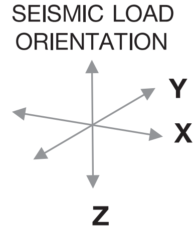
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

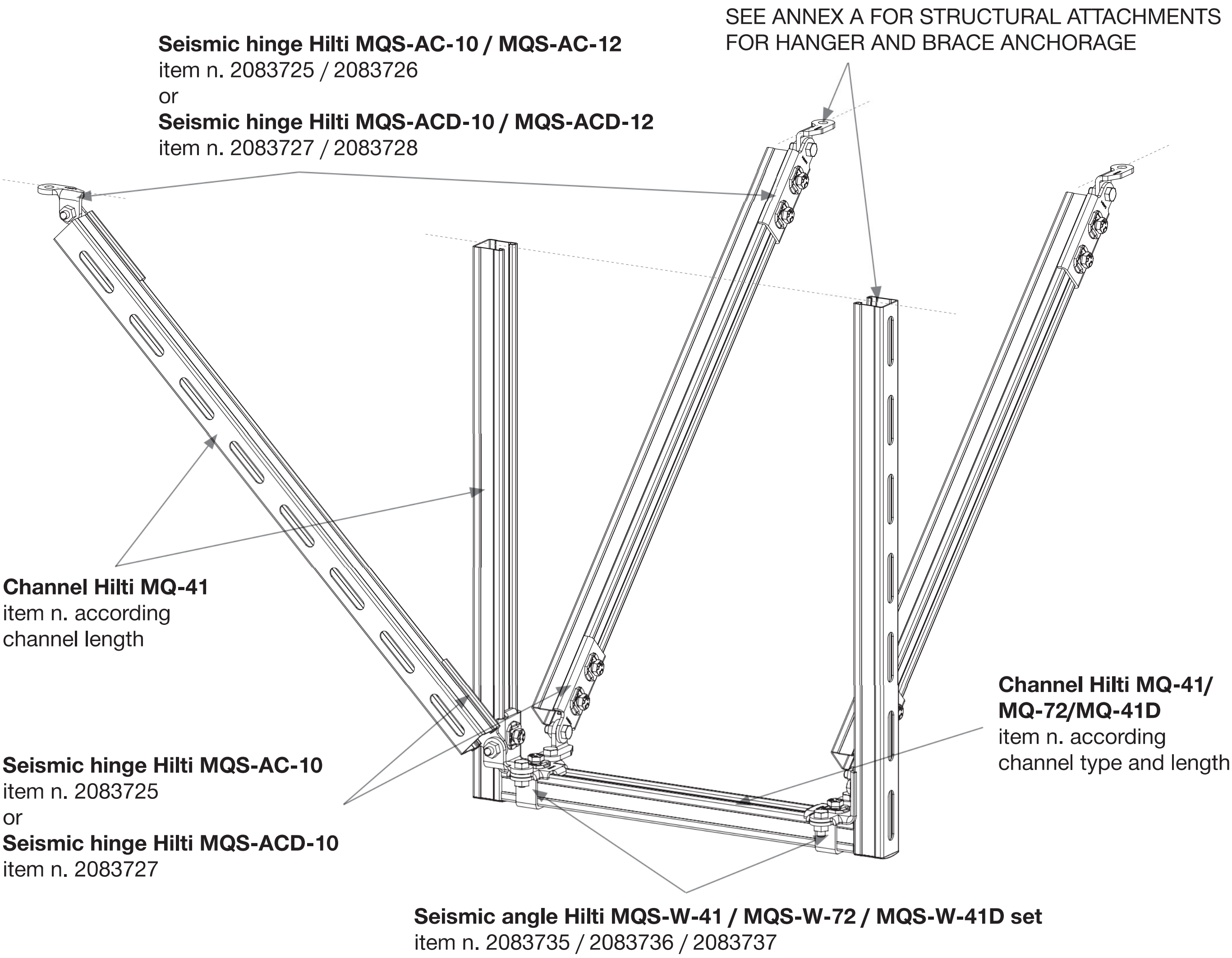
MQS System
Seismic Designed Solutions

Trapeze with channel bracing
4-way bracing

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	**Transversal [X]**
See Annex E - Selection Tables	





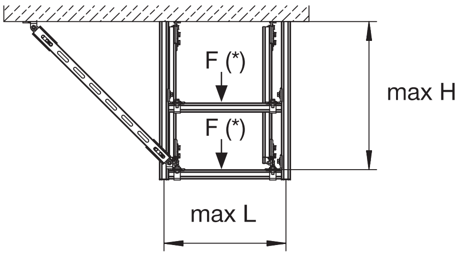


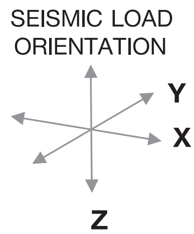
General Design Notes
Design loads are stated in this paper are depending on following conditions:
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

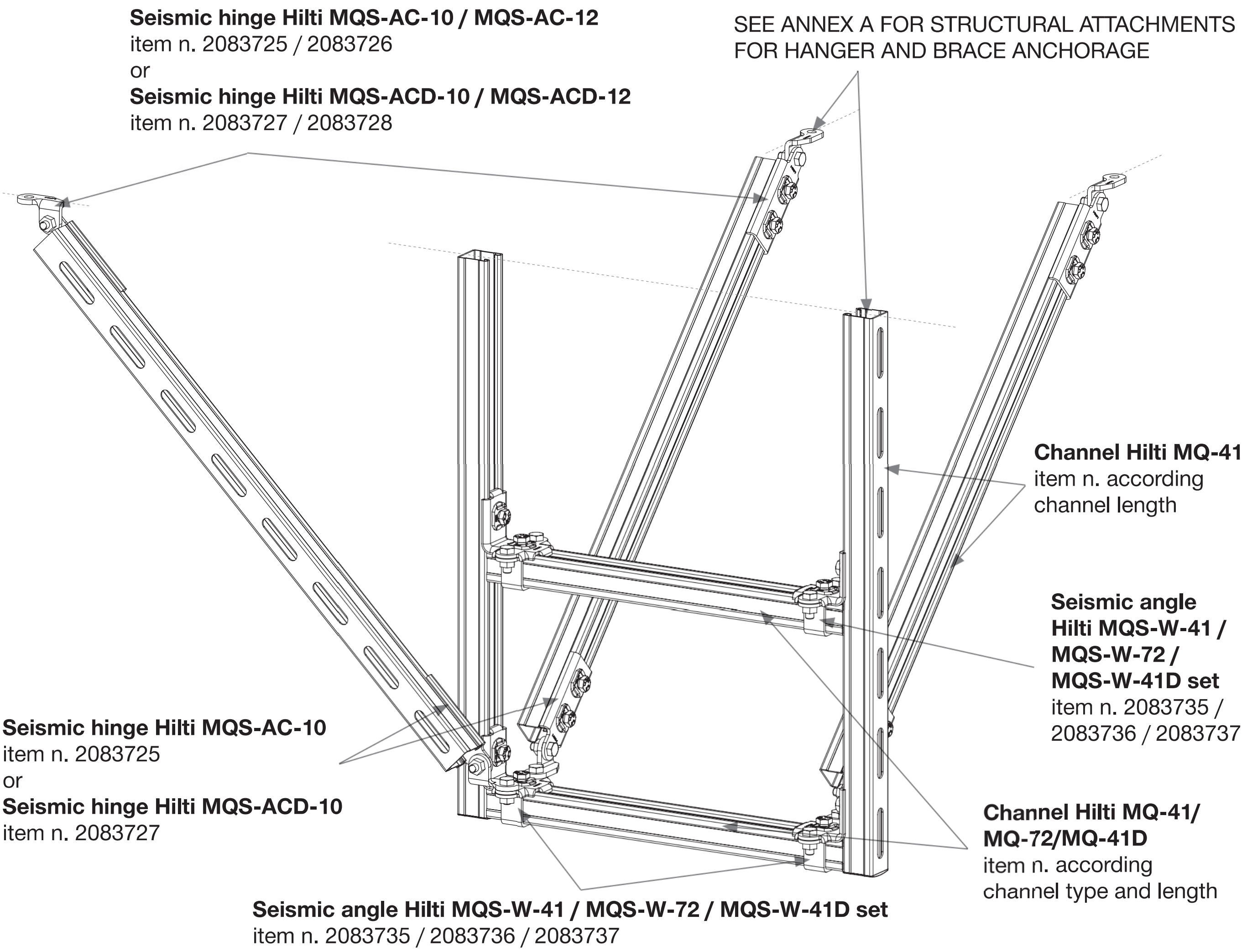
MQS System
Seismic Designed Solutions

Trapeze with channel bracing 4-way bracing – Multilevel

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
Calculation with PROFIS is needed	



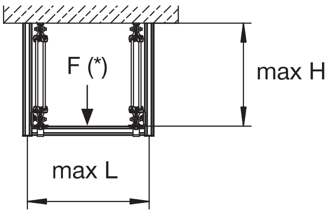


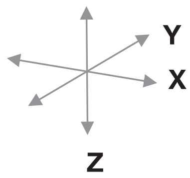


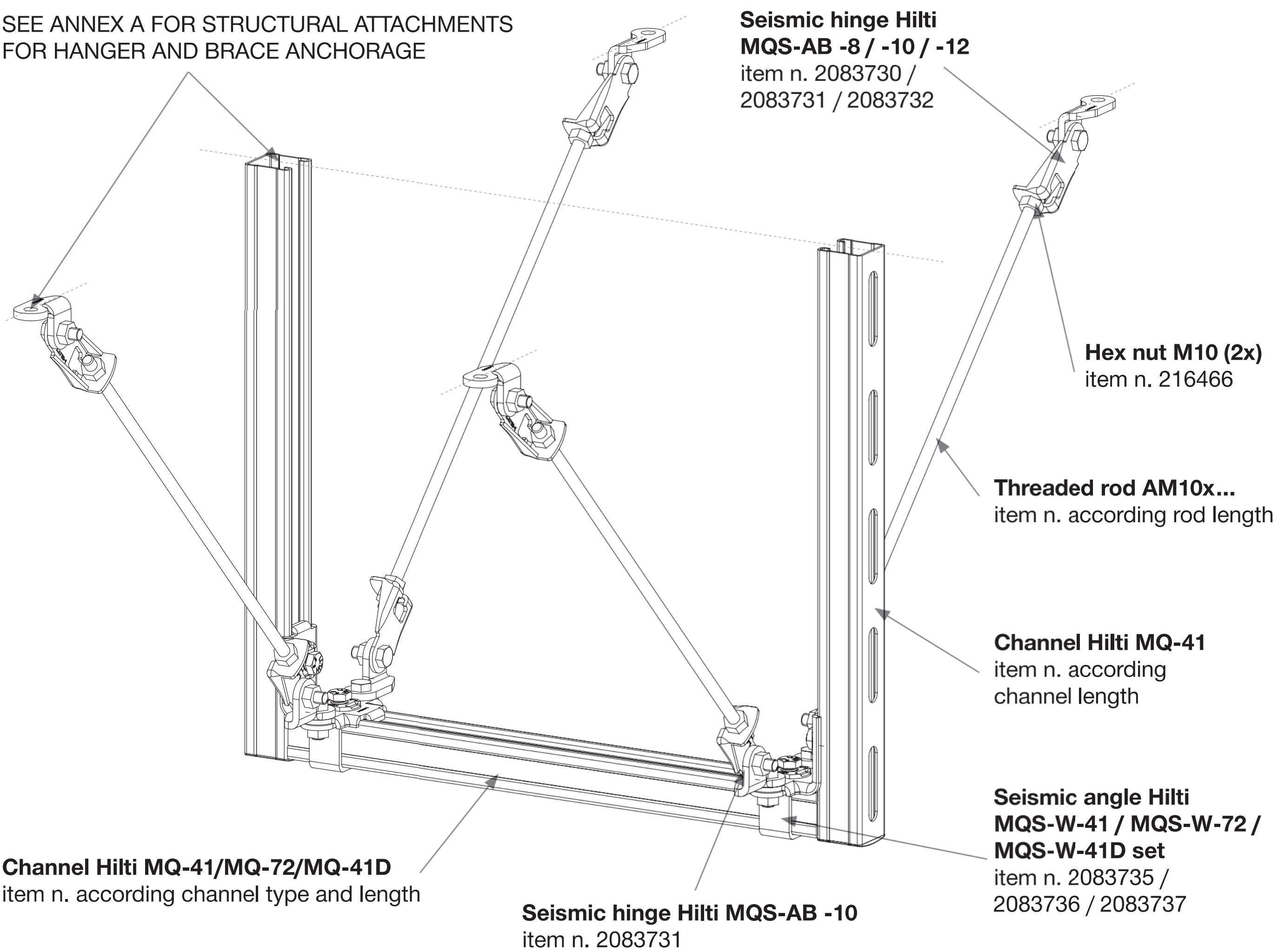
General Design Notes
Design loads are stated in this paper are depending on following conditions:
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

MQS System
Seismic Designed Solutions

Trapeze with rod bracing Longitudinal	Max. design load (seismic horizontal) in [N]	
	Longitudinal [Y]	**Transversal [X]**
	- 2800 -	- 0 -







General Design Notes

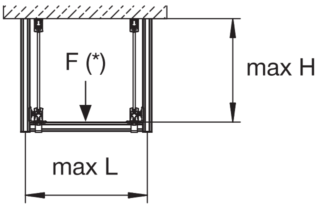
Design loads are stated in this paper are depending on following conditions:

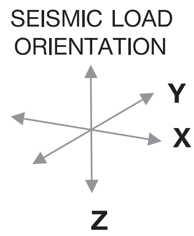
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B "Selection Tables" or use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

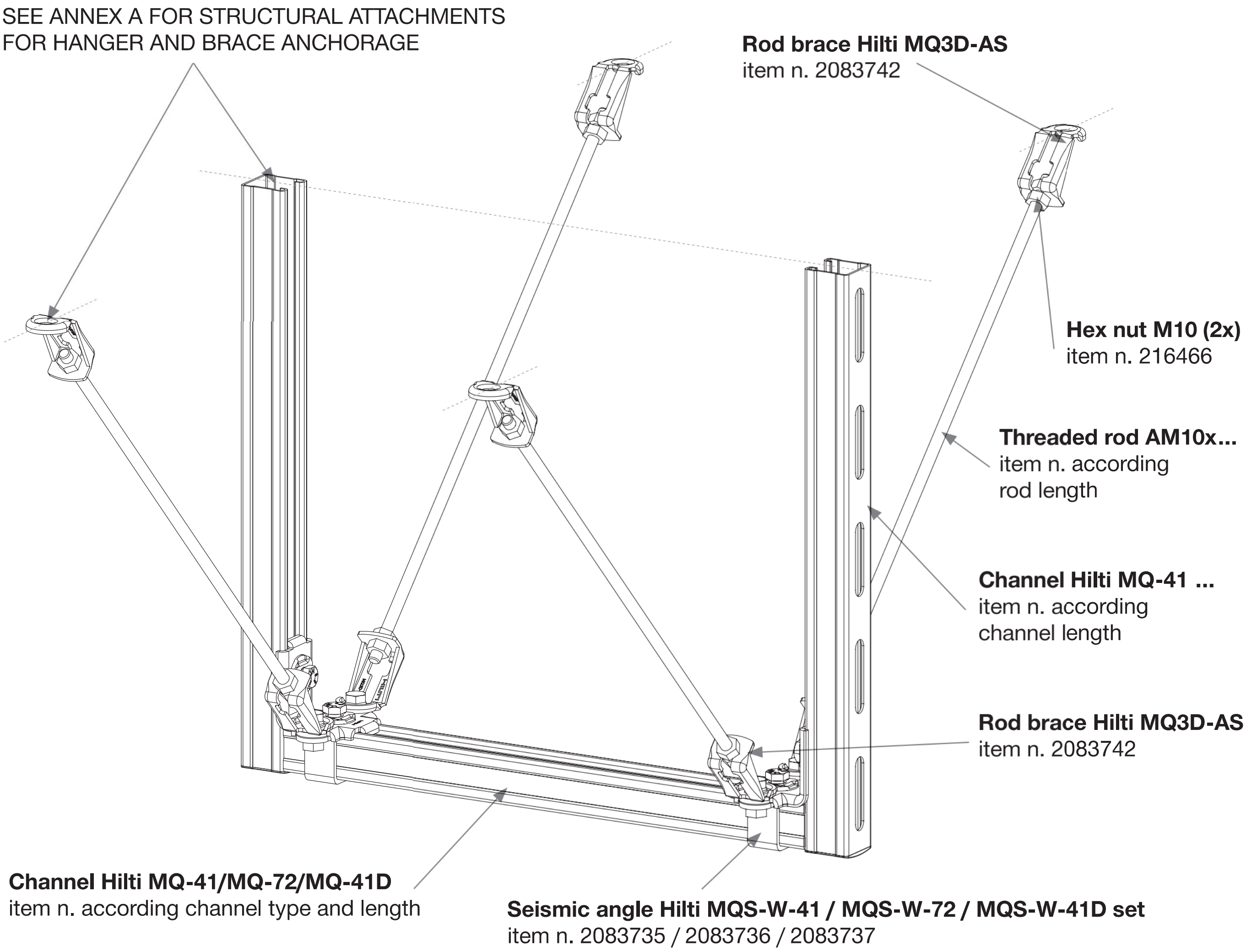
MQS System
Seismic Designed Solutions

Trapeze with rod bracing Longitudinal

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
- 2800 -	- 0 -







General Design Notes

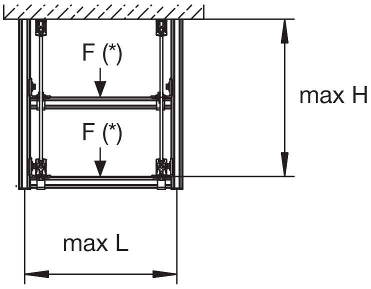
Design loads are stated in this paper are depending on following conditions:

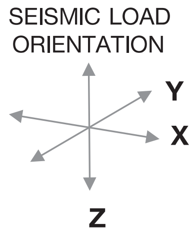
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

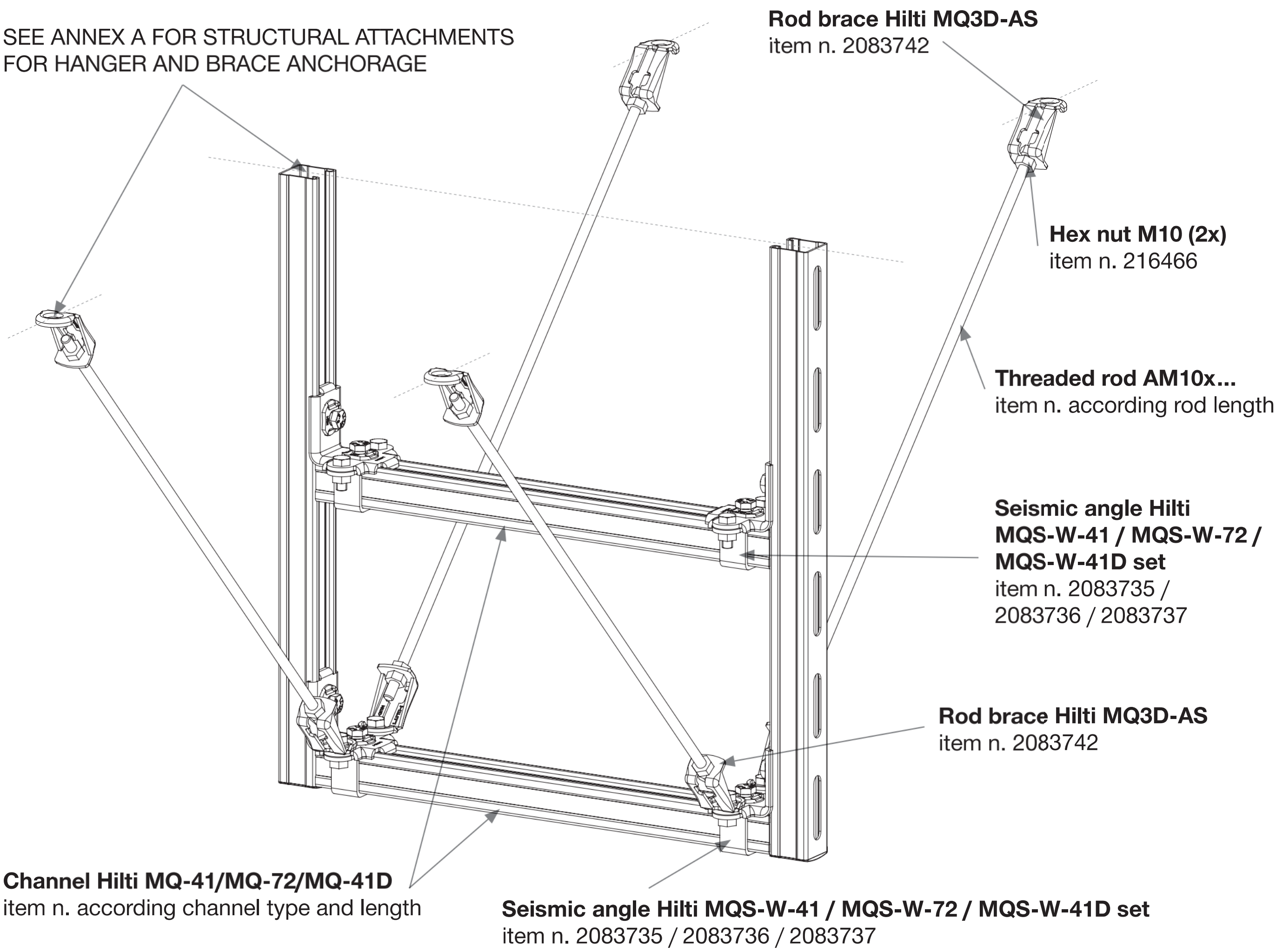
MQS System
Seismic Designed Solutions

Trapeze with rod bracing Longitudinal – Multilevel

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
Calculation with PROFIS is needed	





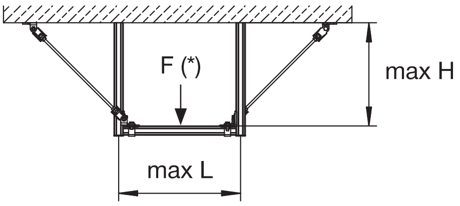


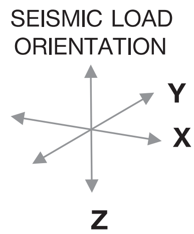
General Design Notes
Design loads are stated in this paper are depending on following conditions:
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

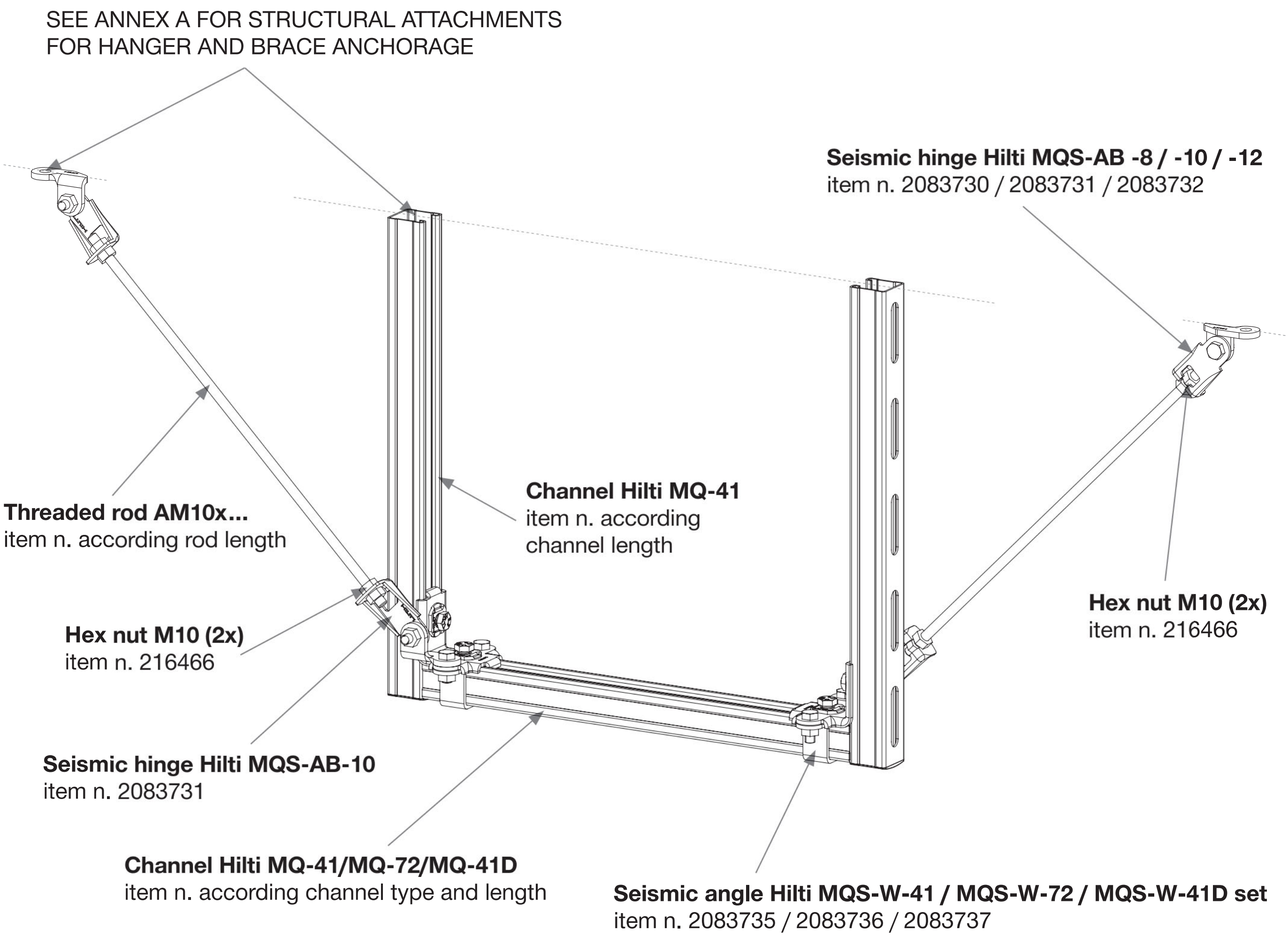
MQS System
Seismic Designed Solutions

Trapeze with rod bracing Transversal

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
- 0 -	- 2800 -





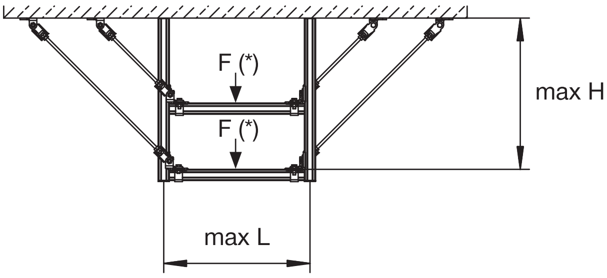


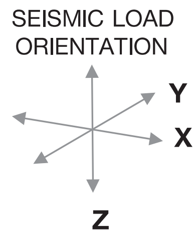
General Design Notes
Design loads are stated in this paper are depending on following conditions:
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B "Selection Tables" or use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

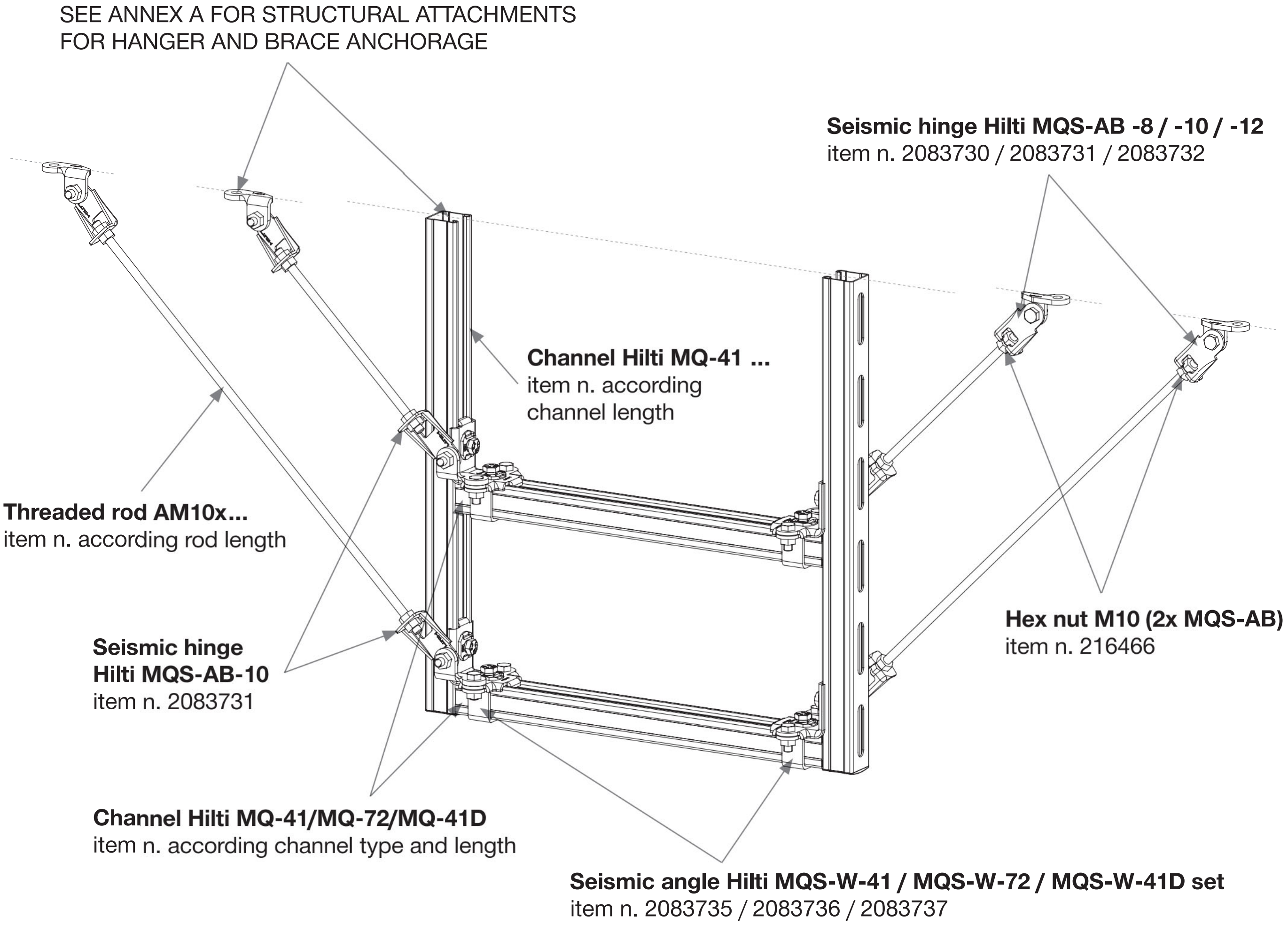
MQS System
Seismic Designed Solutions

Trapeze with rod bracing Transversal – Multilevel

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
Calculation with PROFIS is needed	





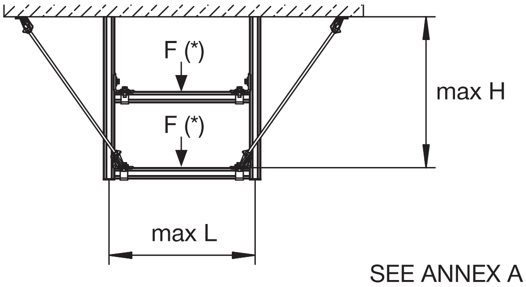


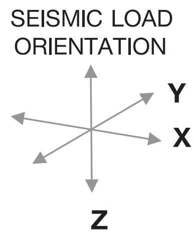
General Design Notes
Design loads are stated in this paper are depending on following conditions:
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

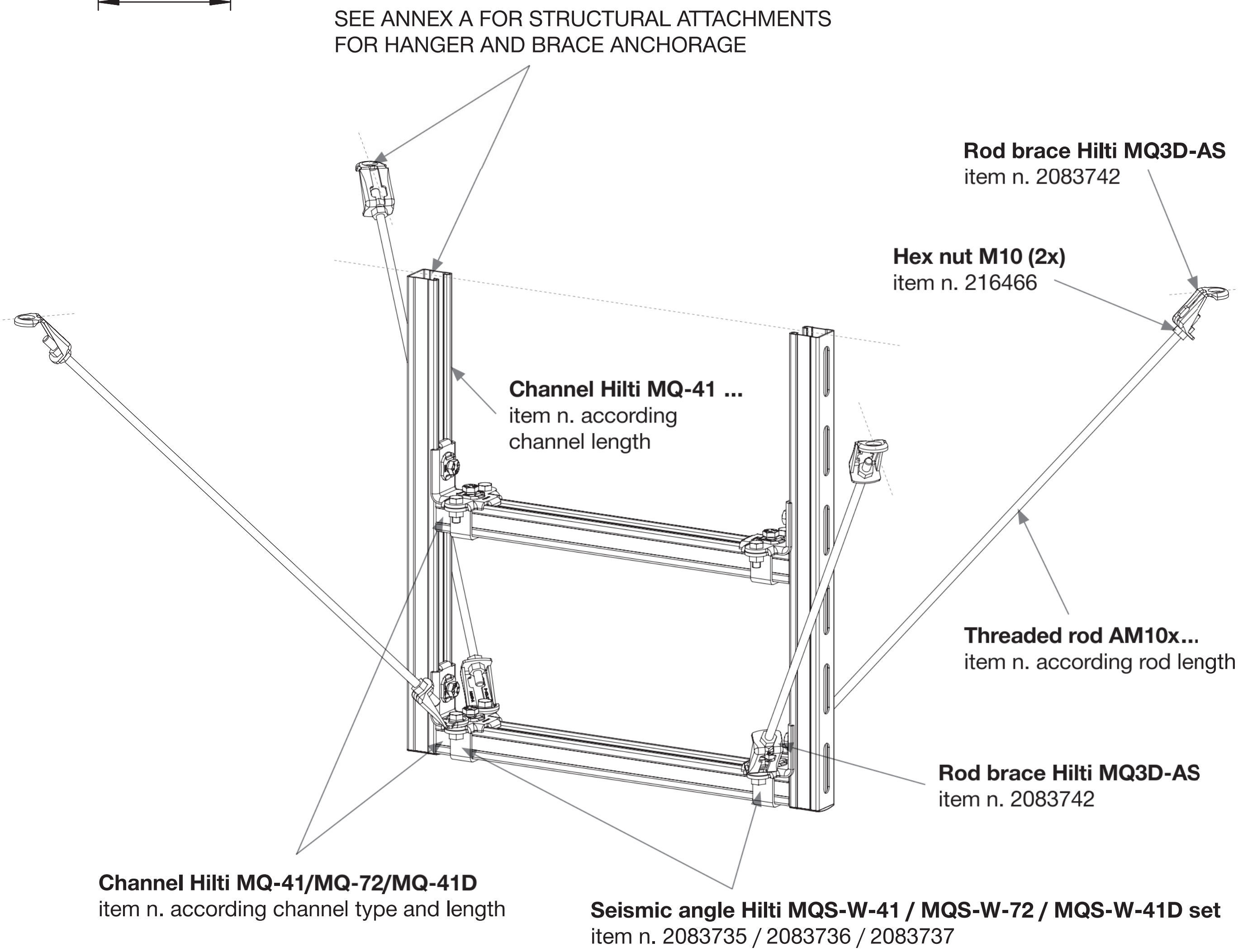
MQS System
Seismic Designed Solutions

Trapeze with rod bracing
4-way bracing – Multilevel

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
Calculation with PROFIS is needed	





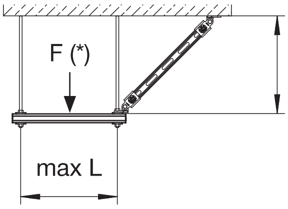


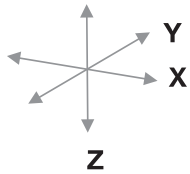
General Design Notes
Design loads are stated in this paper are depending on following conditions:
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

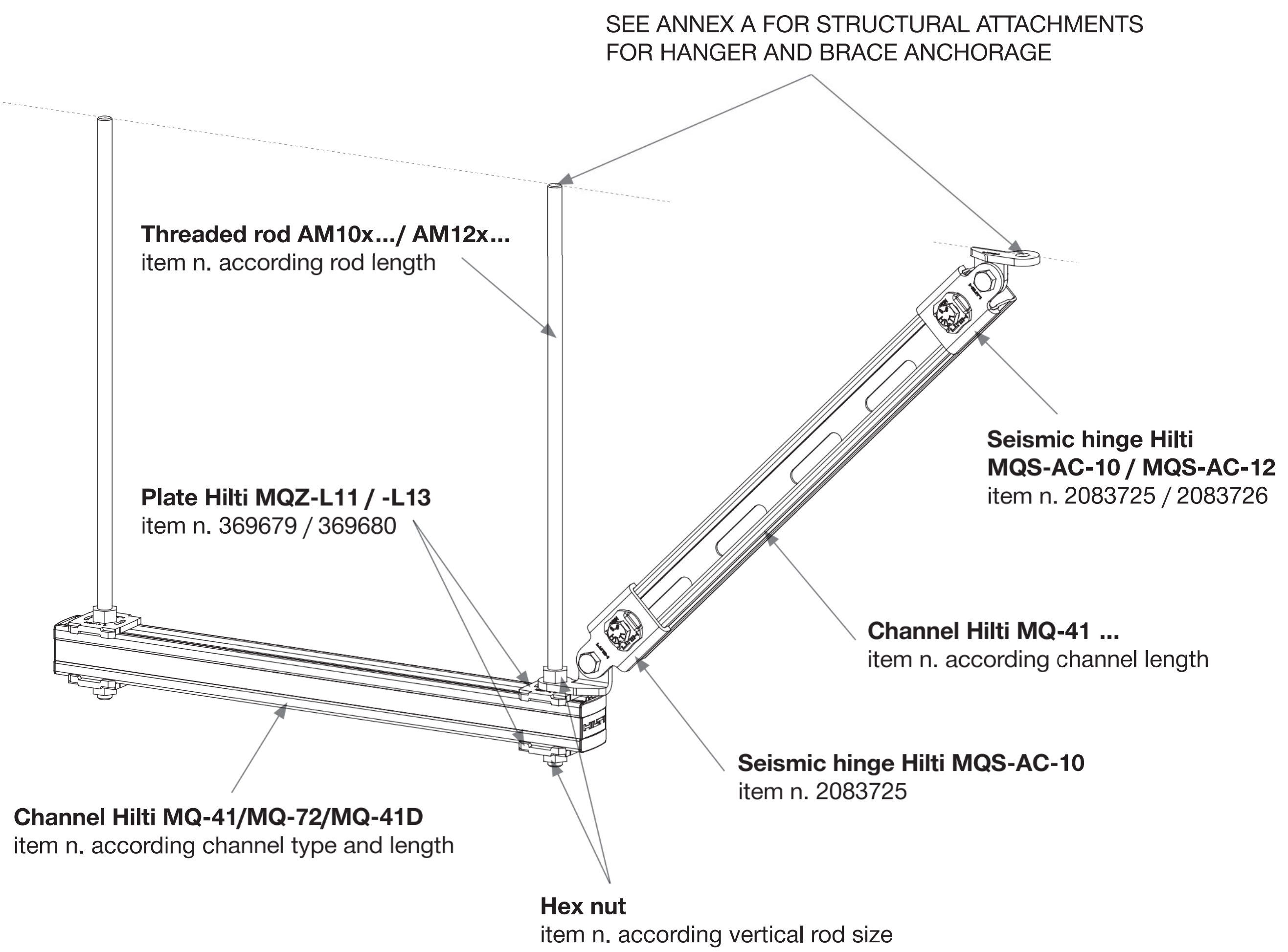
MQS System
Seismic Designed Solutions

Trapeze with channel bracing Transversal

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
- 0 -	- 2500 -





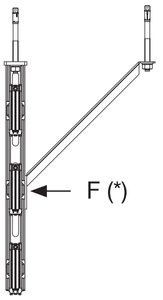


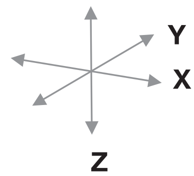
General Design Notes
Design loads are stated in this paper are depending on following conditions:
- max. height H – top of ceiling to top of horizontal channel: 800 mm; max. length L: 1600 mm
- brace angle: 45° – any or all brace locations are permitted to use the full angle variation to meet field conditions – see Annex A
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – see Annex B “Selection Tables” or use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

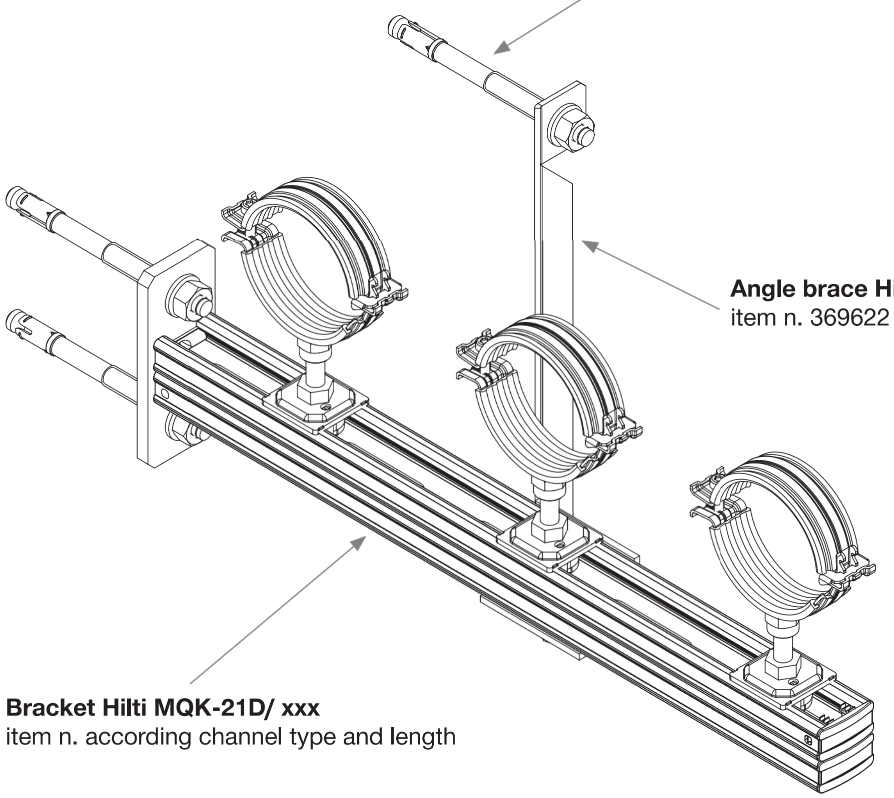
MQS System
Seismic Designed Solutions

Wall bracket

Max. design load (seismic horizontal) in [N]	
Longitudinal [Y]	Transversal [X]
Calculation with PROFIS is needed	



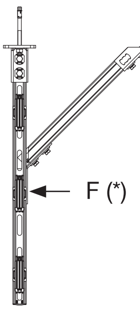




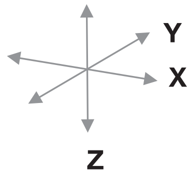
General Design Notes
Design loads are stated in this paper are depending on following conditions:
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

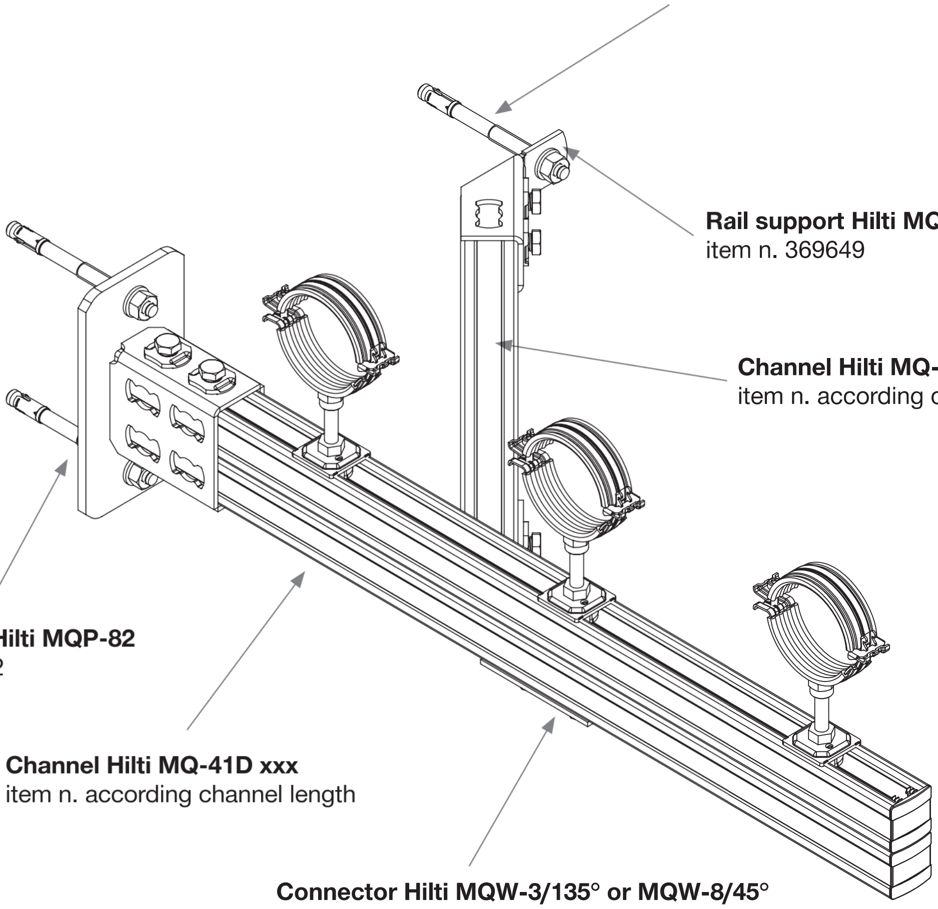
MQS System
Seismic Designed Solutions

Wall bracket	Max. design load (seismic horizontal) in [N]	
	Longitudinal [Y]	Transversal [X]
	Calculation with PROFIS is needed	



SEISMIC LOAD ORIENTATION





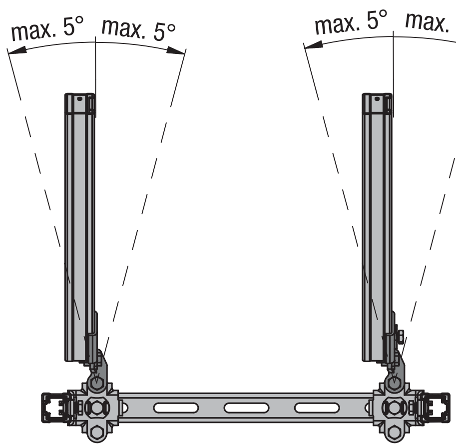
General Design Notes
Design loads are stated in this paper are depending on following conditions:
- structural attachments for hanger and braces – see Annex C
- capacity for particular load situations – use PROFIS Installation
- F(*): for trade relevant attachments (piping / cable trays / air ducts) – see Annex D

MQS System
Seismic Designed Solutions

Angle variation of bracing with channels

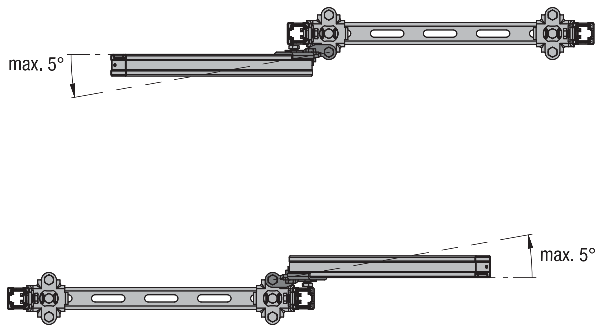
MQS
Seismic System

Longitudinal bracing



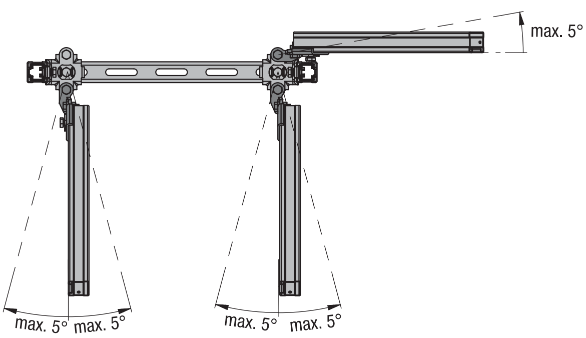
Top view – bracing direction on main axis of the pipe run

Transversal bracing



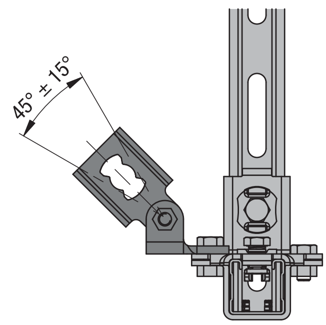
Top view – bracing direction on main axis of the pipe run

4-way bracing



Top view – bracing direction on main axis of the pipe run

Tilt angle – for all bracings

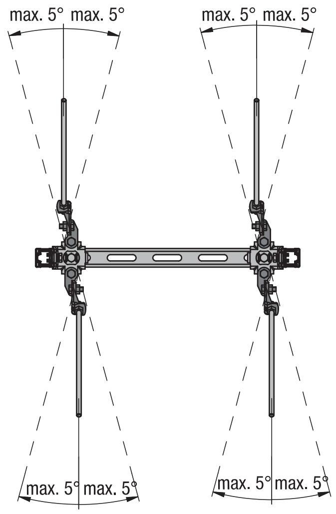


Side view – bracing angle on the horizontal level

Angle variation of bracing with rods

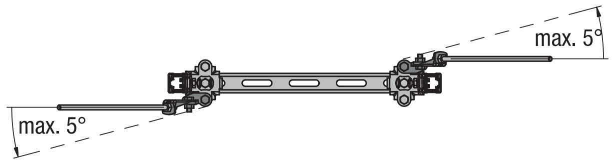
MQS Seismic System

Longitudinal bracing



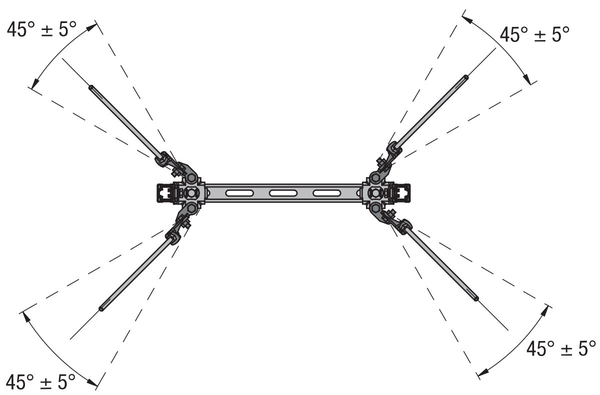
Top view – bracing direction on main axis of the pipe run

Transversal bracing



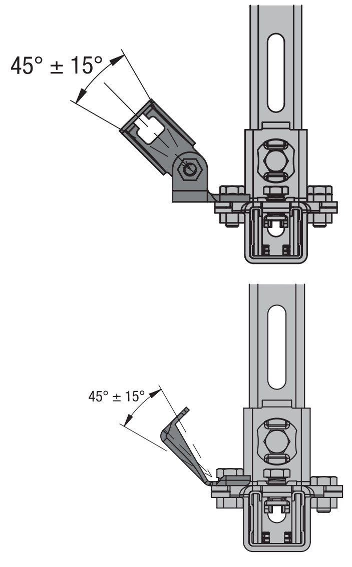
Top view – bracing direction on main axis of the pipe run

4-way bracing



Top view – bracing direction on main axis of the pipe run

Tilt angle – for all bracings

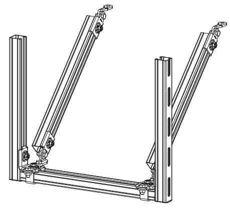


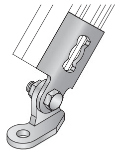
Side view – bracing angle on the horizontal level

Selection Tables – Legend

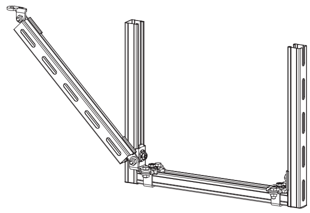
Tables A (A1÷A6) are for Longitudinal or Transversal set-up, for height of trapeze 0.8 m, 1.0 m, 1.2 m
Tables B (B1÷B6) are for 4-way set-up, for height of trapeze 0.8 m, 1.0 m, 1.2m

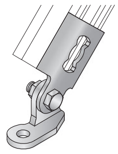
LONGITUDINAL – bracing with MQS-AC



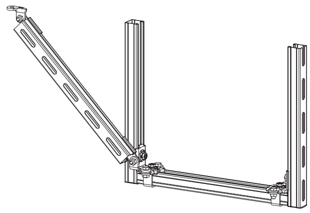
Set-up		Connector
1	Set-up with MQS-W41	
2	Set-up with MQS-W72	
3	Set-up with MQS-W41D	

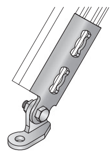
TRANSVERSAL – bracing with MQS-AC



Set-up		Connector
4	Set-up with MQS-W41	
5	Set-up with MQS-W72	
6	Set-up with MQS-W41D	

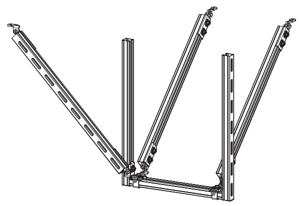
TRANSVERSAL – bracing with MQS-ACD

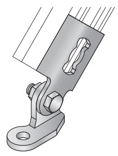


Set-up		Connector
7	Set-up with MQS-W72	
8	Set-up with MQS-W41D	

See Tables A (A1÷A6)

4-WAY – bracing with MQS-AC

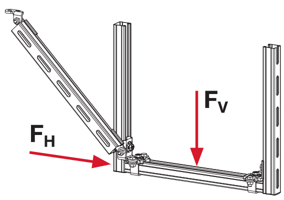


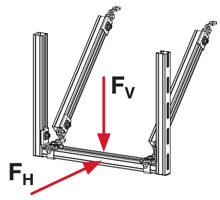
Set-up		Connector
1	Set-up with MQS-W41	
2	Set-up with MQS-W72	
3	Set-up with MQS-W41D	

See Tables B (B1÷B6)

Vertical Point Load

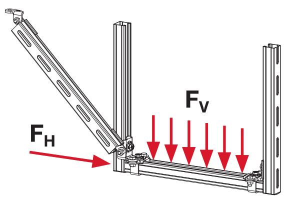
Force concentrated in the middle of the span on horizontal channel





Vertical Line Load

Uniformly distributed load on horizontal channel



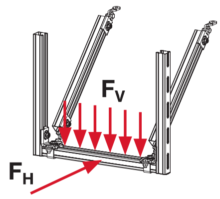
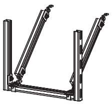


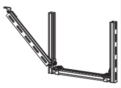
Table N° A1 – point load in the middle of the span, height of the trapeze: 0.8 m

LONGITUNAL with MQS-AC



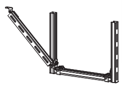
1. set-up with MQS-W41
2. set-up with MQS-W72
3. set-up with MQS-W41D

TRANSVERSAL with MQS-AC



4. set-up with MQS-W41
5. set-up with MQS-W72
6. set-up with MQS-W41D

TRANSVERSAL with MQS-ACD



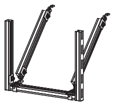
7. set-up with MQS-W72
8. set-up with MQS-W41D

		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.50	0.65	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,
	0.80	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	0.95	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	1.00	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	1.05	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	1.10	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	1.25	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
1.00	0.50	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,
	0.60	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	0.70	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	0.80	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	1.00	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	1.10	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	2.30	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	2.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,5,7,6,8,
1.50	0.60	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	0.75	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	1.05	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	1.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	1.95	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,
	2.10	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,
	2.55	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,
	2.85	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,6,8,
	3.30	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,6,8,
	3.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,6,8,	5,7,6,8,
	3.75	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,6,8,	5,7,6,8,
2.00	0.80	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	1.00	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	1.80	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	2.00	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,	
	2.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,	
	3.00	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,	
	3.40	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,	
	3.80	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,6,8,	5,7,	
	4.00	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,6,8,	5,7,	
	4.20	2,3,	2,3,4,6,8,	2,3,6,8,	2,3,6,8,	2,3,6,8,	6,8,	6,8,		
	4.60	2,3,	2,3,	2,3,	2,3,	2				
	5.00	2,3,	2,3,	2,3,	2,3,					
2.50	0.75	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	1.00	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	2.00	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	2.25	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,		
	2.75	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,		
	3.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,		
	3.75	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,		
	4.00	2,3,	2,3,4,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,		
	5.00	2,3,	2,3,	2,3,	2,3,					
	5.75	2,3,	2,3,	2,3,	2					
	6.25	2,3,	2,3,	2,3,						

Continued on next page...

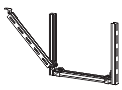
Table N° A1 – point load in the middle of the span, height of the trapeze: 0.8 m

LONGITUNAL with MQS-AC



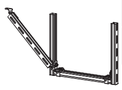
1 set-up with MQS-W41
2 set-up with MQS-W72
3 set-up with MQS-W41D

TRANSVERSAL with MQS-AC



4 set-up with MQS-W41
5 set-up with MQS-W72
6 set-up with MQS-W41D

TRANSVERSAL with MQS-ACD



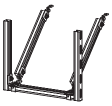
7 set-up with MQS-W72
8 set-up with MQS-W41D

... continued from previous page

		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
3.00	0.60	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,			
	0.90	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,			
	2.10	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,			
	2.70	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,			
	3.30	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,			
	3.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,			
	3.90	2,3,	2,3,4,6,8,	2,3,6,8,	2,3,5,7,6,8,	5,7,6,8,				
	4.50	2,3,	2,3,	2,3,	2,3,					
	5.10	2,3,	2,3,	2,3,	2					
	6.60	2,3,	2,3,	2,3,						
	7.50	3	3							
3.50	0.70	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,				
	2.10	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,				
	2.80	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,				
	3.50	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,				
	3.85	2,3,	2,3,6,8,	2,3,6,8,	2,3,6,8,	6,8,				
	4.55	2,3,	2,3,	2,3,	2					
	5.95	2,3,	2,3,	2,3,						
	6.30	2,3,	2,3,	2						
	8.75	3	3							
4.00	0.80	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,					
	3.20	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,					
	3.60	2,3,4,6,8,	2,3,6,8,	2,3,5,7,6,8,	2,5,7,6,8,					
	4.00	2,3,	2,3,	2,3,	2					
	5.60	2,3,	2,3,	2,3,						
	6.00	2,3,	2,3,	2						
	8.80	3	3							
	9.60	3								
4.50	0.45	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,					
	2.70	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,					
	3.15	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,					
	3.60	2,3,	2,3,6,8,	2,3,6,8,	6,8,					
	4.95	2,3,	2,3,	2,3,						
	5.40	2,3,	2,3,	2						
	5.85	2,3,	2,3,							
	8.10	3	3							
	9.00	3								
5.00	3.00	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,						
	4.00	2,3,	2,3,	2,3,						
	5.00	2,3,	2,3,	2						
	5.50	2,3,	3							
	7.50	3	3							
	8.50	3								

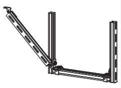
Table N° A2 – uniformly distributed load, height of the trapeze: 0.8 m

LONGITUNAL with MQS-AC



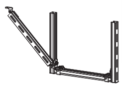
1 set-up with MQS-W41
2 set-up with MQS-W72
3 set-up with MQS-W41D

TRANSVERSAL with MQS-AC



4 set-up with MQS-W41
5 set-up with MQS-W72
6 set-up with MQS-W41D

TRANSVERSAL with MQS-ACD



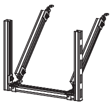
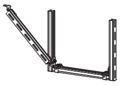
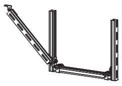
7 set-up with MQS-W72
8 set-up with MQS-W41D

		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.50	1.15	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,
	1.25	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
1.00	1.10	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,
	2.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
1.50	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,
	1.05	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	3.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	3.75	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
2.00	0.80	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,
	1.00	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	3.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	3.80	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	4.00	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	4.20	2,3,	2,3,4,6,8,	2,3,4,6,8,	2,3,4,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,6,8,	2,3,6,8,
	4.40	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,
	5.00	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2
2.50	1.00	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	3.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	3.75	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,
	4.00	2,3,	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,
	4.25	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2
	4.75	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	
	5.50	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2	
	6.00	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,		
	6.25	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
3.00	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,
	3.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,
	3.90	2,3,	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	
	4.80	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2	
	5.40	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,		
	6.00	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
	6.30	2,3,	2,3,	2,3,	2,3,	2,3,	3			
	6.60	2,3,	2,3,	2,3,	2,3,	3	3			
	6.90	2,3,	3	3	3	3	3			
	7.20	3	3	3	3	3	3			
	7.50	3	3	3	3	3				
3.50	1.05	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,
	1.75	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,
	2.80	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2
	3.15	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	
	3.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	
	3.85	2,3,	2,3,4,6,8,	2,3,6,8,	2,3,6,8,	2,3,6,8,	2,3,6,8,	2,3,6,8,	2	
	4.55	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,		
	5.60	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
	5.95	2,3,	2,3,	2,3,	2,3,	2,3,	3			
	6.30	2,3,	2,3,	2,3,	2,3,	3	3			
	6.65	2,3,	3	3	3	3				
	8.75	3	3	3	3	3				

Continued on next page…

Table N° A2 – uniformly distributed load, height of the trapeze: 0.8 m

LONGITUNAL with MQS-AC	TRANSVERSAL with MQS-AC	TRANSVERSAL with MQS-ACD
1 set-up with MQS-W41	4 set-up with MQS-W41	7 set-up with MQS-W72
2 set-up with MQS-W72	5 set-up with MQS-W72	8 set-up with MQS-W41D
3 set-up with MQS-W41D	6 set-up with MQS-W41D	

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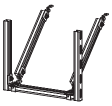
F_V (kN)	$F_{H\,max}$ (kN)	Horizontal channel length (m)								
		0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
4.00	0.80	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	3.20	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	3.60	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,	
	4.80	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
	5.20	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,			
	5.60	2,3,	2,3,	2,3,	2,3,	2,3,	3			
	6.00	2,3,	2,3,	2,3,	2,3,	3				
	6.40	2,3,	3	3	3	3				
	8.00	3	3	3	3	3				
	9.20	3	3	3	3					
	9.60	3	3							
4.50	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	3.15	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	3.60	2,3,	2,3,4,6,8,	2,3,6,8,	2,3,6,8,	2,3,6,8,	2,3,6,8,	2		
	4.05	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
	4.95	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,			
	5.40	2,3,	2,3,	2,3,	2,3,	2,3,				
	5.85	2,3,	2,3,	2,3,	3	3				
	7.20	3	3	3	3	3				
	8.55	3	3	3	3					
	9.00	3	3	3						
	9.45	3								
5.00	1.00	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,			
	3.00	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,			
	4.00	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,			
	4.50	2,3,	2,3,	2,3,	2,3,	2,3,	2			
	5.00	2,3,	2,3,	2,3,	2,3,	3				
	5.50	2,3,	2,3,	3	3	3				
	6.50	3	3	3	3	3				
	7.50	3	3	3	3					
	8.00	3	3	3						
	8.50	3	3							

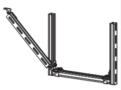
Table N° A3 – point load in the middle of the span, height of the trapeze: 1.0 m

LONGITUNAL with MQS-AC



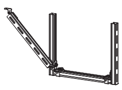
1. set-up with MQS-W41
2. set-up with MQS-W72
3. set-up with MQS-W41D

TRANSVERSAL with MQS-AC



4. set-up with MQS-W41
5. set-up with MQS-W72
6. set-up with MQS-W41D

TRANSVERSAL with MQS-ACD



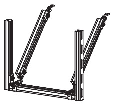
7. set-up with MQS-W72
8. set-up with MQS-W41D

		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.50	**0.65**	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,
	0.80	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	0.95	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	1.00	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	1.05	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	1.10	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	1.25	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
1.00	**0.50**	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,
	0.60	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	0.70	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	0.80	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	1.00	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	1.10	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	2.30	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	2.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,5,7,6,8,
1.50	**0.60**	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	0.75	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	1.05	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	1.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	1.95	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,
	2.10	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,
	2.55	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,
	2.85	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,6,8,
	3.30	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,6,8,
	3.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,6,8,	5,7,6,8,
	3.75	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,6,8,	5,7,6,8,
2.00	**0.80**	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	1.00	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	1.80	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	2.00	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,	
	2.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,	
	3.00	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,	
	3.40	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,	
	3.80	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,6,8,	5,7,	
	4.00	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,6,8,	5,7,	
	4.20	2,3,	2,3,4,6,8,	2,3,4,6,8,	2,3,6,8,	2,3,5,7,6,8,	5,7,6,8,	6,8,		
	4.60	2,3,	2,3,	2,3,	2,3,	2				
	5.00	2,3,	2,3,	2,3,	2,3,					
2.50	**0.75**	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	1.00	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	2.00	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	2.25	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,		
	2.75	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,		
	3.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,		
	3.75	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,		
	4.00	2,3,	2,3,4,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,		
	5.00	2,3,	2,3,	2,3,	2,3,					
	5.75	2,3,	2,3,	2,3,	2					
	6.25	2,3,	2,3,	2,3,						

Continued on next page...

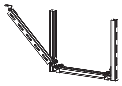
Table N° A3 – point load in the middle of the span, height of the trapeze: 1.0 m

LONGITUNAL with MQS-AC



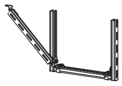
1. set-up with MQS-W41
2. set-up with MQS-W72
3. set-up with MQS-W41D

TRANSVERSAL with MQS-AC



4. set-up with MQS-W41
5. set-up with MQS-W72
6. set-up with MQS-W41D

TRANSVERSAL with MQS-ACD



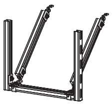
7. set-up with MQS-W72
8. set-up with MQS-W41D

... continued from previous page

		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
3.00	0.60	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,			
	0.90	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,			
	2.10	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,			
	2.70	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,			
	3.30	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,			
	3.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,			
	3.90	2,3,	2,3,4,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,			
	4.50	2,3,	2,3,	2,3,	2,3,					
	5.10	2,3,	2,3,	2,3,	2					
	6.60	2,3,	2,3,	2,3,						
	6.90	2,3,	3							
	7.50	3	3							
3.50	0.70	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,				
	2.10	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,				
	2.80	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,				
	3.50	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,				
	3.85	2,3,	2,3,6,8,	2,3,6,8,	2,3,6,8,	6,8,				
	4.55	2,3,	2,3,	2,3,	2					
	5.95	2,3,	2,3,	2,3,						
	6.30	2,3,	2,3,	2						
	8.75	3	3							
4.00	0.80	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,					
	3.20	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,					
	3.60	2,3,4,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,					
	4.00	2,3,	2,3,	2,3,	2					
	5.60	2,3,	2,3,	2,3,						
	6.00	2,3,	2,3,	2						
	8.80	3	3							
	9.60	3								
4.50	0.45	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,					
	2.70	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,					
	3.15	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,					
	3.60	2,3,4,	2,3,6,8,	2,3,6,8,	6,8,					
	4.95	2,3,	2,3,	2,3,						
	5.40	2,3,	2,3,	2						
	5.85	2,3,	2,3,							
	8.10	3	3							
	9.00	3								
5.00	3.00	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,						
	4.00	2,3,	2,3,	2,3,						
	5.00	2,3,	2,3,	2						
	5.50	2,3,	3							
	7.50	3	3							
	8.50	3								

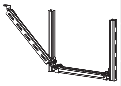
Table N° A4 – uniformly distributed load, height of the trapeze: 1.0 m

LONGITUNAL with MQS-AC



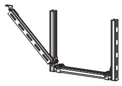
1. set-up with MQS-W41
2. set-up with MQS-W72
3. set-up with MQS-W41D

TRANSVERSAL with MQS-AC



4. set-up with MQS-W41
5. set-up with MQS-W72
6. set-up with MQS-W41D

TRANSVERSAL with MQS-ACD



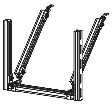
7. set-up with MQS-W72
8. set-up with MQS-W41D

		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.50	1.15	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,
	1.25	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
1.00	1.10	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,
	2.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
1.50	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,
	1.05	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	3.75	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
2.00	0.80	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,
	1.00	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	3.40	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	3.80	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	4.00	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	4.20	2,3,	2,3,4,6,8,	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	4.40	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,
	5.00	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2
2.50	1.00	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	3.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	3.75	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,
	4.00	2,3,	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,
	4.25	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2
	4.75	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	
	5.50	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2	
	6.00	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,		
	6.25	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
3.00	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,
	3.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,
	3.90	2,3,	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,
	4.80	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2	
	5.40	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,		
	6.00	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
	6.30	2,3,	2,3,	2,3,	2,3,	2,3,	3			
	6.60	2,3,	2,3,	2,3,	2,3,	3	3			
	6.90	2,3,	3	3	3	3	3			
	7.20	3	3	3	3	3	3			
	7.50	3	3	3	3	3				
3.50	1.05	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,
	1.75	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,
	2.80	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2
	3.15	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	
	3.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	
	3.85	2,3,	2,3,4,6,8,	2,3,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,6,8,	2,6,8,	
	4.55	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,		
	5.60	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
	5.95	2,3,	2,3,	2,3,	2,3,	2,3,	3			
	6.30	2,3,	2,3,	2,3,	2,3,	3	3			
	6.65	2,3,	3	3	3	3				
	8.75	3	3	3	3	3				

Continued on next page…

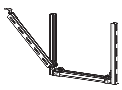
Table N° A4 – uniformly distributed load, height of the trapeze: 1.0 m

LONGITUNAL with MQS-AC



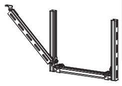
1. set-up with MQS-W41
2. set-up with MQS-W72
3. set-up with MQS-W41D

TRANSVERSAL with MQS-AC



4. set-up with MQS-W41
5. set-up with MQS-W72
6. set-up with MQS-W41D

TRANSVERSAL with MQS-ACD



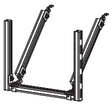
7. set-up with MQS-W72
8. set-up with MQS-W41D

... continued from previous page

		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
4.00	**0.80**	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	3.20	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	3.60	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,	
	4.80	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
	5.20	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,			
	5.60	2,3,	2,3,	2,3,	2,3,	2,3,	3			
	6.00	2,3,	2,3,	2,3,	2,3,	3				
	6.40	2,3,	3	3	3	3				
	8.00	3	3	3	3	3				
	9.20	3	3	3	3					
	9.60	3	3							
4.50	**0.90**	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	3.15	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	3.60	2,3,	2,3,4,6,8,	2,3,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,6,8,	2		
	4.05	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
	4.95	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,			
	5.40	2,3,	2,3,	2,3,	2,3,	2,3,				
	5.85	2,3,	2,3,	2,3,	3	3				
	7.20	3	3	3	3	3				
	8.55	3	3	3	3					
	9.00	3	3	3						
	9.45	3								
5.00	**1.00**	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,			
	3.00	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,			
	4.00	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,			
	4.50	2,3,	2,3,	2,3,	2,3,	2,3,	2			
	5.00	2,3,	2,3,	2,3,	2,3,	3				
	5.50	2,3,	2,3,	3	3	3				
	6.50	3	3	3	3	3				
	7.50	3	3	3	3					
	8.00	3	3	3						
	8.50	3	3							

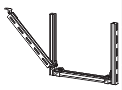
Table N° A5 – point load in the middle of the span, height of the trapeze: 1.2 m

LONGITUNAL with MQS-AC



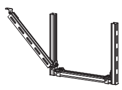
1. set-up with MQS-W41
2. set-up with MQS-W72
3. set-up with MQS-W41D

TRANSVERSAL with MQS-AC



4. set-up with MQS-W41
5. set-up with MQS-W72
6. set-up with MQS-W41D

TRANSVERSAL with MQS-ACD



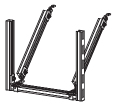
7. set-up with MQS-W72
8. set-up with MQS-W41D

		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.50	0.65	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,
	0.80	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	0.95	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	1.00	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	1.05	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	1.10	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	1.25	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
1.00	0.50	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,
	0.60	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	0.70	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	0.80	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	1.00	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	1.10	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	2.30	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	2.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,5,7,6,8,
1.50	0.60	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	0.75	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	1.05	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	1.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	1.95	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,
	2.10	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,
	2.55	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,
	2.85	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,6,8,
	3.30	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,6,8,
	3.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,6,8,	5,7,6,8,
	3.75	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,6,8,	5,7,6,8,
2.00	0.80	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	1.00	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	1.80	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	2.00	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,	
	2.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,	
	3.00	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,	
	3.40	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,	
	3.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,6,8,	5,7,	
	4.00	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,6,8,	5,7,	
	4.20	2,3,	2,3,4,6,8,	2,3,4,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,6,8,		
	4.60	2,3,	2,3,	2,3,	2,3,	2				
	5.00	2,3,	2,3,	2,3,	2,3,					
2.50	0.75	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	1.00	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	2.00	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	2.25	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,		
	2.75	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,		
	3.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,		
	3.75	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,		
	4.00	2,3,	2,3,4,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,6,8,	5,7,		
	5.00	2,3,	2,3,	2,3,	2,3,					
	5.75	2,3,	2,3,	2,3,	2					
	6.25	2,3,	2,3,	2,3,						

Continued on next page...

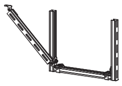
Table N° A5 – point load in the middle of the span, height of the trapeze: 1.2 m

LONGITUNAL with MQS-AC



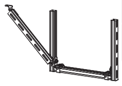
1. set-up with MQS-W41
2. set-up with MQS-W72
3. set-up with MQS-W41D

TRANSVERSAL with MQS-AC



4. set-up with MQS-W41
5. set-up with MQS-W72
6. set-up with MQS-W41D

TRANSVERSAL with MQS-ACD



7. set-up with MQS-W72
8. set-up with MQS-W41D

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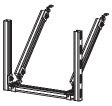
		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
3.00	0.60	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,			
	0.90	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,			
	2.10	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,			
	2.70	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,			
	3.30	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	5,7,			
	3.60	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,			
	3.90	2,3,	2,3,4,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,	5,7,			
	4.50	2,3,	2,3,	2,3,	2,3,					
	5.10	2,3,	2,3,	2,3,	2					
	6.60	2,3,	2,3,	2,3,						
	6.90	2,3,	3							
	7.50	3	3							
3.50	0.70	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,				
	2.10	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,				
	2.80	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,				
	3.15	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,				
	3.50	2,3,4,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,6,8,				
	3.85	2,3,	2,3,6,8,	2,3,6,8,	2,3,6,8,	6,8,				
	4.55	2,3,	2,3,	2,3,	2					
	5.95	2,3,	2,3,	2,3,						
	6.30	2,3,	2,3,	2						
	6.65	2,3,	3							
	8.75	3	3							
4.00	0.80	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,					
	3.20	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,					
	3.60	2,3,4,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,					
	4.00	2,3,	2,3,	2,3,	2					
	5.60	2,3,	2,3,	2,3,						
	6.00	2,3,	2,3,	2						
	8.80	3	3							
	9.60	3								
4.50	0.45	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,					
	2.70	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,					
	3.15	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,					
	3.60	2,3,4,	2,3,6,8,	2,3,6,8,	6,8,					
	4.95	2,3,	2,3,	2,3,						
	5.40	2,3,	2,3,	2						
	5.85	2,3,	2,3,							
	8.10	3	3							
	9.00	3								
5.00	3.00	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,						
	4.00	2,3,	2,3,	2,3,						
	5.00	2,3,	2,3,	2						
	5.50	2,3,	3							
	7.50	3	3							
	8.50	3								

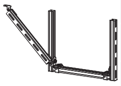
Table N° A6 – uniformly distributed load, height of the trapeze: 1.2 m

LONGITUNAL with MQS-AC



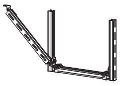
1. set-up with MQS-W41
2. set-up with MQS-W72
3. set-up with MQS-W41D

TRANSVERSAL with MQS-AC



4. set-up with MQS-W41
5. set-up with MQS-W72
6. set-up with MQS-W41D

TRANSVERSAL with MQS-ACD



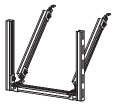
7. set-up with MQS-W72
8. set-up with MQS-W41D

		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.50	1.15	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,
	1.25	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
1.00	1.10	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,
	2.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
1.50	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,
	1.05	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
	3.75	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,
2.00	0.80	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,
	1.00	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	3.40	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,
	3.80	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	4.00	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	4.20	2,3,	2,3,4,6,8,	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	4.40	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,
	5.00	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2
2.50	1.00	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	3.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,
	3.75	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,
	4.00	2,3,	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,
	4.25	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2
	4.75	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	
	5.50	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2	
	6.00	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,		
	6.25	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
3.00	0.90	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,
	3.60	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,
	3.90	2,3,	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,
	4.80	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2	
	5.40	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,		
	6.00	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
	6.30	2,3,	2,3,	2,3,	2,3,	2,3,	3			
	6.60	2,3,	2,3,	2,3,	2,3,	3	3			
	6.90	2,3,	3	3	3	3	3			
	7.20	3	3	3	3	3	3			
	7.50	3	3	3	3	3				
3.50	1.05	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,
	1.75	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,
	2.80	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2
	3.15	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	
	3.50	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,6,8,	
	3.85	2,3,	2,3,4,6,8,	2,3,4,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,6,8,	
	4.55	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,		
	5.60	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
	5.95	2,3,	2,3,	2,3,	2,3,	2,3,	3			
	6.30	2,3,	2,3,	2,3,	2,3,	3	3			
	6.65	2,3,	3	3	3	3				
	8.75	3	3	3	3	3				

Continued on next page...

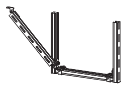
Table N° A6 – uniformly distributed load, height of the trapeze: 1.2 m

LONGITUNAL with MQS-AC



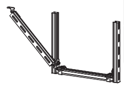
1. set-up with MQS-W41
2. set-up with MQS-W72
3. set-up with MQS-W41D

TRANSVERSAL with MQS-AC



4. set-up with MQS-W41
5. set-up with MQS-W72
6. set-up with MQS-W41D

TRANSVERSAL with MQS-ACD



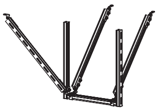
7. set-up with MQS-W72
8. set-up with MQS-W41D

... continued from previous page

		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
4.00	**0.80**	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	3.20	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,	
	3.60	2,3,4,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	5,7,	
	4.80	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
	5.20	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,			
	5.60	2,3,	2,3,	2,3,	2,3,	2,3,	3			
	6.00	2,3,	2,3,	2,3,	2,3,	3				
	6.40	2,3,	3	3	3	3				
	8.00	3	3	3	3	3				
	9.20	3	3	3	3					
	9.60	3	3							
4.50	**0.90**	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	3.15	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,5,7,		
	3.60	2,3,	2,3,4,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2		
	4.05	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,	2		
	4.95	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,			
	5.40	2,3,	2,3,	2,3,	2,3,	2,3,				
	5.85	2,3,	2,3,	2,3,	3	3				
	7.20	3	3	3	3	3				
	8.55	3	3	3	3					
	9.00	3	3	3						
	9.45	3								
5.00	**1.00**	1,2,3,4,5,7,6,8,	1,2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,			
	3.00	2,3,4,5,7,6,8,	2,3,4,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,	2,3,5,7,6,8,			
	4.00	2,3,	2,3,	2,3,	2,3,	2,3,	2,3,			
	4.50	2,3,	2,3,	2,3,	2,3,	2,3,	2			
	5.00	2,3,	2,3,	2,3,	2,3,	3				
	5.50	2,3,	2,3,	3	3	3				
	6.50	3	3	3	3	3				
	7.50	3	3	3	3					
	8.00	3	3	3						
	8.50	3	3							

Table N° B1 – point load in the middle of the span, height of the trapeze: 0.8 m

4-WAY with MQS-AC



1. set-up with MQS-W41
2. set-up with MQS-W72
3. set-up with MQS-W41D

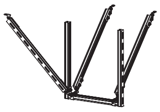
		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.50	1.25	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
1.00	1.20	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3
	1.60	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3
	2.10	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3
1.50	1.80	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3
	2.25	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2.3
	2.70	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2.3	2.3
	3.15	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	3.45	1,2,3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
2.00	2.20	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2	
	2.80	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2.3	2	
	3.20	1,2,3	2.3	2.3	2.3	2.3	2.3	2.3	2	
	3.40	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2	
2.50	2.50	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2		
	3.00	1,2,3	2.3	2.3	2.3	2.3	2.3	2		
	3.50	2.3	2.3	2.3	2.3	2.3	2.3	2		
3.00	2.10	1,2,3	1,2,3	2.3	2.3	2.3	2			
	2.70	1,2,3	2.3	2.3	2.3	2.3	2			
	3.30	2.3	2.3	2.3	2.3	2.3	2			
3.50	2.45	1,2,3	2.3	2.3	2.3	2.3				
	3.50	2.3	2.3	2.3	2.3	2.3				
4.00	2.40	1,2,3	2.3	2.3	2.3					
	3.20	2.3	2.3	2.3	2.3					
4.50	2.25	1,2,3	2.3	2.3	2.3					
	3.15	2.3	2.3	2.3	2.3					
5.00	3.00	2.3	2.3	2.3						

Table N° B2 – uniformly distributed load, height of the trapeze: 0.8 m

		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.50	1.25	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
1.00	2.50	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
1.50	2.25	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
	2.70	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3
	3.45	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3
2.00	2.00	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3
	2.80	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3
	3.40	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3
2.50	2.75	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3
	3.50	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3
3.00	3.30	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2
3.50	1.75	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2
	3.50	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	
4.00	3.20	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2	
4.50	3.15	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2		
5.00	3.00	1,2,3	1,2,3	2.3	2.3	2.3	2.3			

Table N° B3 – point load in the middle of the span, height of the trapeze: 1.0 m

4-WAY with MQS-AC



1. set-up with MQS-W41
2. set-up with MQS-W72
3. set-up with MQS-W41D

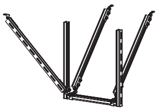
		Horizontal channel length (m)								
F_V (kN)	$F_{H\ max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.50	**1.25**	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
1.00	**1.20**	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3
	1.60	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3
	2.10	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3
	2.50	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3
1.50	**1.80**	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3
	2.25	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2.3
	2.70	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2.3	2.3
	3.15	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	3.45	1,2,3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
2.00	**2.20**	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2	
	2.80	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2.3	2	
	3.20	1,2,3	2.3	2.3	2.3	2.3	2.3	2.3	2	
	3.40	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2	
2.50	**2.50**	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2		
	3.00	1,2,3	2.3	2.3	2.3	2.3	2.3	2		
	3.50	2.3	2.3	2.3	2.3	2.3	2.3	2		
3.00	**2.10**	1,2,3	1,2,3	2.3	2.3	2.3	2			
	2.70	1,2,3	2.3	2.3	2.3	2.3	2			
	3.30	2.3	2.3	2.3	2.3	2.3	2			
3.50	**2.45**	1,2,3	2.3	2.3	2.3	2.3				
	3.50	2.3	2.3	2.3	2.3	2.3				
4.00	**2.40**	1,2,3	2.3	2.3	2.3					
	3.20	2.3	2.3	2.3	2.3					
4.50	**2.25**	1,2,3	2.3	2.3	2.3					
	3.15	2.3	2.3	2.3	2.3					
5.00	**3.00**	2.3	2.3	2.3						

Table N° B4 – uniformly distributed load, height of the trapeze: 1.0 m

		Horizontal channel length (m)								
F_V (kN)	$F_{H\ max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.50	**1.25**	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
1.00	**2.50**	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
1.50	**2.25**	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
	2.70	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3
	3.45	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3
2.00	**2.00**	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3
	2.80	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3
	3.40	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3
2.50	**2.75**	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3
	3.50	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3
3.00	**3.30**	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2
3.50	**1.75**	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2
	3.50	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	
4.00	**3.20**	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2	
4.50	**3.15**	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2		
5.00	**3.00**	1,2,3	1,2,3	2.3	2.3	2.3	2.3			

Table N° B5 – point load in the middle of the span, height of the trapeze: 1.2 m

4-WAY with MQS-AC



1. set-up with MQS-W41
2. set-up with MQS-W72
3. set-up with MQS-W41D

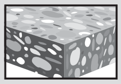
		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.50	1.25	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
1.00	1.20	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3
	1.60	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3
	2.10	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3
	2.50	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3
1.50	1.80	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3
	2.25	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2.3
	2.70	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2.3	2.3
	3.15	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	3.45	1,2,3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
2.00	2.20	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2	
	2.80	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2.3	2	
	3.20	1,2,3	2.3	2.3	2.3	2.3	2.3	2.3	2	
	3.40	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2	
2.50	2.50	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2		
	3.00	1,2,3	2.3	2.3	2.3	2.3	2.3	2		
	3.50	2.3	2.3	2.3	2.3	2.3	2.3	2		
3.00	2.10	1,2,3	1,2,3	2.3	2.3	2.3	2			
	2.70	1,2,3	2.3	2.3	2.3	2.3	2			
	3.30	2.3	2.3	2.3	2.3	2.3	2			
3.50	2.45	1,2,3	2.3	2.3	2.3	2.3				
	3.50	2.3	2.3	2.3	2.3	2.3				
4.00	2.40	1,2,3	2.3	2.3	2.3					
	3.20	2.3	2.3	2.3	2.3					
4.50	2.25	1,2,3	2.3	2.3	2.3					
	3.15	2.3	2.3	2.3	2.3					
5.00	3.00	2.3	2.3	2.3						

Table N° B6 – uniformly distributed load, height of the trapeze: 1.2 m

		Horizontal channel length (m)								
F_V (kN)	$F_{H\,max}$ (kN)	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.50	1.25	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
1.00	2.50	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
1.50	2.25	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
	2.70	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3
	3.45	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3
2.00	2.00	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3
	2.80	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3
	3.40	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3
2.50	2.75	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3
	3.50	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3
3.00	3.30	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2
3.50	1.75	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2
	3.50	1,2,3	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	
4.00	3.20	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2.3	2	
4.50	3.15	1,2,3	1,2,3	1,2,3	2.3	2.3	2.3	2		
5.00	3.00	1,2,3	1,2,3	2.3	2.3	2.3	2.3			

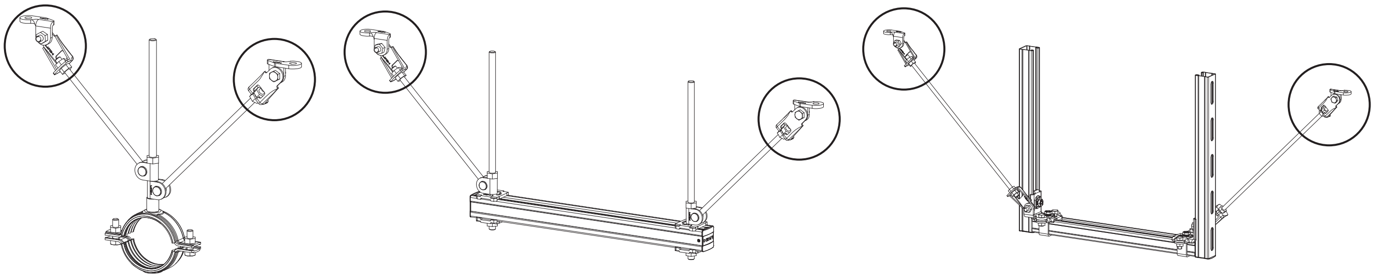
Structural attachment on solid concrete
Fastening of seismic rod bracing

Base material

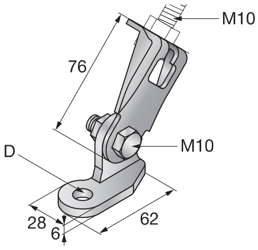


Solid concrete

Applications:

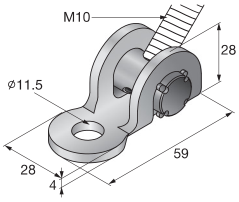


Seismic hinge MQS-AB



	Stud anchor	Screw anchor	Chemical anchor
MQS-AB-8 Item n.: 2083730	**HST-M8x75** 3) Item n.: 371581	**HUS-H 6x80** 3) Item n.: 416737	**HIT-HY 200-A + HIT-V M8x80** 1) Item n.: 2022696 + 387054 or **HIT-HY 200-A + HIT-Z M8x80** 2) Item n.: 2022696 + 2018364
MQS-AB-10 Item n.: 2083731	**HST-M10x90** 2) Item n.: 371584	**HUS-H 8x90** 1) Item n.: 368731	**HIT-HY 200-A + HIT-V M10x95** 1) Item n.: 2022696 + 387057 or **HIT-HY 200-A + HIT-Z M10x95** 2) Item n.: 2022696 + 2018367
MQS-AB-12 Item n.: 2083732	**HST-M12x115** 2) Item n.: 371587	**HUS-H 10x90** 1) Item n.: 401439	**HIT-HY 200-A + HIT-V M12x120** 2) Item n.: 2022696 + 387147 or **HIT-HY 200-A + HIT-Z M12x105** 2) Item n.: 2022696 + 2018411

Seismic hinge MQS-CH



	Stud anchor	Screw anchor	Chemical anchor
MQS-CH Item n.: 2083741	**HST-M10x90** 2) Item n.: 371584	**HUS-H 8x90** 1) Item n.: 368731	**HIT-HY 200-A + HIT-V M10x95** 1) Item n.: 2022696 + 387057 or **HIT-HY 200-A + HIT-Z M10x95** 2) Item n.: 2022696 + 2018367

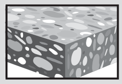
1) approved anchor according to the new European Guideline ETAG 001 Annex E, seismic category ETA C1
2) approved anchor according to the new European Guideline ETAG 001 Annex E, seismic category ETA C1 and C2
3) approved anchor according to the European Guideline ETAG 001-1, Option 1

General Design Notes
The anchoring system must be verified separately through the software **Hilti PROFIS Anchor** or using the **Hilti Fastening Technology Manual**, considering the real forces acting on the anchor and the actual boundary conditions for the specific application, such as, for non-exhaustive example, the strength class of the concrete, the presence of edges close to the anchor and the base material thickness.

MQS System
Seismic Designed Solutions

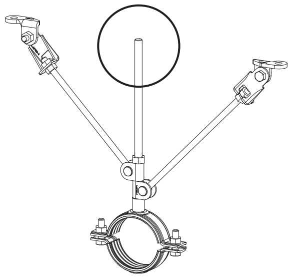
Structural attachment on solid concrete
Fastening of rod hanging

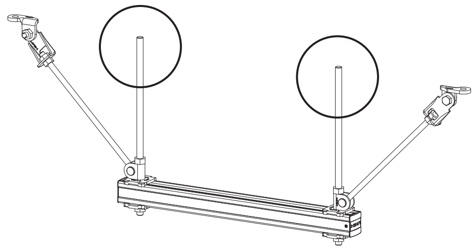
Base material

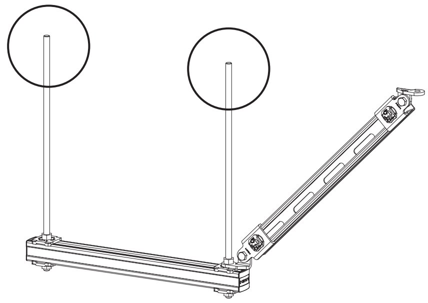


Solid concrete

Applications:







Fastening of threaded rod

	Stud anchor	Chemical anchor
Threaded rod M8 Item n.: according to length	**HST-M8x75** 3) **+ M8 coupler** Item n.: 371581 + 216703	**HIT-HY 200-A + threaded rod** 1) Item n.: 2022696
Threaded rod M10 Item n.: according to length	**HST-M10x90** 2) **+ M10 coupler** Item n.: 371584 + 216704	**HIT-HY 200-A + threaded rod** 1) Item n.: 2022696
Threaded rod M12 Item n.: according to length	**HST-M12x115** 2) **+ M12 coupler** Item n.: 371587 + 216705	**HIT-HY 200-A + threaded rod** 1) Item n.: 2022696
Threaded rod M16 Item n.: according to length	**HST-M16x140** 2) **+ M16 coupler** Item n.: 371593 + 216706	**HIT-HY 200-A + threaded rod** 1) Item n.: 2022696

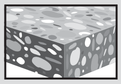
1) approved anchor according to the new European Guideline ETAG 001 Annex E, seismic category ETA C1
2) approved anchor according to the new European Guideline ETAG 001 Annex E, seismic category ETA C1 and C2
3) approved anchor according to the European Guideline ETAG 001-1, Option 1

General Design Notes
The anchoring system must be verified separately through the software **Hilti PROFIS Anchor** or using the **Hilti Fastening Technology Manual**, considering the real forces acting on the anchor and the actual boundary conditions for the specific application, such as, for non-exhaustive example, the strength class of the concrete, the presence of edges close to the anchor and the base material thickness.

MQS System
Seismic Designed Solutions

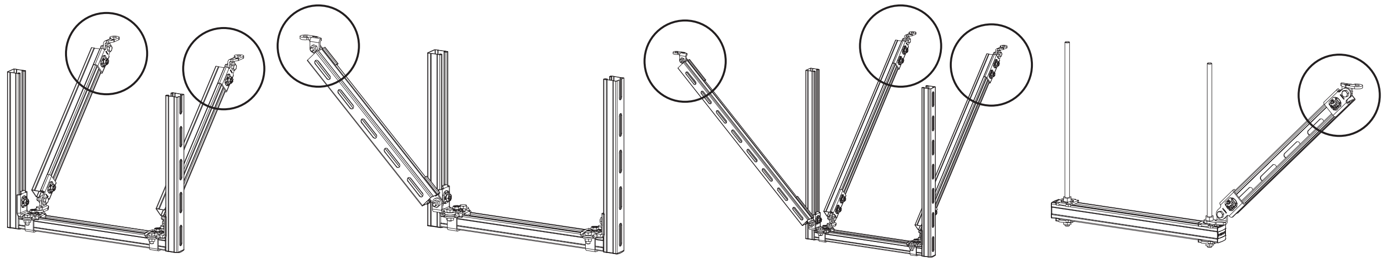
Structural attachment on solid concrete Fastening of seismic channel bracing

Base material

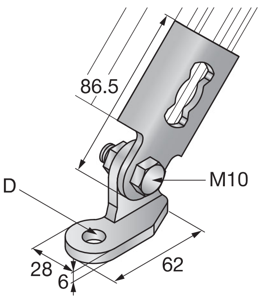


Solid concrete

Applications:



Seismic hinge MQS-AC/-ACD



	Stud anchor	Screw anchor	Chemical anchor
MQS-AC-10/-ACD-10 Item n.: 2083725 / 2083727	**HST-M10x90** 2) Item n.: 371584	**HUS-H 8x90** 1) Item n.: 368731	**HIT-HY 200-A + HIT-V M10x95** 1) Item n.: 2022696 + 387057 or **HIT-HY 200-A + HIT-Z M10x95** 2) Item n.: 2022696 + 2018367
MQS-AC-12/-ACD-12 Item n.: 2083726 / 2083728	**HST-M12x115** 2) Item n.: 371587	**HUS-H 10x90** 1) Item n.: 401439	**HIT-HY 200-A + HIT-V M12x120** 1) Item n.: 2022696 + 387147 or **HIT-HY 200-A + HIT-Z M12x105** 2) Item n.: 2022696 + 2018411

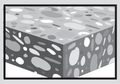
1) approved anchor according to the new European Guideline ETAG 001 Annex E, seismic category ETA C1
2) approved anchor according to the new European Guideline ETAG 001 Annex E, seismic category ETA C1 and C2

General Design Notes
The anchoring system must be verified separately through the software **Hilti PROFIS Anchor** or using the **Hilti Fastening Technology Manual**, considering the real forces acting on the anchor and the actual boundary conditions for the specific application, such as, for non-exhaustive example, the strength class of the concrete, the presence of edges close to the anchor and the base material thickness.

MQS System
Seismic Designed Solutions

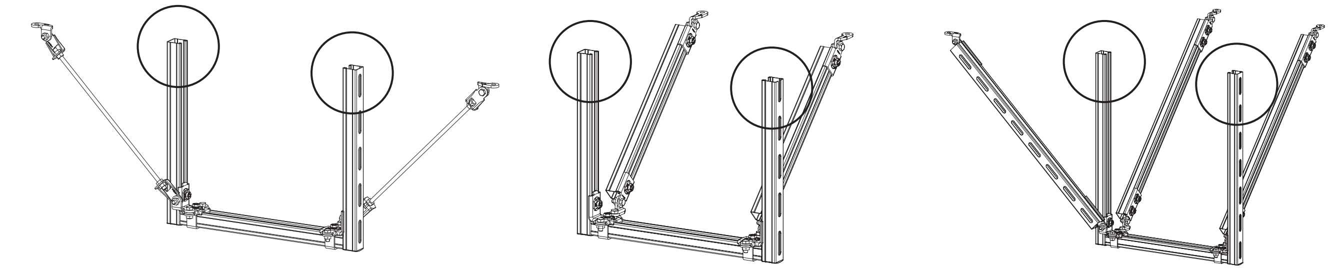
Structural attachment on solid concrete
Fastening of channel hanging

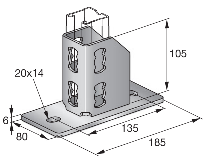
Base material



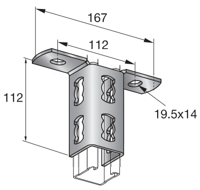
Solid concrete

Applications:

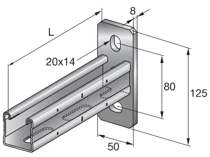




Base MQP-21-72
Item n.: 369651



Connector MQV-2/2D-14
Item n.: 369639



Bracket MQK
Item n.: according bracket type and length

Stud anchor	Screw anchor	Chemical anchor
HST-M10x90 2) Item n.: 371584	**HUS-H 8x90** 1) Item n.: 368731	**HIT-HY 200-A + HIT-V M10x95** 1) Item n.: 2022696 + 387057 or **HIT-HY 200-A + HIT-Z M10x95** 2) Item n.: 2022696 + 2018367
HST-M12x115 2) Item n.: 371587	**HUS-H 10x90** 1) Item n.: 401439	**HIT-HY 200-A + HIT-V M12x120** 1) Item n.: 2022696 + 387147 or **HIT-HY 200-A + HIT-Z M12x105** 2) Item n.: 2022696 + 2018411

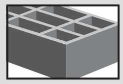
1) approved anchor according to the new European Guideline ETAG 001 Annex E, seismic category ETA C1
2) approved anchor according to the new European Guideline ETAG 001 Annex E, seismic category ETA C1 and C2

General Design Notes
The anchoring system must be verified separately through the software **Hilti PROFIS Anchor** or using the **Hilti Fastening Technology Manual**, considering the real forces acting on the anchor and the actual boundary conditions for the specific application, such as, for non-exhaustive example, the strength class of the concrete, the presence of edges close to the anchor and the base material thickness.

MQS System
Seismic Designed Solutions

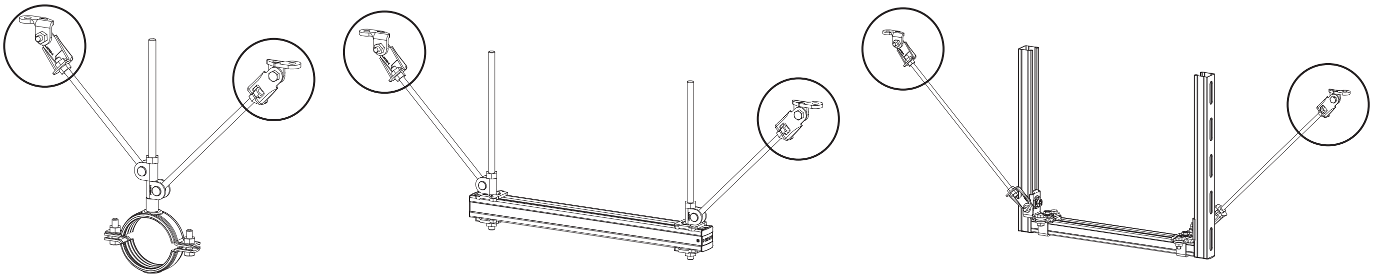
Structural attachment on hollow brick
Fastening of seismic rod bracing

Base material

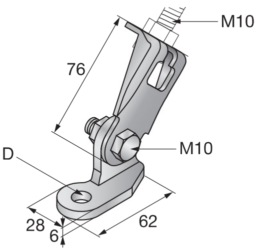


Hollow brick

Applications:

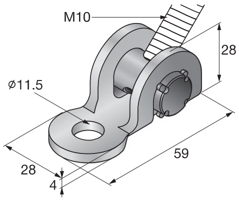


Seismic hinge MQS-AB



		Chemical anchor	
	Mortar	Anchor rod or threaded rod	Mesh sleeve
MQS-AB-8 Item n.: 2083730	**HIT-HY 70** Item n.: 383677	**HIT-V-5.8 M8x80 / x110 or AM8 8.8 rod** Item n.: 387054 / 387055 or 407496	**HIT-SC M16x...** Item n.: 375981 or 375982
MQS-AB-10 Item n.: 2083731		**HIT-V-5.8 M10x95 / x115 / x130 or AM10 8.8 rod** Item n.: 387057 / 387146 / 387058 or 407497	**HIT-SC M18x...** Item n.: 360485 or 360486
MQS-AB-12 Item n.: 2083732		**HIT-V-5.8 M12x120 / x150 or AM12 8.8 rod** Item n.: 387147 / 387061 or 407498	**HIT-SC M22x...** Item n.: 273662 or 284511

Seismic hinge MQS-CH



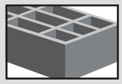
		Chemical anchor	
	Mortar	Anchor rod or threaded rod	Mesh sleeve
MQS-CH Item n.: 2083741	**HIT-HY 70** Item n.: 383677	**HIT-V-5.8 M10x95 / x115 / x130 or AM10 8.8 rod** Item n.: 387057 / 387146 / 387058 or 407497	**HIT-SC M18x...** Item n.: 360485 or 360486

General Design Notes
The anchoring system must be verified separately through the software **Hilti PROFIS Anchor** or using the **Hilti Fastening Technology Manual**, considering the real forces acting on the anchor and the actual boundary conditions for the specific application, such as, for non-exhaustive example, the strength class of the concrete, the presence of edges close to the anchor and the base material thickness.

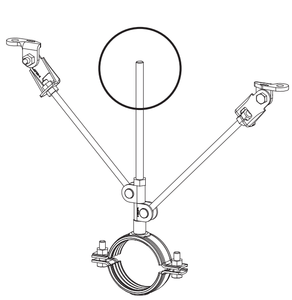
MQS System
Seismic Designed Solutions

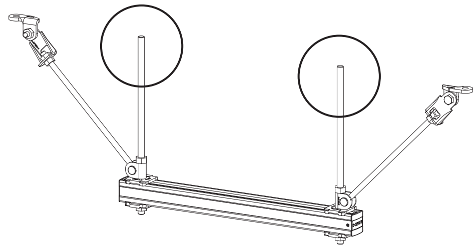
Structural attachment on hollow brick
Fastening of rod hanging

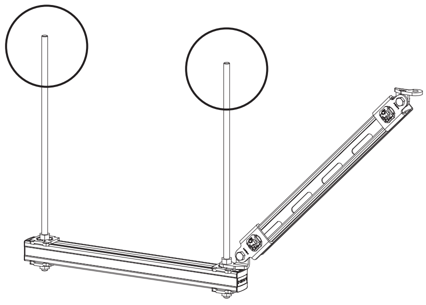
Base material


Hollow brick

Applications:







Fastening of threaded rod

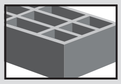
	Chemical anchor				
	Mortar	**Fastening of threaded rod**		**Fastening with internally threaded sleeve**	
		Threaded rod	**Mesh sleeve**	**Internally threaded sleeve**	**Mesh sleeve**
Threaded rod M8 Item n.: according to length	**HIT-HY 70** Item n.: 383677	**AM8x...**	**HIT-SC M16x...** Item n.: 375981 or 375982	**HIT-IC M8** Item n.: 47935	**HIT-SC M16x...** Item n.: 375981 or 375982
Threaded rod M10 Item n.: according to length		**AM10x...**	**HIT-SC M18x...** Item n.: 360485 or 360486	**HIT-IC M10** Item n.: 47936	**HIT-SC M18x...** Item n.: 360485 or 360486
Threaded rod M12 Item n.: according to length		**AM12x...**	**HIT-SC M22x...** Item n.: 273662 or 284511	**HIT-IC M12** Item n.: 47937	**HIT-SC M22x...** Item n.: 273662 or 284511
Threaded rod M16 Item n.: according to length		Fastening with base plate MQS 2-M16 (Item n. 246915) and 2 anchors composed of M10 threaded rod and HIT-SC M18 mesh sleeve is recommended		-	-

General Design Notes
The anchoring system must be verified separately through the software **Hilti PROFIS Anchor** or using the **Hilti Fastening Technology Manual**, considering the real forces acting on the anchor and the actual boundary conditions for the specific application, such as, for non-exhaustive example, the strength class of the concrete, the presence of edges close to the anchor and the base material thickness.

MQS System
Seismic Designed Solutions

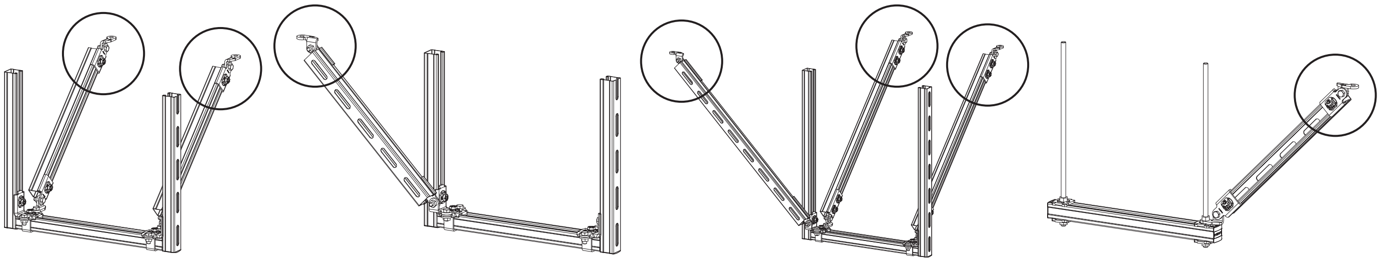
Structural attachment on hollow brick
Fastening of seismic channel bracing

Base material

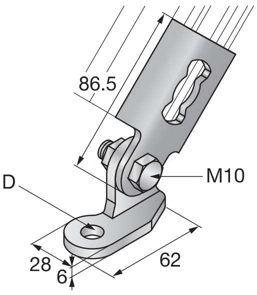


Hollow brick

Applications:



Seismic hinge MQS-AC/-ACD



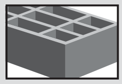
	Chemical anchor		
	Mortar	Anchor rod or threaded rod	Mesh sleeve
MQS-AC-10/-ACD-10 Item n.: 2083725 / 2083727	**HIT-HY 70** Item n.: 383677	**HIT-V-5.8 M10x95 / x115 / x130 or AM10 8.8 rod** Item n.: 387057 / 387146 / 387058 or 407497	**HIT-SC M18x...** Item n.: 360485 or 360486
MQS-AC-12/-ACD-12 Item n.: 2083726 / 2083728		**HIT-V-5.8 M12x120 / x150 or AM12 8.8 rod** Item n.: 387147 / 387061 or 407498	**HIT-SC M22x...** Item n.: 273662 or 284511

General Design Notes
The anchoring system must be verified separately through the software **Hilti PROFIS Anchor** or using the **Hilti Fastening Technology Manual**, considering the real forces acting on the anchor and the actual boundary conditions for the specific application, such as, for non-exhaustive example, the strength class of the concrete, the presence of edges close to the anchor and the base material thickness.

MQS System
Seismic Designed Solutions

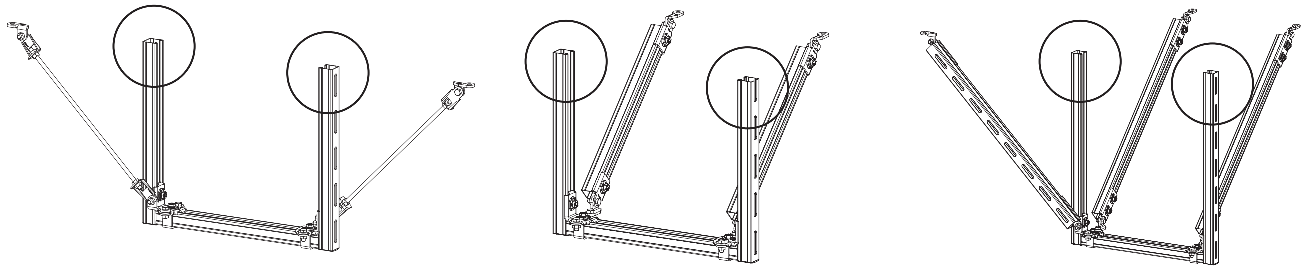
Structural attachment on hollow brick
Fastening of channel hanging

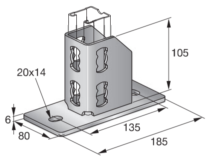
Base material



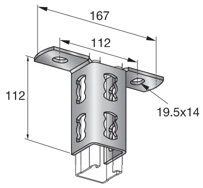
Hollow brick

Applications:

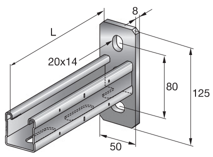




Base MQP-21-72
Item n.: 369651



Connector MQV-2/2D-14
Item n.: 369639



Bracket MQK
Item n.: according bracket type and length

	Chemical anchor	
Mortar	**Anchor rod or threaded rod**	**Mesh sleeve**
HIT-HY 70 Item n.: 383677	**HIT-V-5.8 M10x95 / x115 / x130 or AM10 8.8 rod** Item n.: 387057 / 387146 / 387058 or 407497	**HIT-SC M18x...** Item n.: 360485 or 360486
	HIT-V-5.8 M12x120 / x150 or AM12 8.8 rod Item n.: 387147 / 387061 or 407498	**HIT-SC M22x...** Item n.: 273662 or 284511

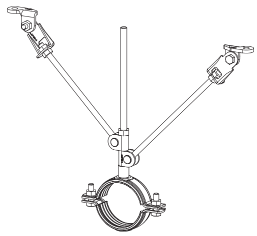
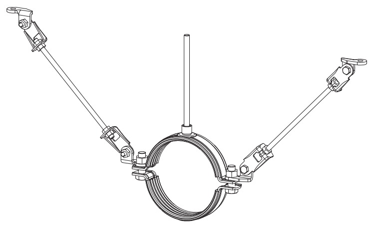
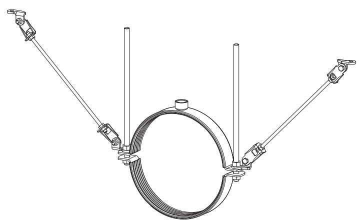
General Design Notes
The anchoring system must be verified separately through the software **Hilti PROFIS Anchor** or using the **Hilti Fastening Technology Manual**, considering the real forces acting on the anchor and the actual boundary conditions for the specific application, such as, for non-exhaustive example, the strength class of the concrete, the presence of edges close to the anchor and the base material thickness.

MQS System
Seismic Designed Solutions

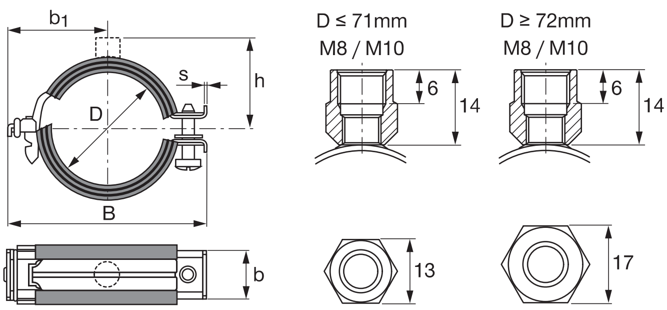
Trade attachments
Piping – single pipe

MQS Seismic System

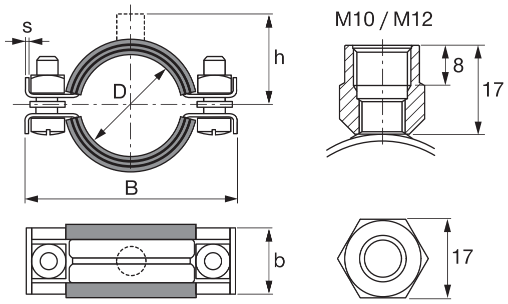
Recommendations on type of application and type of pipe ring for the correct transfer of horizontal seismic loads, according to typicals in Chapter 3

Application		Pipe: Dimension	Pipe: Pipe ring
Single rod hanging – seismic bracing installed on vertical rod		∅ < 4”	MPN-RC 1) MP-MI 2)
Single rod hanging – seismic bracing installed on pipe ring flanges		4” ≤ ∅ < 324 mm	MP-MX 3) MP-MXI 4)
Double rod hanging – seismic bracing installed on pipe ring flanges		∅ ≥ 324 mm	MP-MX 3) MP-MXI 4)

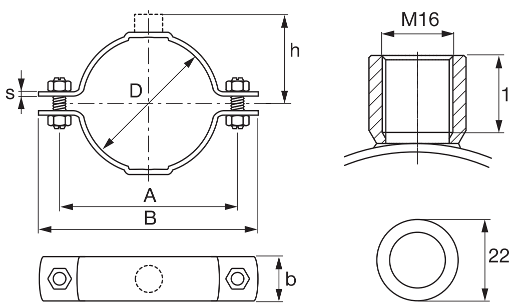
1) MPN-RC pipe rings



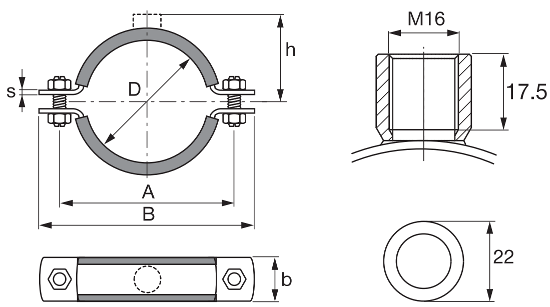
2) MP-MI pipe rings



3) MP-MX pipe rings



4) MP-MXI pipe rings

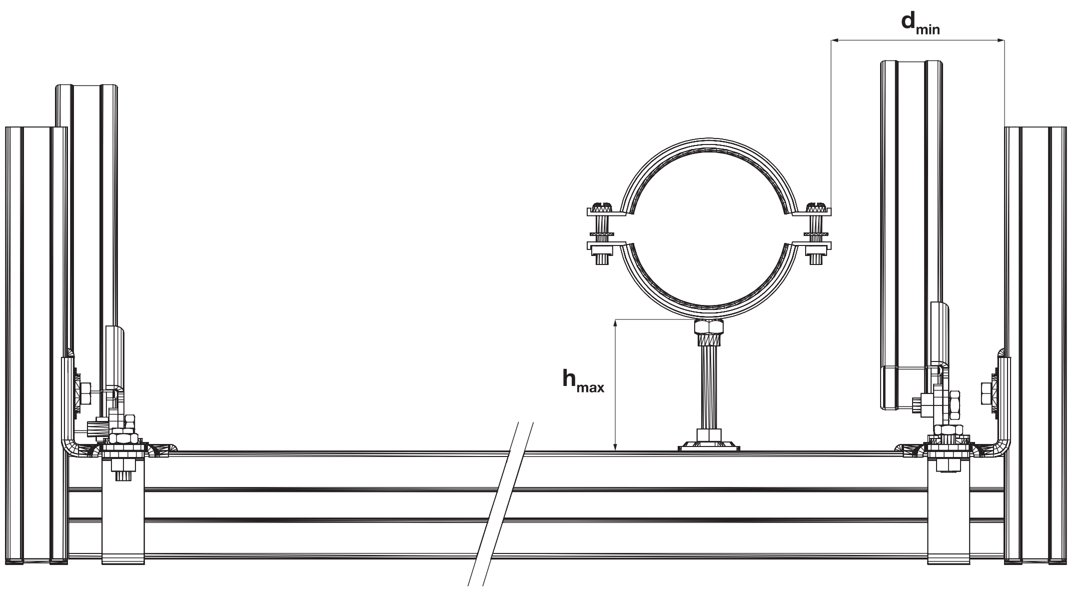


Trade attachments
Piping – multiple pipe

MQS
Seismic System

Recommendations on type of application and type of pipe ring for the correct transfer of horizontal seismic loads, according to typicals in Chapter 3

Based on pipe ring type (and pipe diameter as a consequence) table shows:
- threaded rod diameter recommended, to fix pipe-ring to the channel
- Pipe ring saddle nut (MQA type), for the fixation of the rod to the channel
- Max distance **h** from the connection boss to the horizontal channel
- Min distance **d** from the vertical channel (for the longitudinal bracing installation)

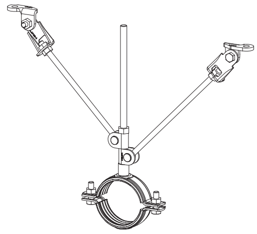
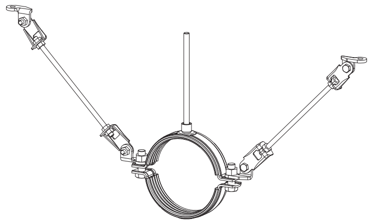
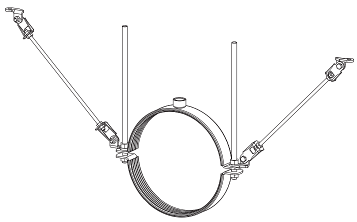


Pipe ring	Rod diameter	Pipe ring saddle	h_{max} [mm]	d_{min} [mm]
MPN-RC	M10	MQA-M10	100	100
MP-MI	M10/M12	MQA-M10/M12	100	100
MP-MX(I)	M16	MQA-M16	100	100

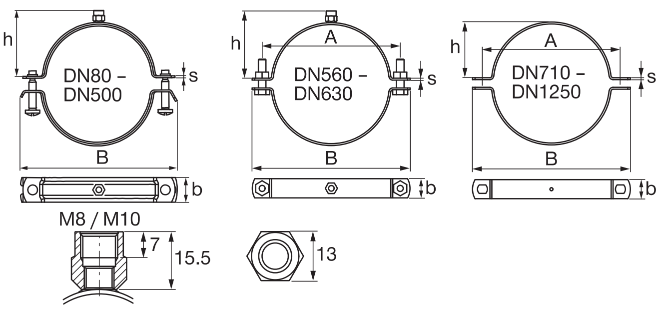
Trade attachments
Ventilation air ducts (without insulation)

MQS Seismic System

Recommendations on type of application and type of ventilation pipe ring for the correct transfer of horizontal seismic loads, according to typicals in Chapter 3

Application		Circular air duct (without sound insulation)	
		Dimension	Pipe ring
Single rod hanging – seismic bracing installed on vertical rod		Ø < DN 560	MV-P
Single rod hanging – seismic bracing installed on pipe ring flanges		DN 560 ≤ Ø ≤ DN 630	MV-P
Double rod hanging – seismic bracing installed on pipe ring flanges		Ø > DN 630	MV-P

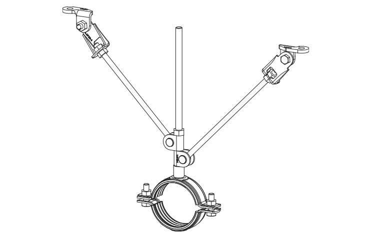
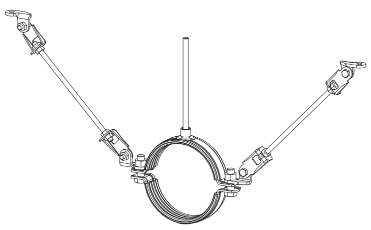
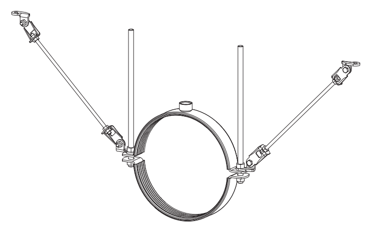
MV-P pipe rings



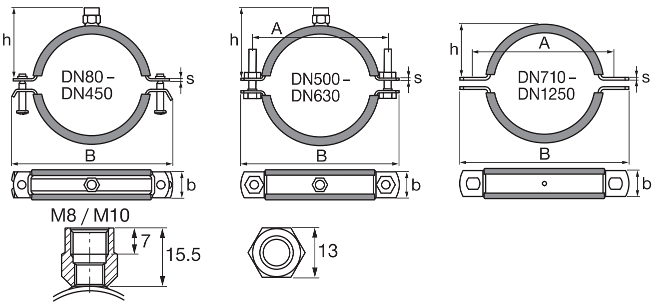
Trade attachments
Ventilation air ducts (with insulation)

MQS
Seismic System

Recommendations on type of application and type of ventilation pipe ring for the correct transfer of horizontal seismic loads, according to typicals in Chapter 3

Application		**Circular air duct** (with sound insulation)	
		Dimension	**Pipe ring**
Single rod hanging – seismic bracing installed on vertical rod		∅ < DN 500	MV-PI
Single rod hanging – seismic bracing installed on pipe ring flanges		DN 500 ≤ ∅ ≤ DN 630	MV-PI
Double rod hanging – seismic bracing installed on pipe ring flanges		∅ > DN 630	MV-PI

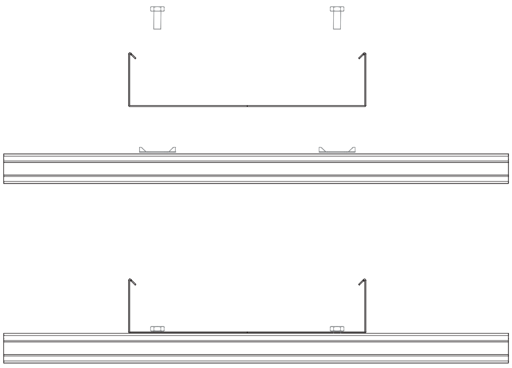
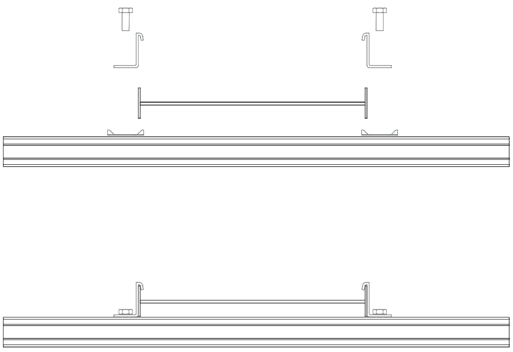
MV-PI pipe rings



Trade attachments Cable trays

MQS Seismic System

Recommendations on type of application and type of attachment for the correct transfer of horizontal seismic loads, according to typicals in Chapter 3

Application	Fastening	
Cable tray	**Channel accessory**	**Cable tray accessory**
	Wing nut MQM – according given bolts	Bolt – according specification of cable tray manufacturer
Cable ladder	**Channel accessory**	**Cable ladder accessory**
	Wing nut MQM – according given bolts	Clip – according specification of cable ladder manufacturer

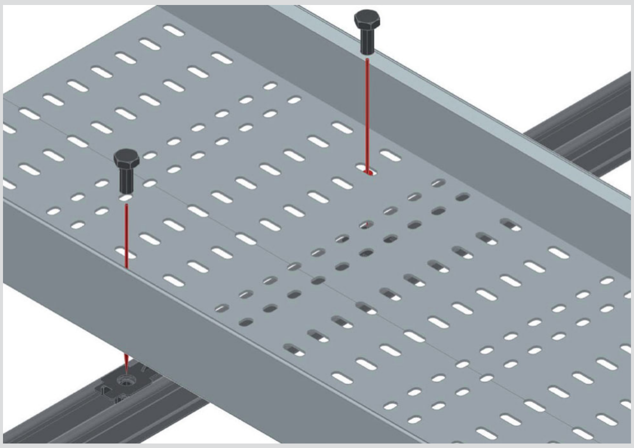


Fig. D.1 – direct fixation using cable tray holes

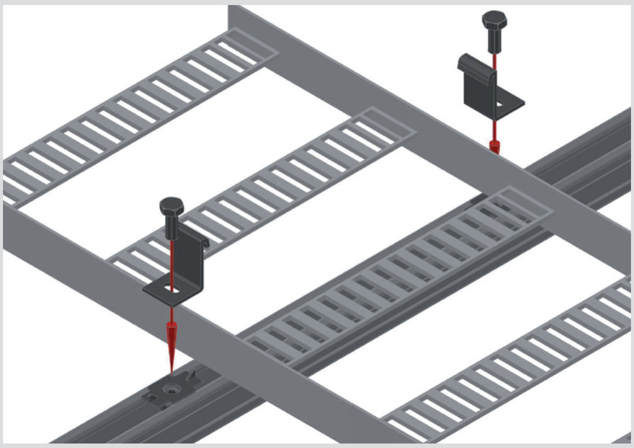
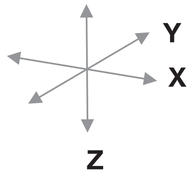
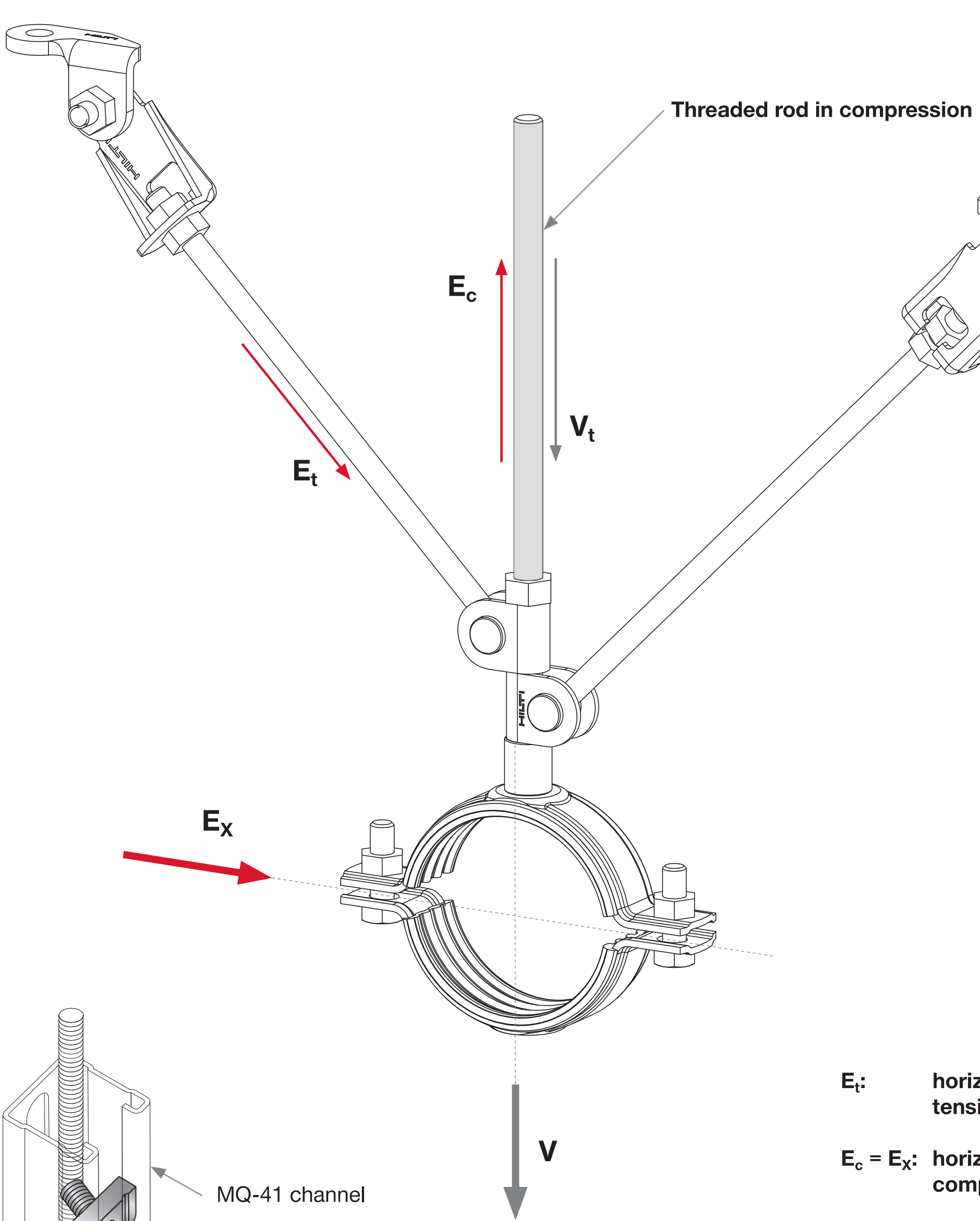


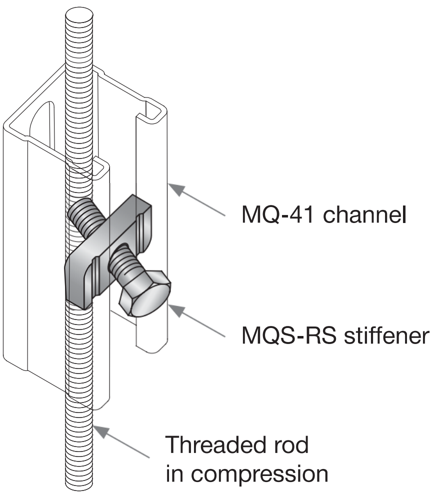
Fig. D.2 – cable ladder fixation with clips

Use of Rod Stiffener

MQS Seismic System







E_t: **horizontal force E_X causes tension in the bracing**

$E_c = E_X$: **horizontal force E_X causes compression in the main rod**

$V_t = V$: **vertical force V causes tension in the main rod**

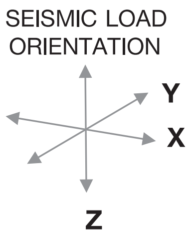
If $E_X > V$: rod stiffener required*

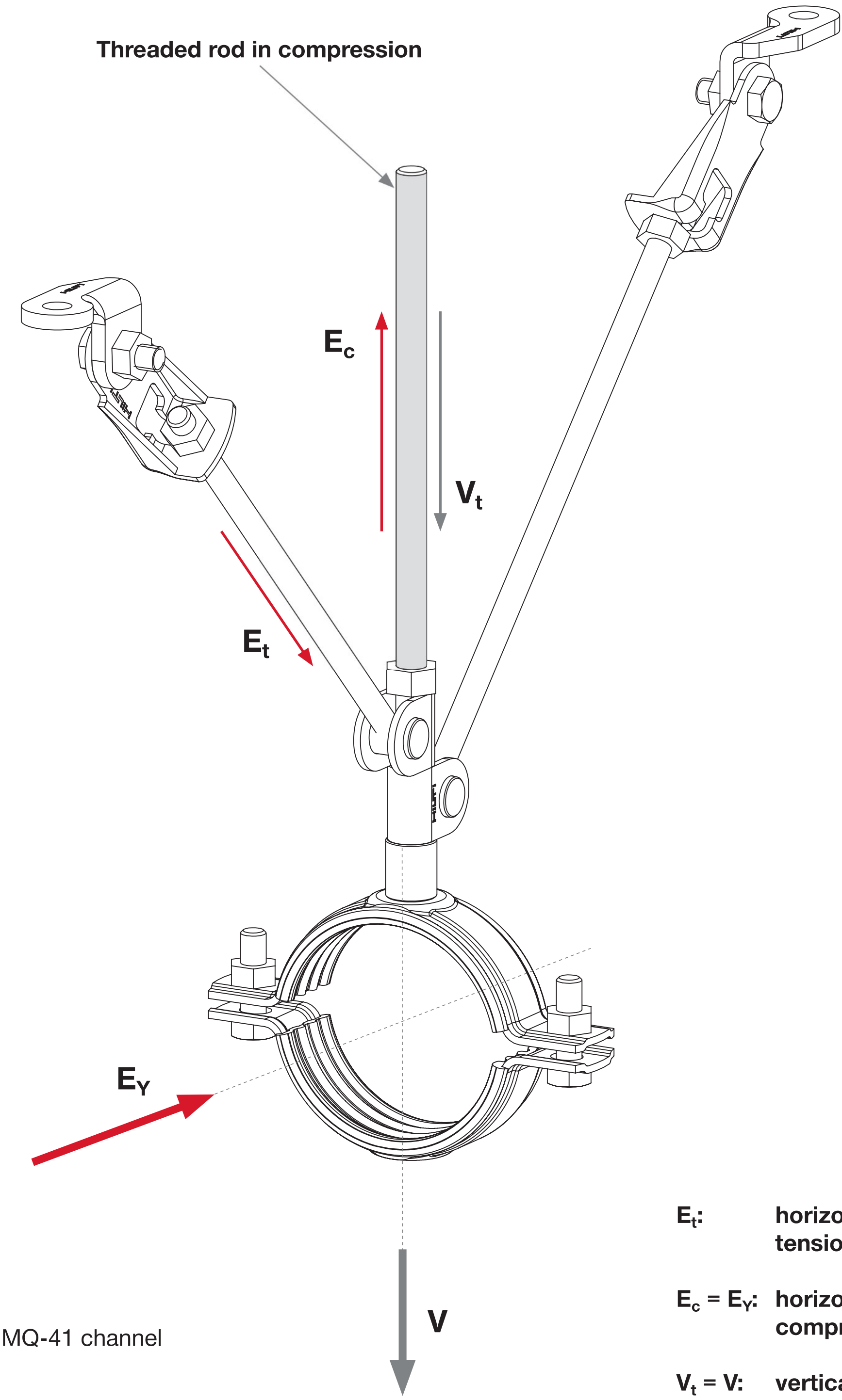
for detailed information see Annex I (MQS-RS Instruction For Use)

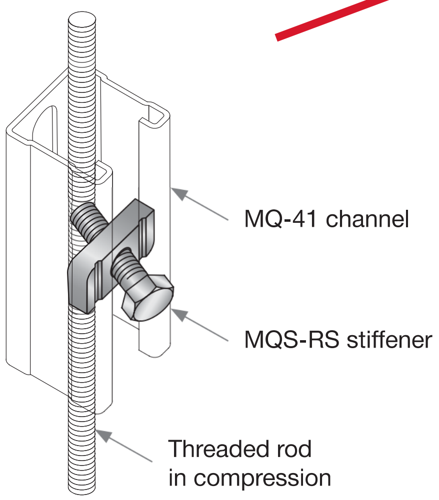
* rule applicable to 45° braced applications

Use of Rod Stiffener

MQS Seismic System







E_t:	**horizontal force E_Y causes tension in the bracing**
$E_c = E_Y$:	**horizontal force E_Y causes compression in the main rod**
$V_t = V$:	**vertical force V causes tension in the main rod**

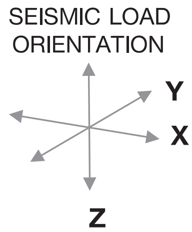
If $E_Y > V$: rod stiffener required*

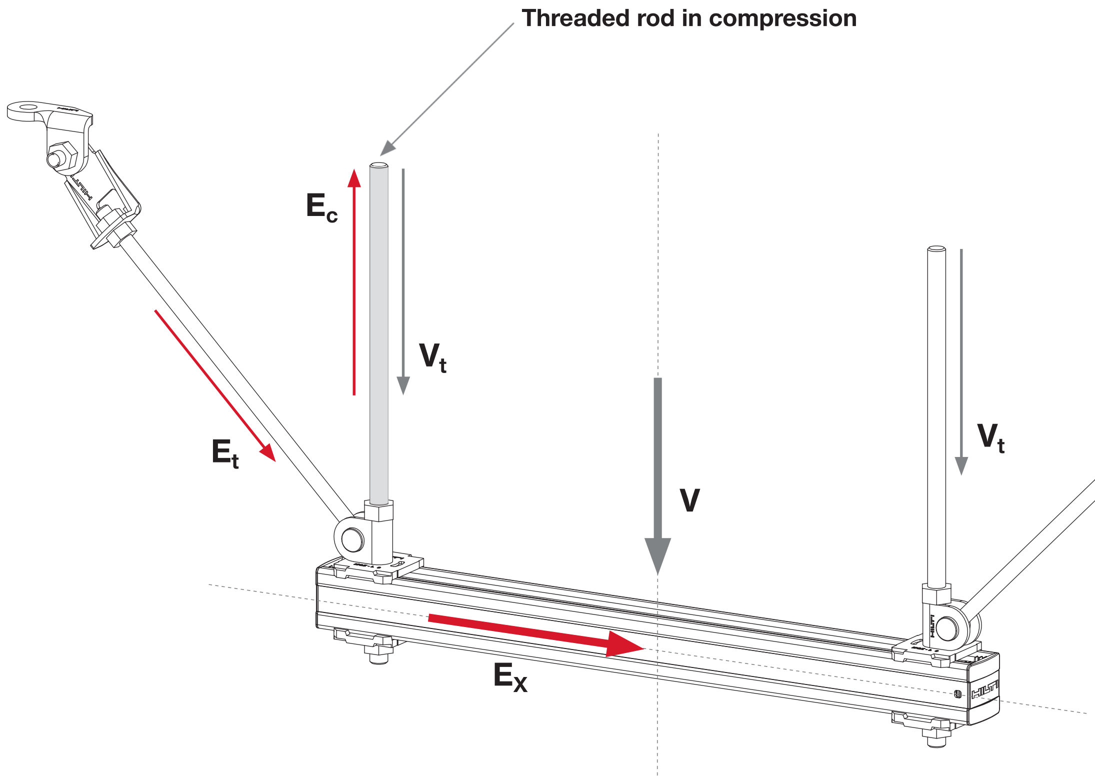
for detailed information see Annex I (MQS-RS Instruction For Use)

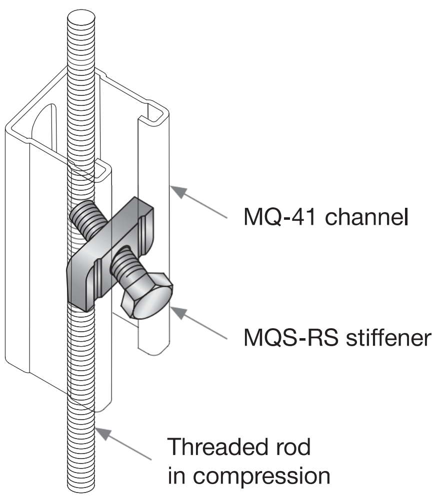
* rule applicable to 45° braced applications

Use of Rod Stiffener

MQS Seismic System







E_t: **horizontal force E_X causes tension in the bracing**

$E_c = E_X$: **horizontal force E_X causes compression in the main rod**

$V_t = V/2$: **vertical force V causes tension in the main rod**

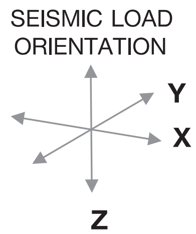
If $E_X > V/2$: rod stiffener required*

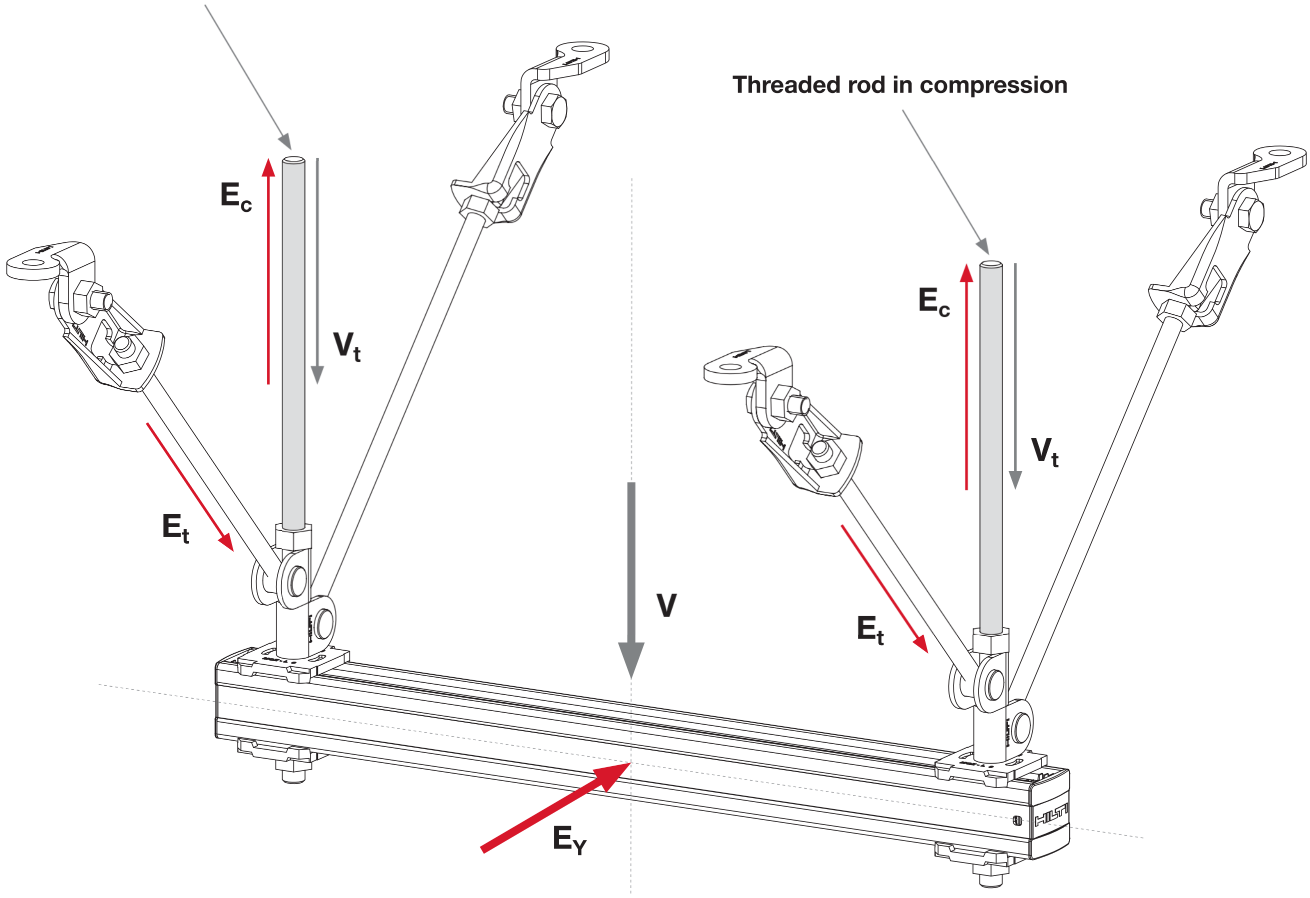
for detailed information see Annex I (MQS-RS Instruction For Use)

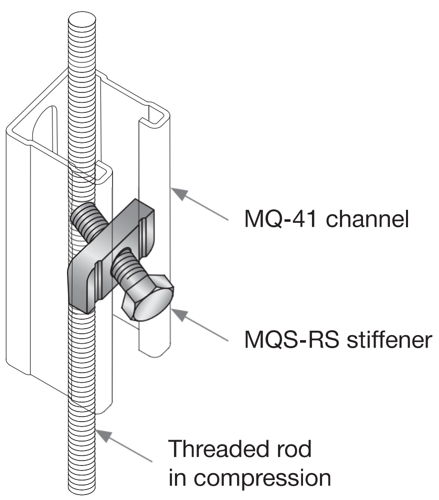
* rule applicable to 45° braced applications

Use of Rod Stiffener

MQS Seismic System







E_t:	**horizontal force E_Y causes tension in the bracing**
$E_c = E_Y/2$:	**horizontal force E_Y causes compression in the main rod**
$V_t = V/2$:	**vertical force V causes tension in the main rod**

If E_Y > V: rod stiffener required*

for detailed information see Annex I (MQS-RS Instruction For Use)

* rule applicable to 45° braced applications

Modal frequencies on non-structural elements

MQS Seismic System

Extract out of: EN 1998-1:2004

$$S_a = \alpha \cdot S \cdot \left[\left(\frac{3 \cdot (1 + Z/H)}{1 + (1 - T_a/T_1)^2}\right) - 0.5\right]$$

where:

T_a	fundamental vibration period of the non-structural element	[s]
T_1	fundamental vibration period of the building in the direction concerned	[s]

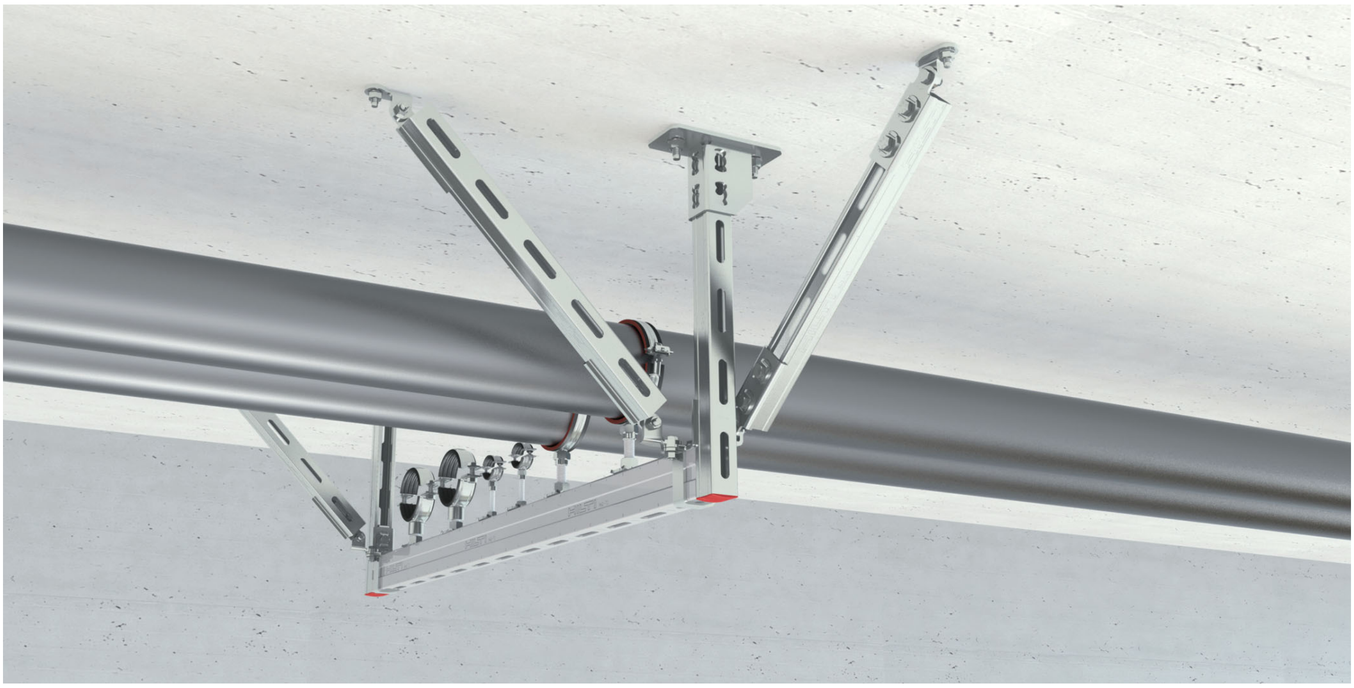
T_a/T_1 optimization

Building structures normally shows comparatively small fundamental frequencies. Especially for high and/or less stiff buildings values smaller then 1Hz (fundamental vibration period T_1 > 1s) are decisive.1)
Non structural elements, in particular comparatively small and light components like braced electric and ventilation lines, are compared to building structures much more stiffer and shows fundamental frequencies of more then 10Hz. The danger of resonance and/or an amplification of the static substitute load is not decisive. To determine the modal characteristics (natural frequencies and mode shapes), impact hammer tests were conducted on the installed field systems.

The ratio T_a/T_1 in that case (braced electric and ventilation applications) is very small and it is tolerable to set it zero ($T_a/T_1 \cong 0$) to determine the static substitute load.

For piping applications the system stiffness is highly variable. Therefore, Ta needs to be reasonably evaluated. Otherwise conservatively T_a/T_1 = 1 can be assumed.

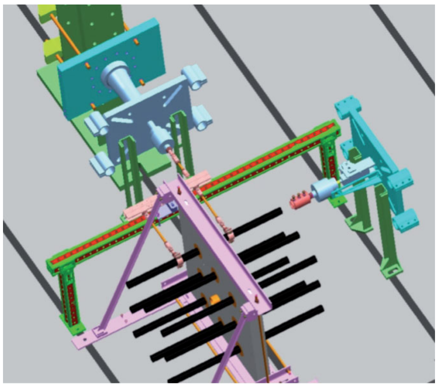
Fig. F.1 – Trapeze support with channels

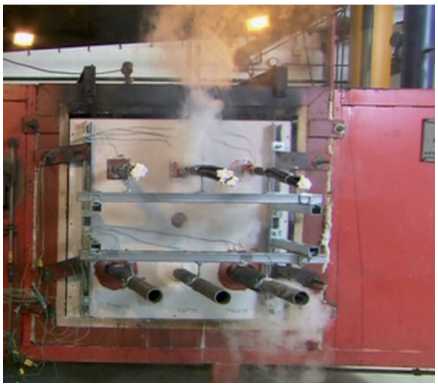


(1): Report BBS Engineers – 1013.1 (2010) / Simplified Rayleigh Method (Prof. Dr. Alessandro Dazio and Dr. Thomas Wenk)
(2): Department of Structural Engineering University of California, San Diego, report N°: SSRP–2013/16

Behaviour of firestop penetration seals under seismic actions

Guiding Principles





The damage of non-structural components represents a key risk of post-earthquake impacts. The proper functioning of passive, as well as active, fire protection systems during fire following an earthquake can help reduce the risk to people and property.

The right Firestop reduces the extensive need for maintenance, repair and reinspection.

Seismic and fire resistance tests conducted by Hilti clearly showed the following results:

- different Firestop systems have varied ability to resist deformation without damage
- pre-engineered products were, in general, more tolerant to deformation than bulk sealants
- firestop products with a high intumescent performance are better than normal not expanding materials as gaps which appear during the movement will be closed in a fire; however, the smoke rating was in some cases significantly reduced
- The use of bracing of penetrants (pipe systems, cabling), is highly recommended to limit the absolute movement of the penetrants.

Seismic tests of penetration seals

The results of internal tests show big differences in the behaviour, appearance and failure modes of different Firestop product systems. These results were verified in a large scale seismic shake table test at University of California, San Diego.

- Quasi- static cyclic loads according to FEMA* 461 protocol applied directly on one single penetrant, whereas the wall was fixed
- The use of stiff and unflexible materials with low elasticity (e.g. mortars and grouts, board systems, semi-plastic sealants) may be critical especially in connection with pipes or cable trays where displacement forces are high
- Metal pipes may be deformed, plastic pipes may be bent during movement. A low flexibility of the Firestop system will not be able to make up for the penetrant movement. Penetrants or walls might break or even be destroyed. With the consequence of a lower or non-existing smoke tightness or fire integrity
- The subsequent fire tests confirmed the seismic results. Damaged, stiff and hard board systems did not pass the fire tests. Flexible Firestop systems or pre-engineered devices passed the tests and achieved the desired fire integrity due to limited damage during a seismic event. High performance intumescent products clearly add an additional safety level to the compartimentation of a building

* Federal Emergency Management Agency: Code for Interim testing protocol for determining the seismic performance characteristics of structural and non-structural components

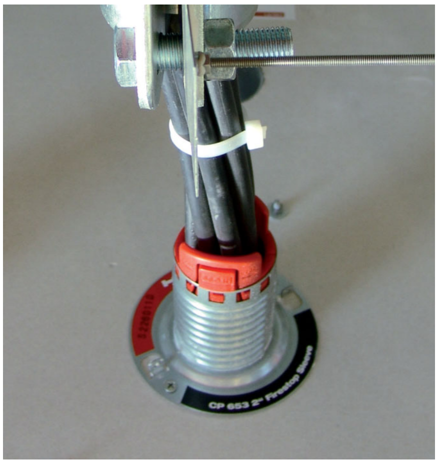
Hilti Firestop Sleeve CFS-SL
Seismic performance test sheet

Product description: Hilti firestop sleeve is a pre-engineered device used for firestop seals in small openings, offering 2” and 4” dimensions diameter for high traffic cable penetrations with an easy repenetration of cables.

Tested application: cable bundle.

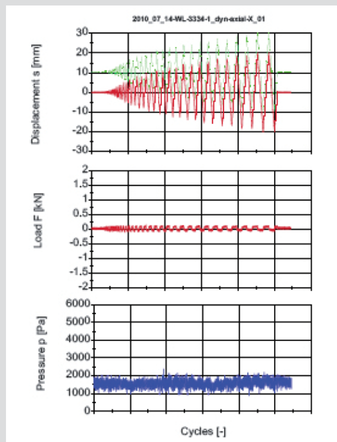
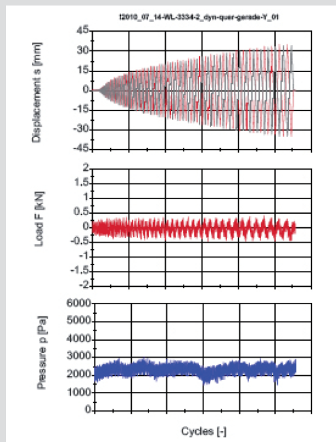
Test setup / description: Simulated seismic firestop tests conducted in the Hilti research laboratory, accredited by the DAP (German Accreditation System for Testing) regarding the standard DIN EN ISO / IEC 17025. The quasi-static cyclic loads according to FEMA 461* protocol were applied directly on one single penetrant, whereas the wall was fixed.

* Federal Emergency Management Agency: code for interim testing protocol for determining the seismic performance characteristics of structural and non-structural components



Test results

Test configuration: cable penetration to represent the key application. Firestop sleeve tested in typical opening size. Installation in a drywall.

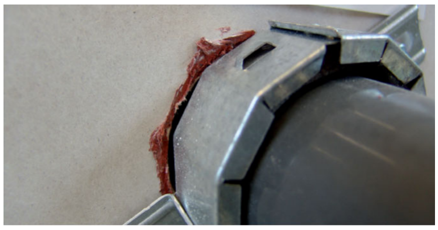
Results:	x-direction	y-direction	zz-direction
1. Displacement amplitude 2. Movement force 3. Pressure			Not tested as rotation in flexible material is comparable to x- and y-direction
Movement	± 20 mm	± 32 mm	
Resistance to movement	Low (<1kN)	Low (<1kN)	
Initial pressure	1500 Pa	2500 Pa	
Pressure drop	No	No	
Airtight during test	Yes	Yes	
Firestop functionality	Passed	Passed	

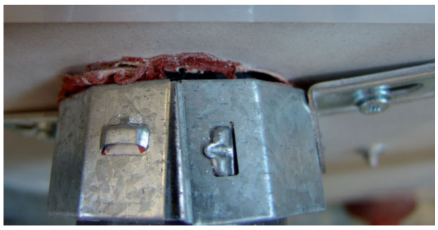
Summary and interpretation of results

- No cracks or deformations were observed during movement of the penetrating cables
- The high stability of the firestop sleeve at the outside and the flexible membrane in the inside of the device allowed a maximum of movement of the cables
- No deformation of penetrating items
- The air- and gas-tightness was fully maintained during the whole test
- In the subsequent orientation fire test the firestop sleeve successfully kept smoke-tightness and ensured the fire integrity of the penetration

For specific application details the national approvals or the European Technical Approval must be observed. All results are based upon the test constellation and its respective parameters described in the Hilti seismic firestop test reports and the application details set out in the Hilti installation instructions.

Hilti Firestop Collar CFS-C, CFC-P
Seismic performance test sheet





Product description: Hilti firestop collar used for firestop seals of plastic pipe penetrations in walls and floors.

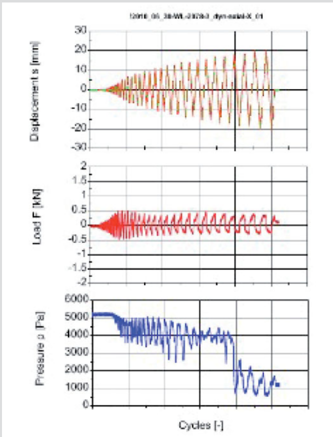
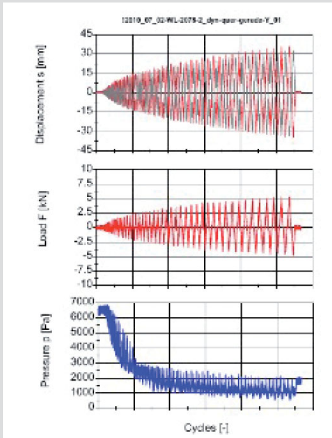
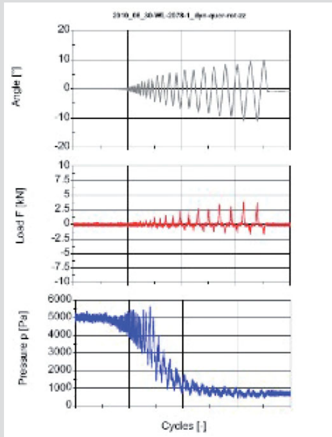
Tested application: plastic pipe penetration.

Test setup / description: Simulated seismic firestop tests conducted in the Hilti research laboratory, accredited by the DAP (German Accreditation System for Testing) regarding the standard DIN EN ISO / IEC 17025. The quasi-static cyclic loads according to the FEMA 461* protocol were applied directly on one single penetrant, whereas the wall was fixed.

* Federal Emergency Management Agency: code for interim testing protocol for determining the seismic performance characteristics of structural and non-structural components

Test results

Test configuration: cable penetration to represent the key application. Firestop sleeve tested in typical opening size. Installation in a drywall.

Results:	**x-direction**	**y-direction**	**zz-direction**
1. Displacement amplitude 2. Movement force 3. Pressure			
Movement	± 20 mm	± 32 mm	± 10°
Resistance to movement	Low (<1kN)	Medium (<5kN)	Medium (<5kN)
Initial pressure	5000 Pa	6000 Pa	5000 Pa
Pressure drop**	Low-to-medium	Low-to-high	Medium-to-high Pronounced plateau
Airtight during test**	Yes / Partly	Yes / No	Yes / No
Firestop functionality	Passed	Passed	Passed

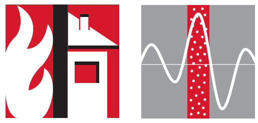
** Performance data influenced by smoke seal system.

Summary and interpretation of results

- No cracks or deformations were observed during movement of the pipes
- The collar was still fixed to the wall and fully intact
- High intumescent performance of the collar ensured fire integrity of the penetration
- The sealant, functioning as a smoke seal in the annular gap, is the critical component. The usage of an equivalent smoke seal product (such as Hilti firestop acrylic sealant CP606 / CFS-S ACR) is recommended

For specific application details the national approvals or the European Technical Approval must be observed. All results are based upon the test constellation and its respective parameters described in the Hilti seismic firestop test reports and the application details set out in the Hilti installation instructions.

Hilti Firestop Acrylic Sealant CFS-S ACR
Seismic performance test sheet



Product description: Hilti firestop acrylic sealant used for firestop seals of metal pipe penetrations and various other applications together with other Hilti firestop systems as a gap filler or smoke seal in walls and floors.

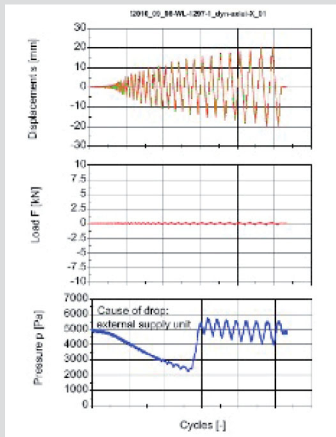
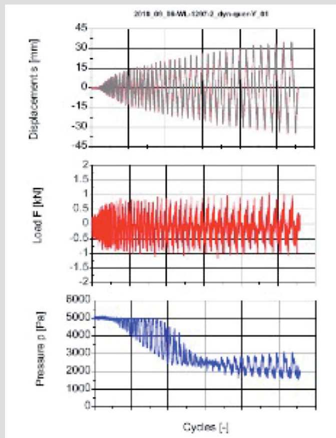
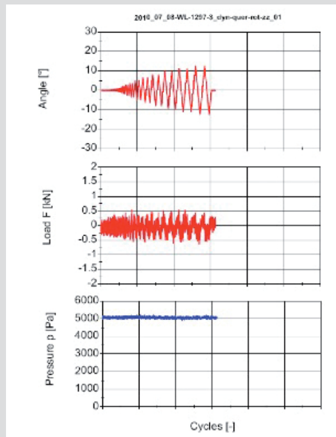
Tested application: pipe penetration.

Test setup / description: Simulated seismic firestop tests conducted in the Hilti research laboratory, accredited by the DAP (German Accreditation System for Testing) regarding the standard DIN EN ISO / IEC 17025. The quasi-static cyclic loads according to the FEMA 461* protocol were applied directly on one single penetrant, whereas the wall was fixed.

* Federal Emergency Management Agency: code for interim testing protocol for determining the seismic performance characteristics of structural and non-structural components

Test results

Test configuration: cable penetration to represent the key application. Firestop sleeve tested in typical opening size. Installation in a drywall.

Results:	**x-direction**	**y-direction**	**zz-direction**
1. Displacement amplitude 2. Movement force 3. Pressure			
Movement	± 20 mm	± 30 mm	± 10°
Resistance to movement	Low (<1kN)	Low (<1kN)	Low (<1kN)
Initial pressure	5000 Pa	5000 Pa	5000 Pa
Pressure drop	No (drop in chart caused by external supply unit)	Medium, Pronounced plateau	No
Airtight during test	Partly (yes)	Partly	Yes
Firestop functionality	No rated due to non-insulated metal pipe		

Summary and interpretation of results

- No cracks or deformations were observed during movement of the pipe in x- and zz-directions. During movement in y-direction, one crack at the edge of the drywall occurred. The air- and gas-tightness was maintained during a long period of the test.
- The high flexibility of the sealant followed most of the movement of the penetrants
- The sealant showed excellent elastic behavior and very good adhesion to penetrants, no deformation
- In the subsequent orientation fire test the firestop acrylic sealant was not able to fully keep smoke-tightness and to ensure the fire integrity. The reason for this was the missing temperature rating due to the missing insulation of the metal pipe. With a regular mineral-wool insulated pipe, the fire integrity would have met the requirements

For specific application details the national approvals or the European Technical Approval must be observed. All results are based upon the test constellation and its respective parameters described in the Hilti seismic firestop test reports and the application details set out in the Hilti installation instructions.

Hilti Firestop Foam Hilti CFS-F FX
Seismic performance test sheet

Product description: Hilti Firestop Foam is used for permanent firestop seals in small and medium sized openings (optimum size range 100x100 to 300x300 mm) for cable, pipe and mixed penetrations.

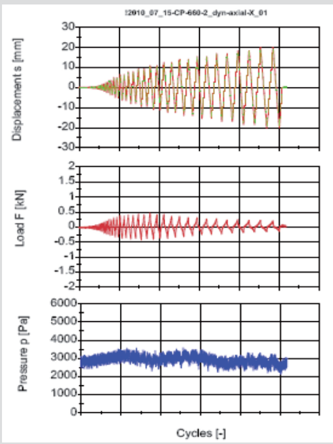
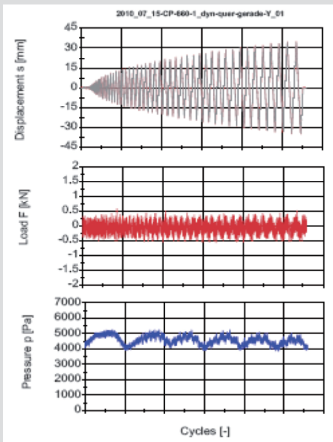
Tested application: cable bundle.

Test setup / description: Simulated seismic firestop tests conducted in the Hilti research laboratory, accredited by the DAP (German Accreditation System for Testing) regarding the standard DIN EN ISO / IEC 17025. The quasi-static cyclic loads according to the FEMA 461* protocol were applied directly on one single penetrant, whereas the wall was fixed.

* Federal Emergency Management Agency: code for interim testing protocol for determining the seismic performance characteristics of structural and non-structural components

Test results

Test configuration: cable penetration to represent the key application. Firestop sleeve tested in typical opening size. Installation in a drywall.

Results:	x-direction	y-direction	zz-direction
1. Displacement amplitude 2. Movement force 3. Pressure			Not tested as rotation in flexible material is comparable to x- and y-direction
Movement	± 20 mm	± 32 mm	
Resistance to movement	Low (<1kN) due to flexible foam	Low (<1kN) due to flexible foam	
Initial pressure	2800 Pa	4500 Pa	
Pressure drop	Low	Low	
Airtight during test	Yes	Yes	
Firestop functionality	Passed	Passed	

Summary and interpretation of results

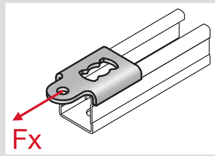
- No cracks or deformations were observed during movement of the penetrating cables
- The high flexibility of the Firestop Foam followed the movement of the penetrants
- Slight release of foam and cables shows positive result on flexibility under large forces (product stays in opening)
- No damage or deformation of penetrating items
- The air and gas tightness was maintained during the whole test
- In the subsequent orientation fire test the intumescent Firestop Foam successfully kept smoke tightness and ensured the fire integrity of the penetration
- In the seismic compliance test no damage visible

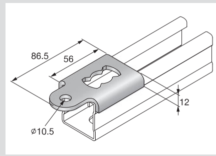
For specific application details the national approvals or the European Technical Approval must be observed. All results are based upon the test constellation and its respective parameters described in the Hilti seismic firestop test reports and the application details set out in the Hilti installation instructions.

Product Data Sheet

MQS Seismic System

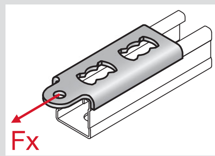
Order description	Desing load	
	$+ F_X$	$- F_X$
MQS-C	6.24 kN	6.24 kN

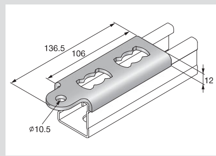




Shown load values are desing values (F_{Rd}). The partial safety factor for the action is 1.0.
Note: final load for a particular seismic support is depending on the set up of the used items!

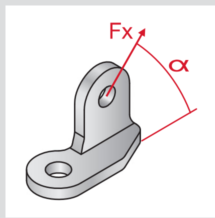
Order description	Desing load	
	$+ F_X$	$- F_X$
MQS-CD	12.48 kN	12.48 kN

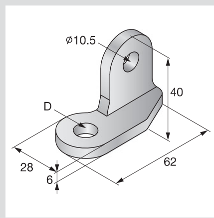




Shown load values are desing values (F_{Rd}). The partial safety factor for the action is 1.0.
Note: final load for a particular seismic support is depending on the set up of the used items!

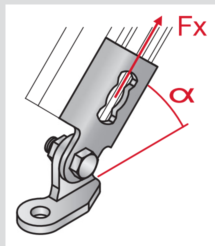
Order description	D	Desing load	
		$+ F_X$	$- F_X$
MQS-A-8	9.4 mm	11.60 kN	11.60 kN
MQS-A-10	11.5 mm		
MQS-A-12	13.6 mm		
MQS-A-16	16.3 mm		

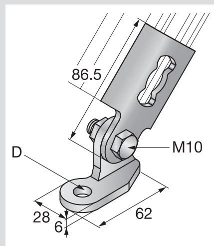




Shown load values are desing values (F_{Rd}). The partial safety factor for the action is 1.0. Load values are valid for α = 45°±15°.
Note: final load for a particular seismic support is depending on the set up of the used items!

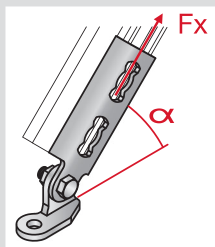
Order description	D	Desing load	
		$+ F_X$	$- F_X$
MQS-AC-10	11.5 mm	6.24 kN	6.24 kN
MQS-AC-12	13.6 mm		

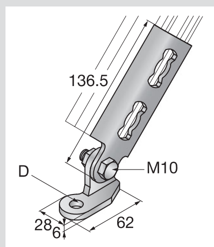




Shown load values are desing values (F_{Rd}). The partial safety factor for the action is 1.0. Load values are valid for α = 45°±15°.
Note: final load for a particular seismic support is depending on the set up of the used items!

Order description	D	Desing load	
		$+ F_X$	$- F_X$
MQS-ACD-10	11.5 mm	11.60 kN	11.60 kN
MQS-ACD-12	13.6 mm		



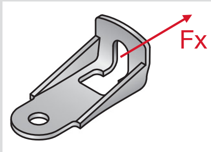


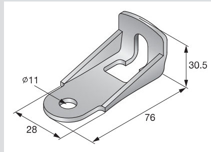
Shown load values are desing values (F_{Rd}). The partial safety factor for the action is 1.0. Load values are valid for α = 45°±15°.
Note: final load for a particular seismic support is depending on the set up of the used items!

Product Data Sheet

MQS Seismic System

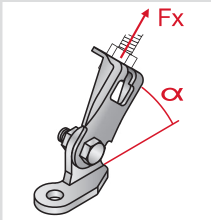
Order description	Desing load	
	+ F_X	- F_X
MQS-B	4.56 kN	n.a.

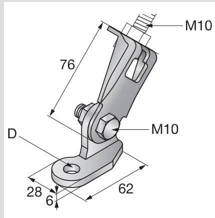




Shown load values are desing values (F_{Rd}). The partial safety factor for the action is 1.0.
Note: final load for a particular seismic support is depending on the set up of the used items!

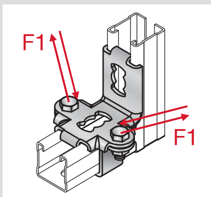
Order description	D	Desing load	
		+ F_X	- F_X
MQS-AB-8	9.4 mm	4.56 kN	n.a.
MQS-AB-10	11.5 mm		
MQS-AB-12	13.6 mm		
MQS-AB-16	16.3 mm		

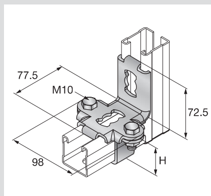




Shown load values are desing values (F_{Rd}). The partial safety factor for the action is 1.0. Load values are valid for α = 45°±15°.
Note: final load for a particular seismic support is depending on the set up of the used items!

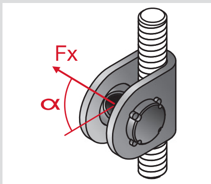
Order description	Desing load	
	+ F_1	- F_1
MQS-W-41/-72/-41D	6.10 kN	6.10 kN

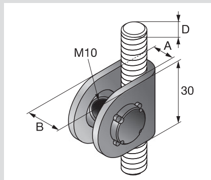




Shown load values are desing values (F_{Rd}). The partial safety factor for the action is 1.0. Load values are valid for all angles.
Note: final load for a particular seismic support is depending on the set up of the used items!

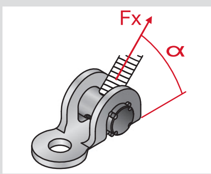
Order description	D	A	Desing load	
			+ F_X	- F_X
MQS-H-8	M8	8.3 mm	12.96 kN	n.a.
MQS-H-10	M10	10.3 mm		
MQS-H-12	M12	12.3 mm		

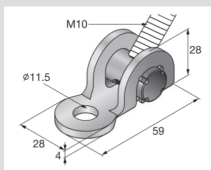




Shown load values are desing values (F_{Rd}). The partial safety factor for the action is 1.0. Load values are valid f or α = 45°±15°.
Note: final load for a particular seismic support is depending on the set up of the used items!

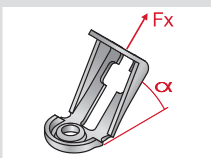
Order description	Desing load	
	+ F_X	- F_X
MQS-CH	4.67 kN	n.a.

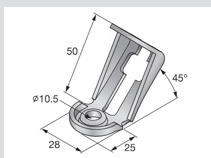




Shown load values are desing values (F_{Rd}). The partial safety factor for the action is 1.0. Load values are valid f or α = 45°±15°.
Note: final load for a particular seismic support is depending on the set up of the used items!

Order description	Desing load	
	+ F_X	- F_X
MQ3D-AS	4.56 kN	n.a.





Shown load values are desing values (F_{Rd}). The partial safety factor for the action is 1.0. Load values are valid f or α = 45°±15°.
Note: final load for a particular seismic support is depending on the set up of the used items!

Product development and tests

MQS Seismic System

In addition to static analysis, taking into account the above design rules (see Chapter 2) static or dynamic load tests were performed on all MQS parts.

With these results of the load tests, the supporting FEM model could be calibrated and optimized, thus, the suitability of specific applications could be demonstrated and verified.

The following figures show examples of the test setup on MQS-ACD connector (Fig. H.1) as well as the results of the FEM analysis (Fig. H.2).

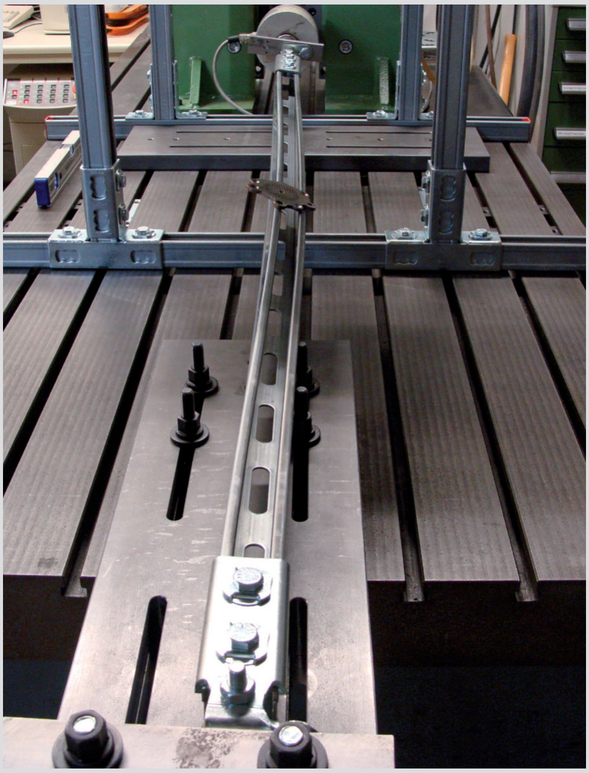


Fig. H.1 – Compression load test on MQS-ACD component with MQ-41

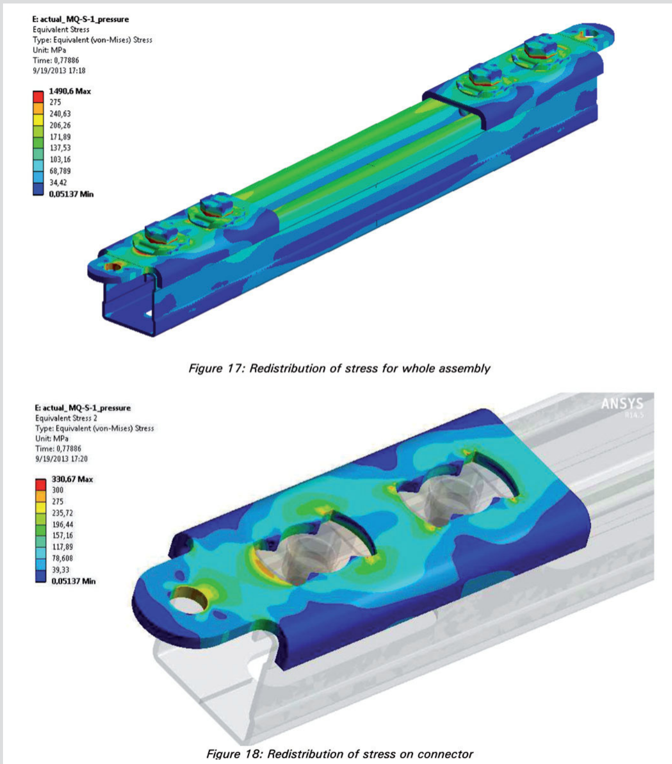
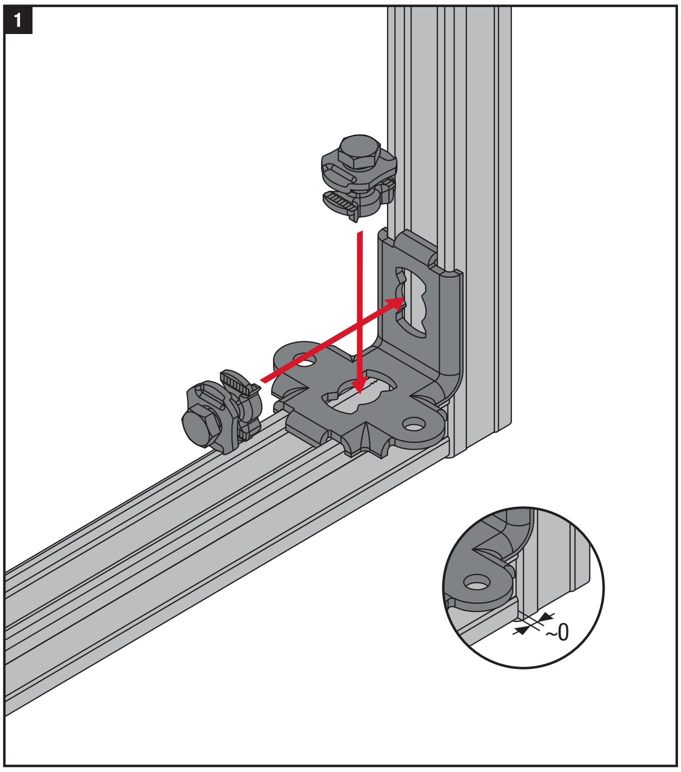


Fig. H.2 – Finite Elements Analysis on MQS-ACD component

Instruction for use MQS-W

MQS Seismic System

1



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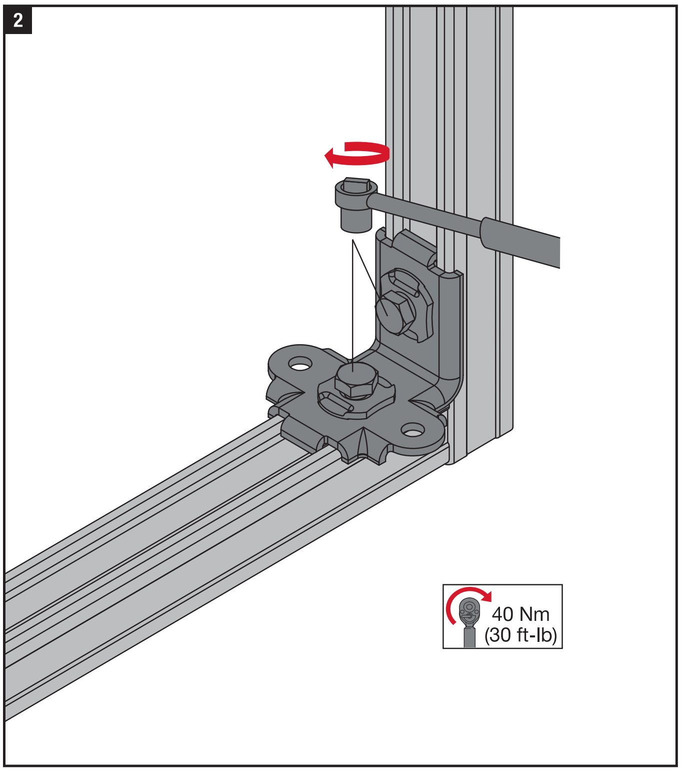
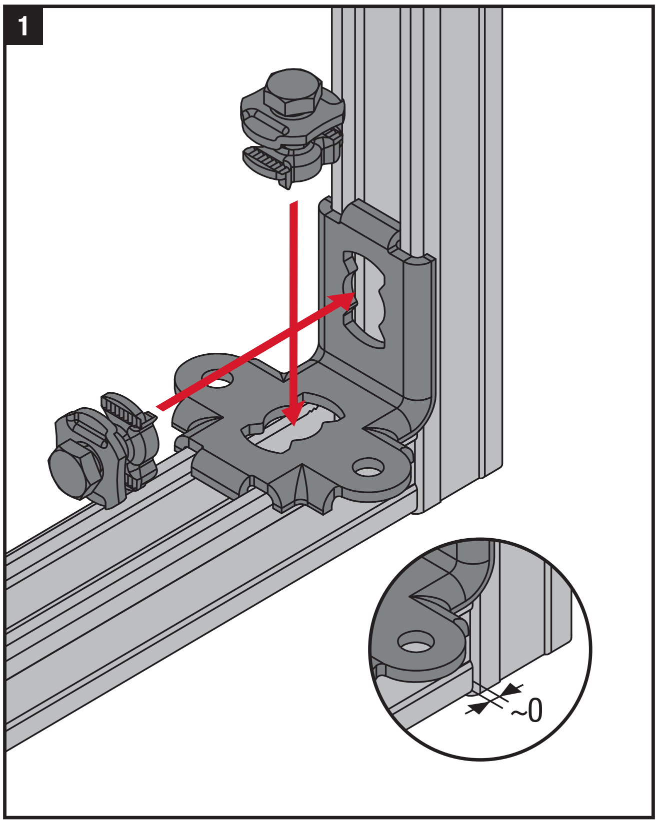
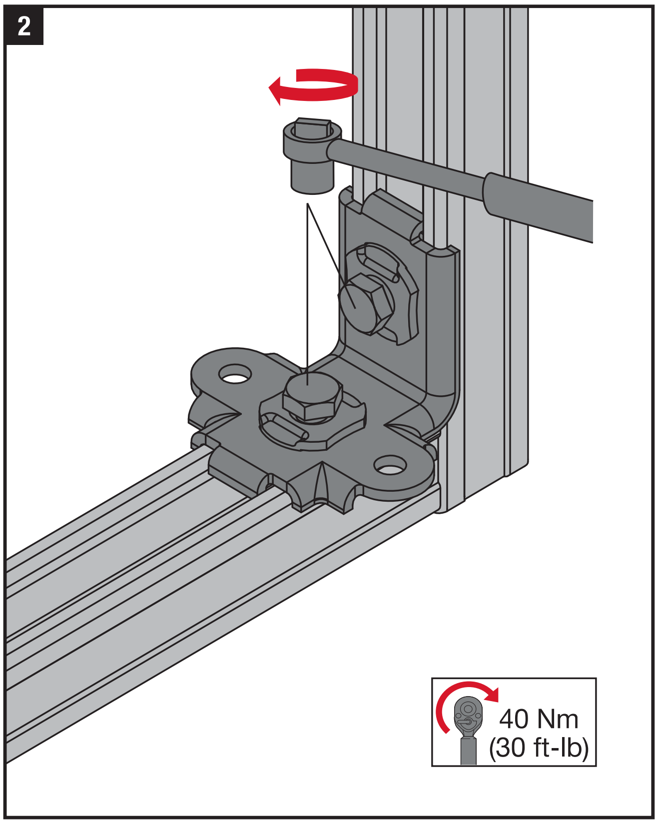
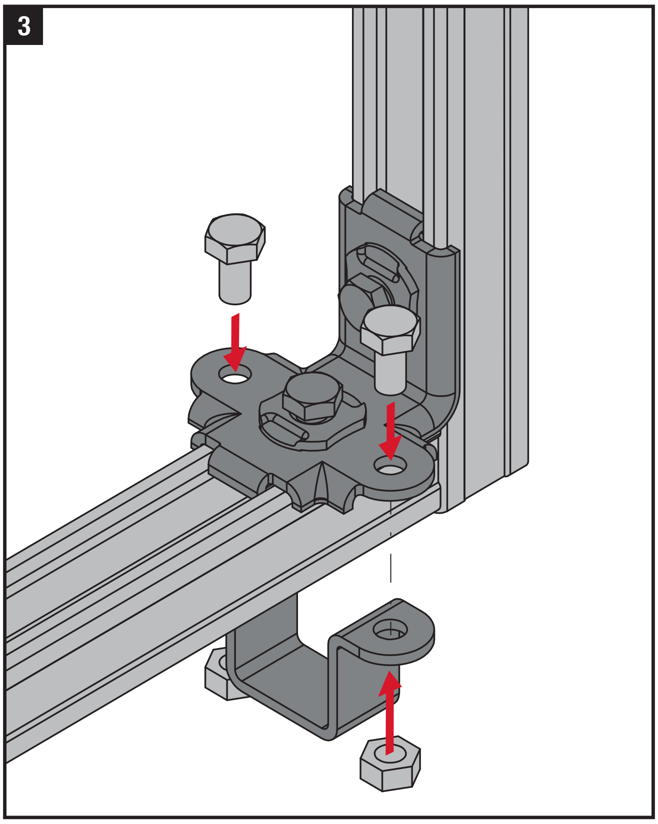


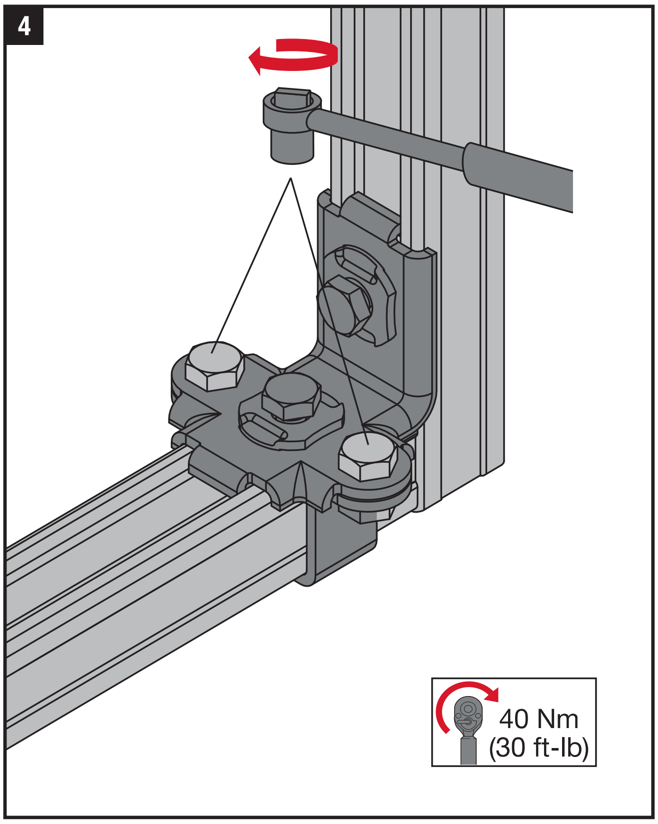
Instruction for use MQS-W Set

MQS Seismic System









Instruction for use MQS-AC/ACD with MQS-W Set

MQS Seismic System

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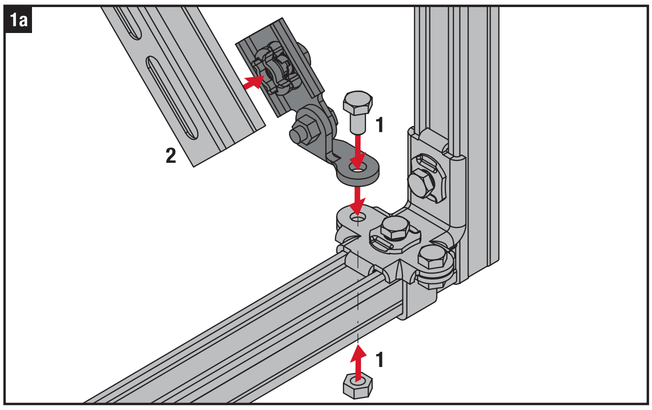

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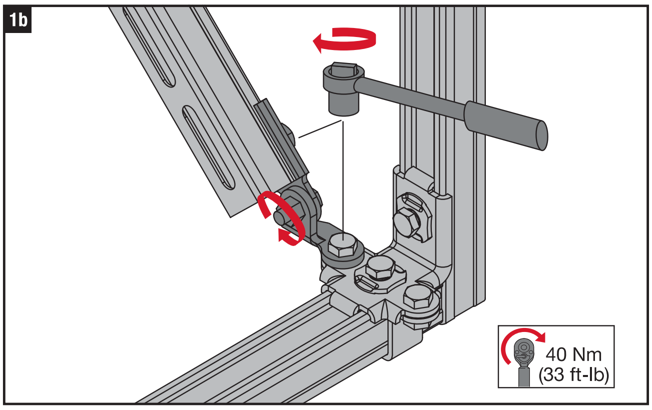

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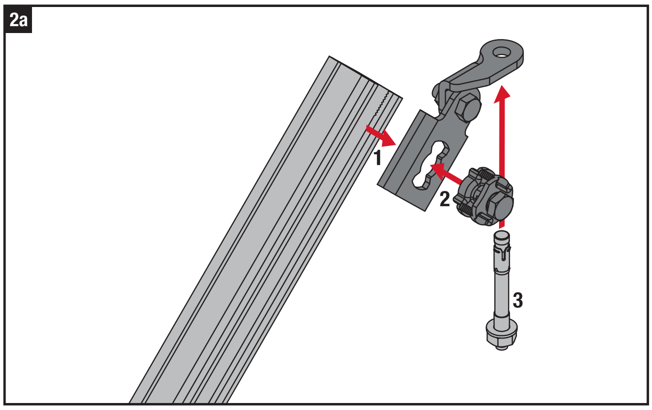

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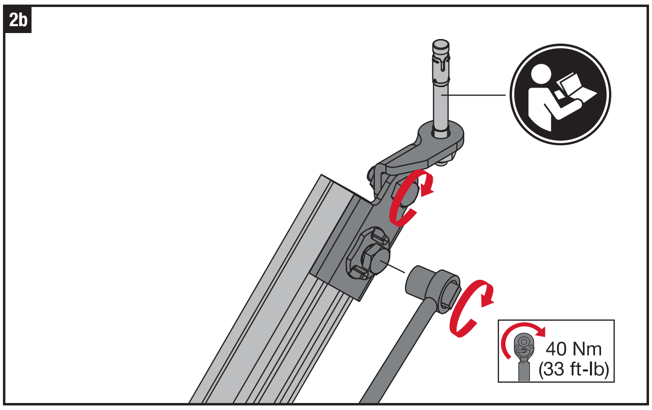

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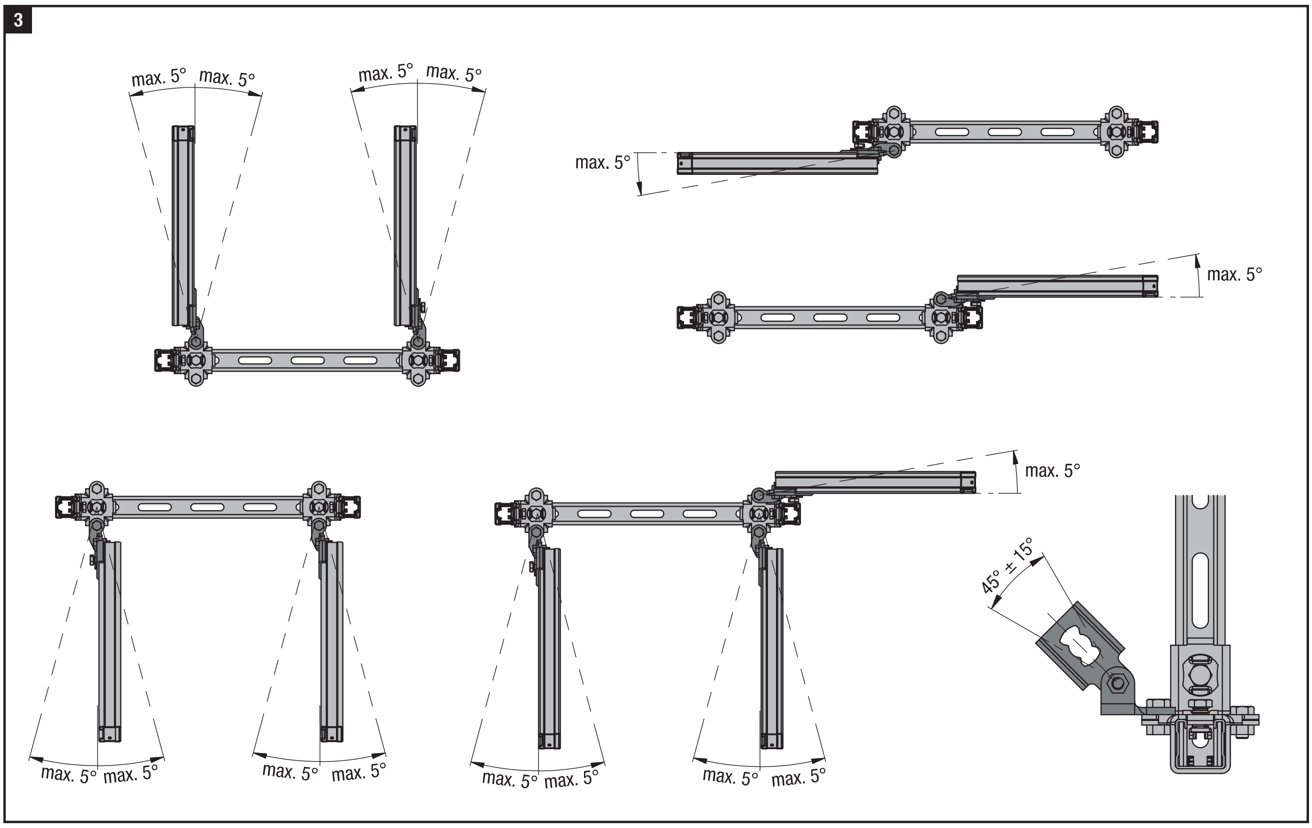
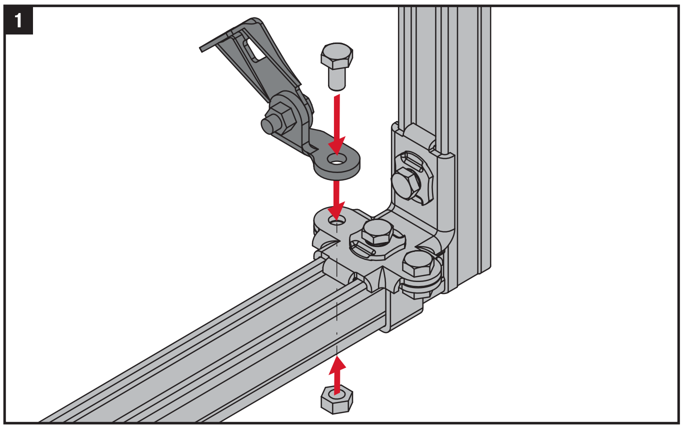
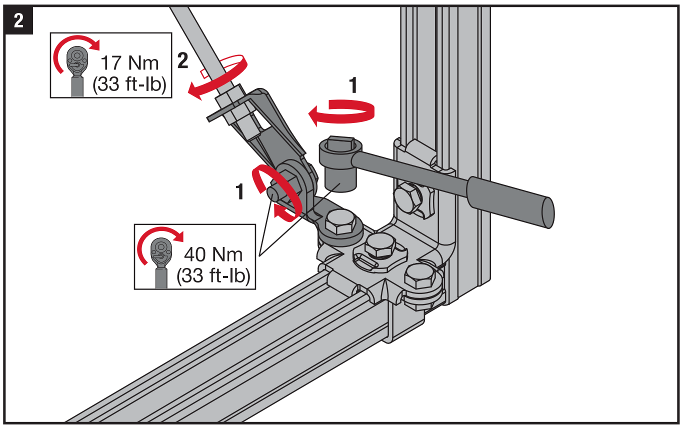
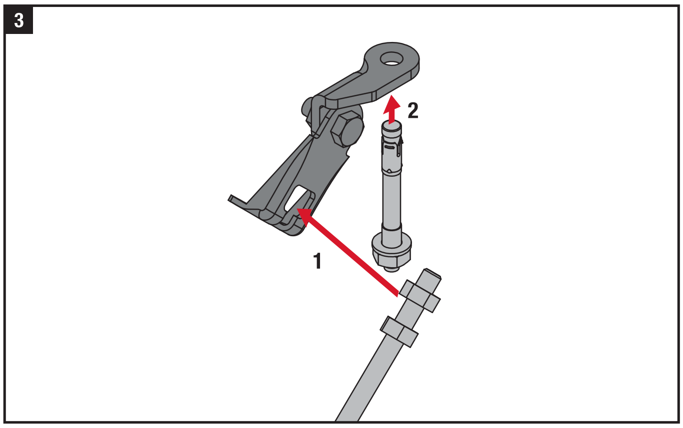


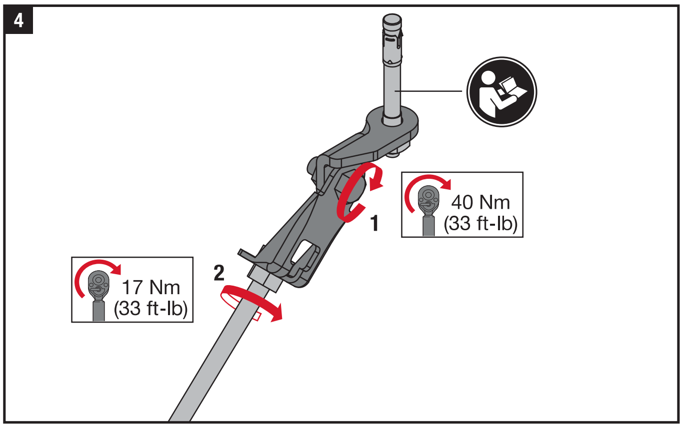
Instruction for use MQS-AB with MQS-W Set

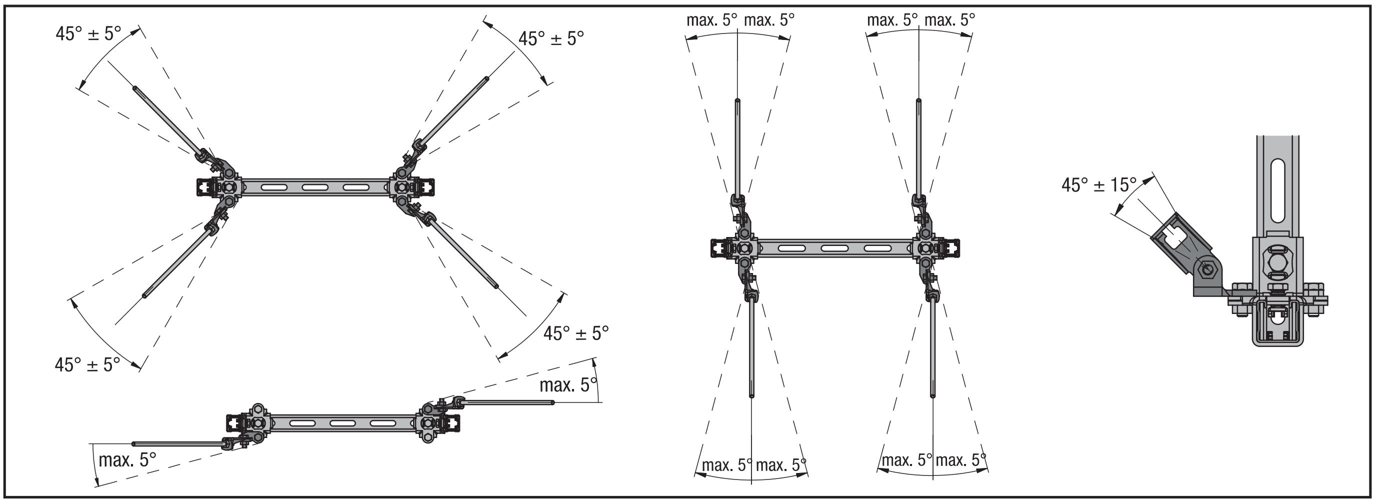
MQS
Seismic System





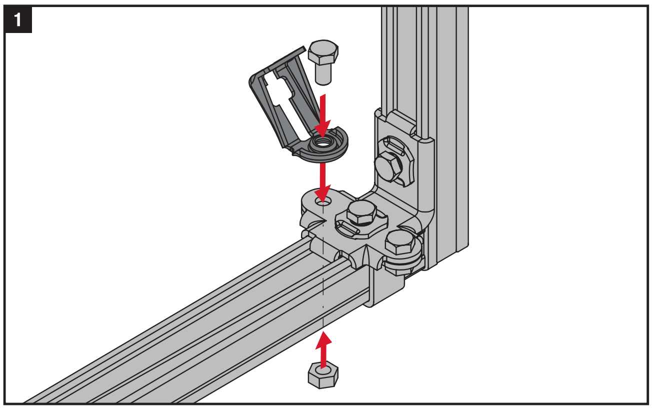


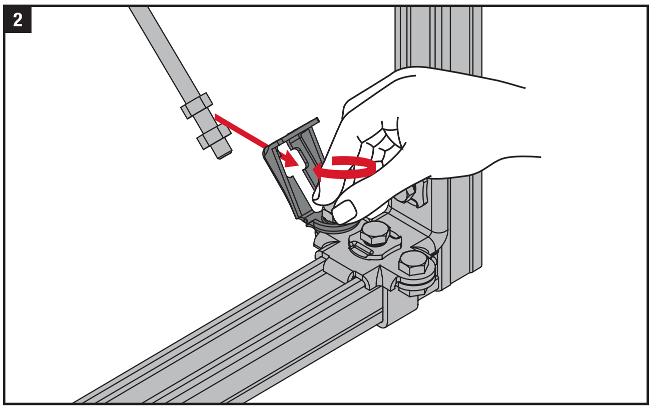


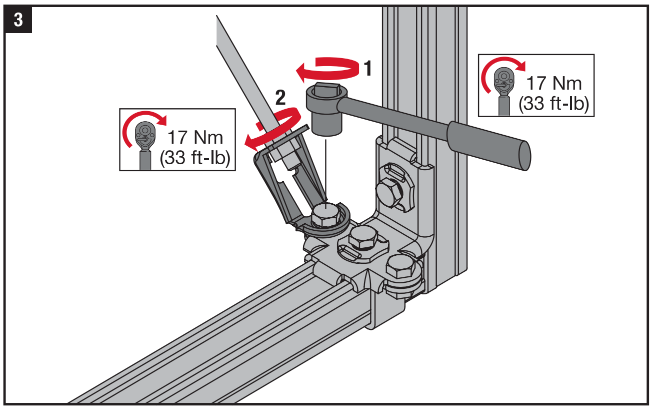


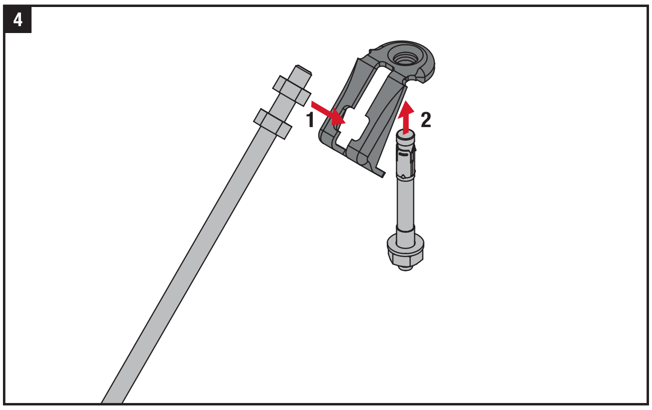
Instruction for use MQ3D-AS with MQS-W Set

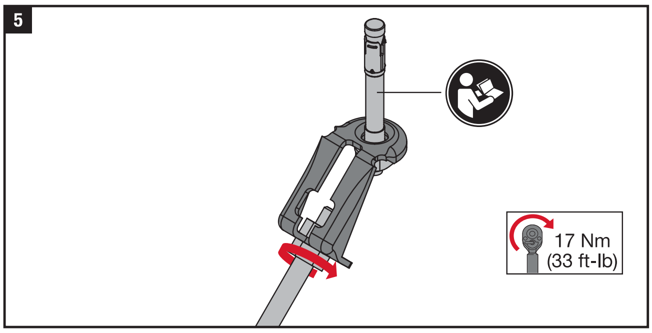
MQS Seismic System

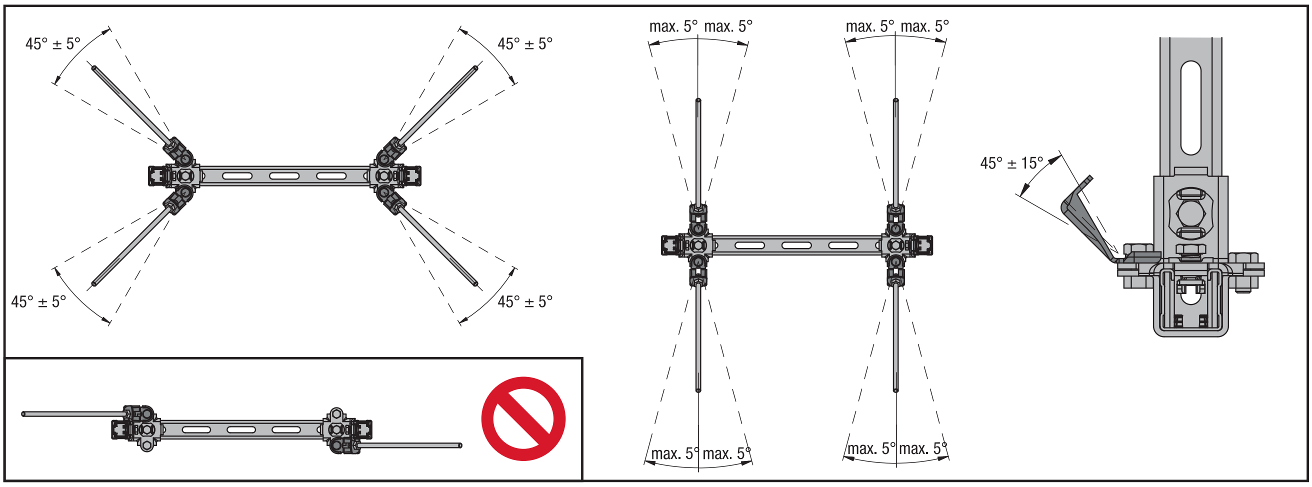






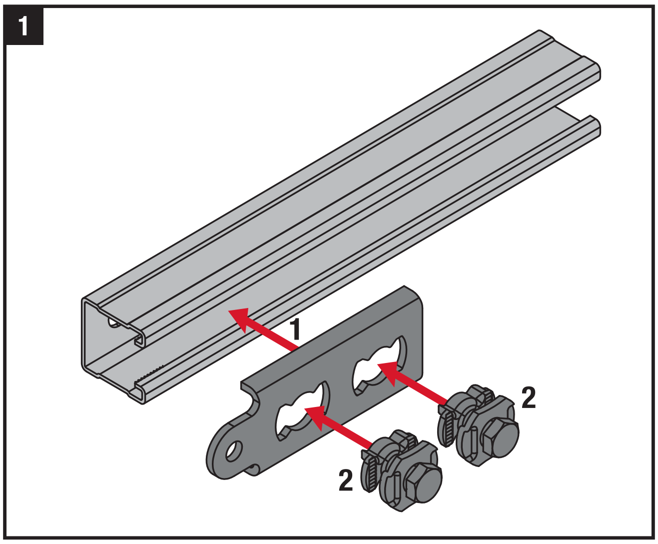


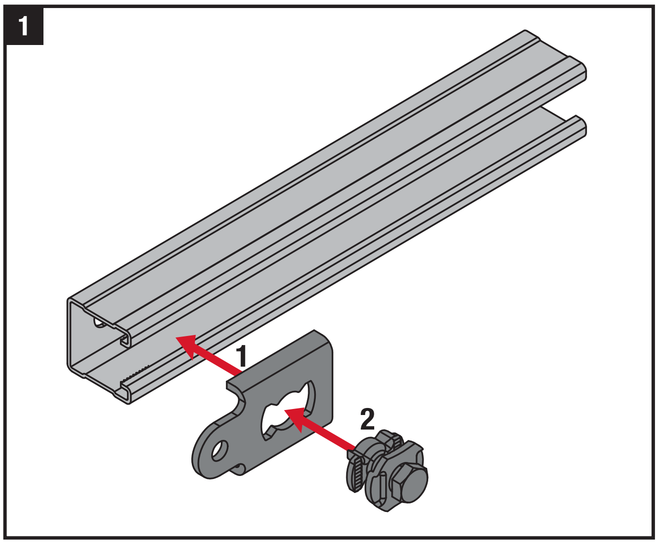


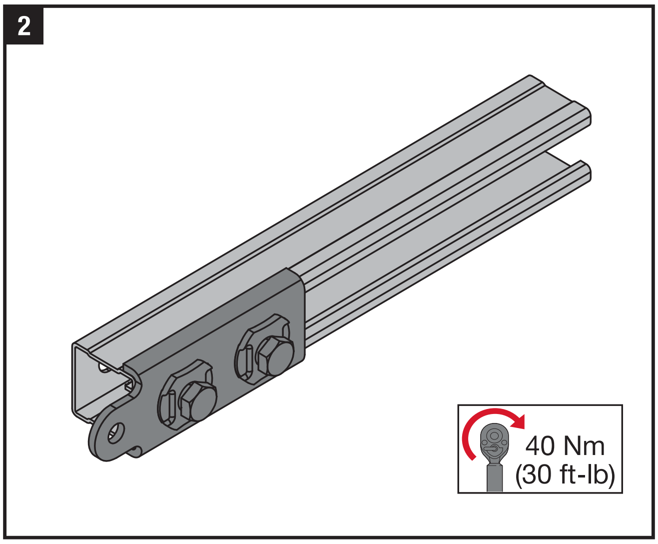


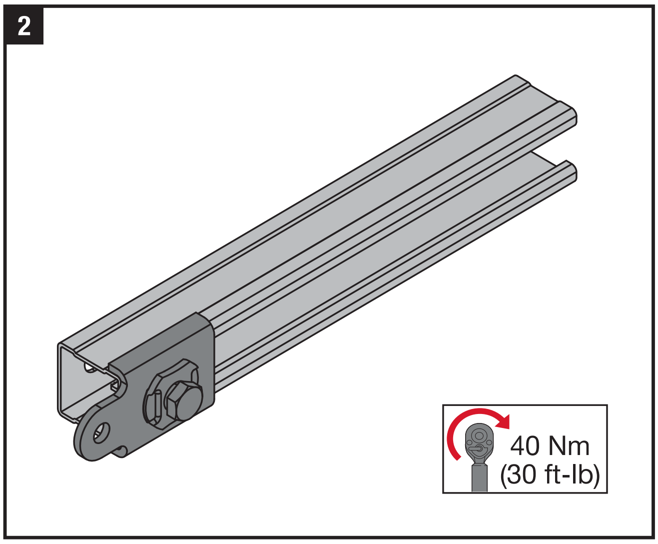
Instruction for use MQS-C/CD

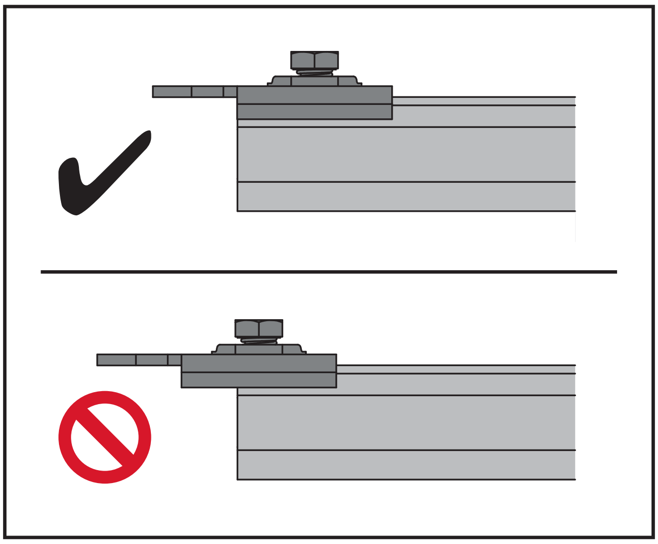
MQS Seismic System





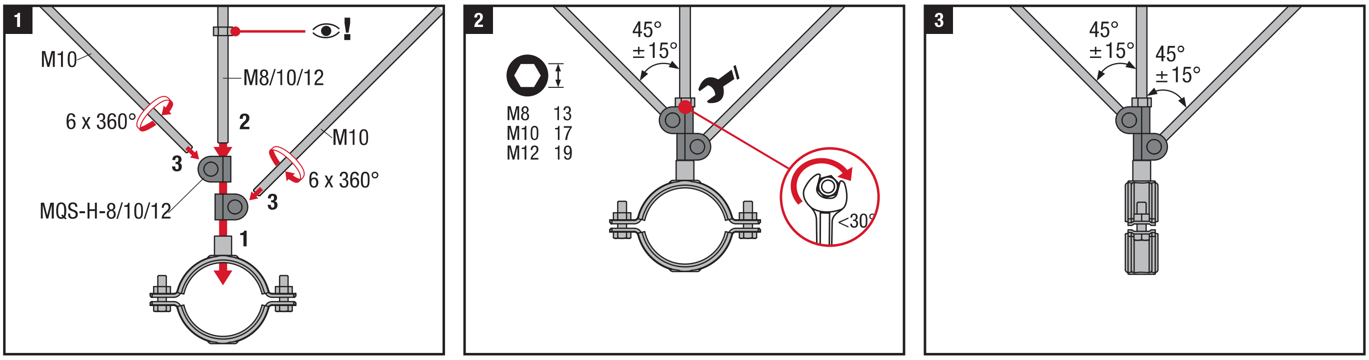


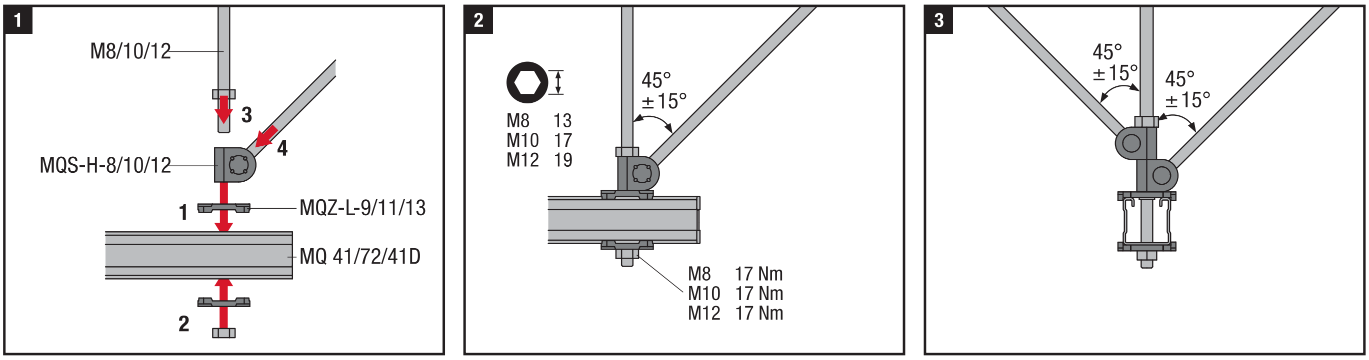




Instruction for use MQS-H

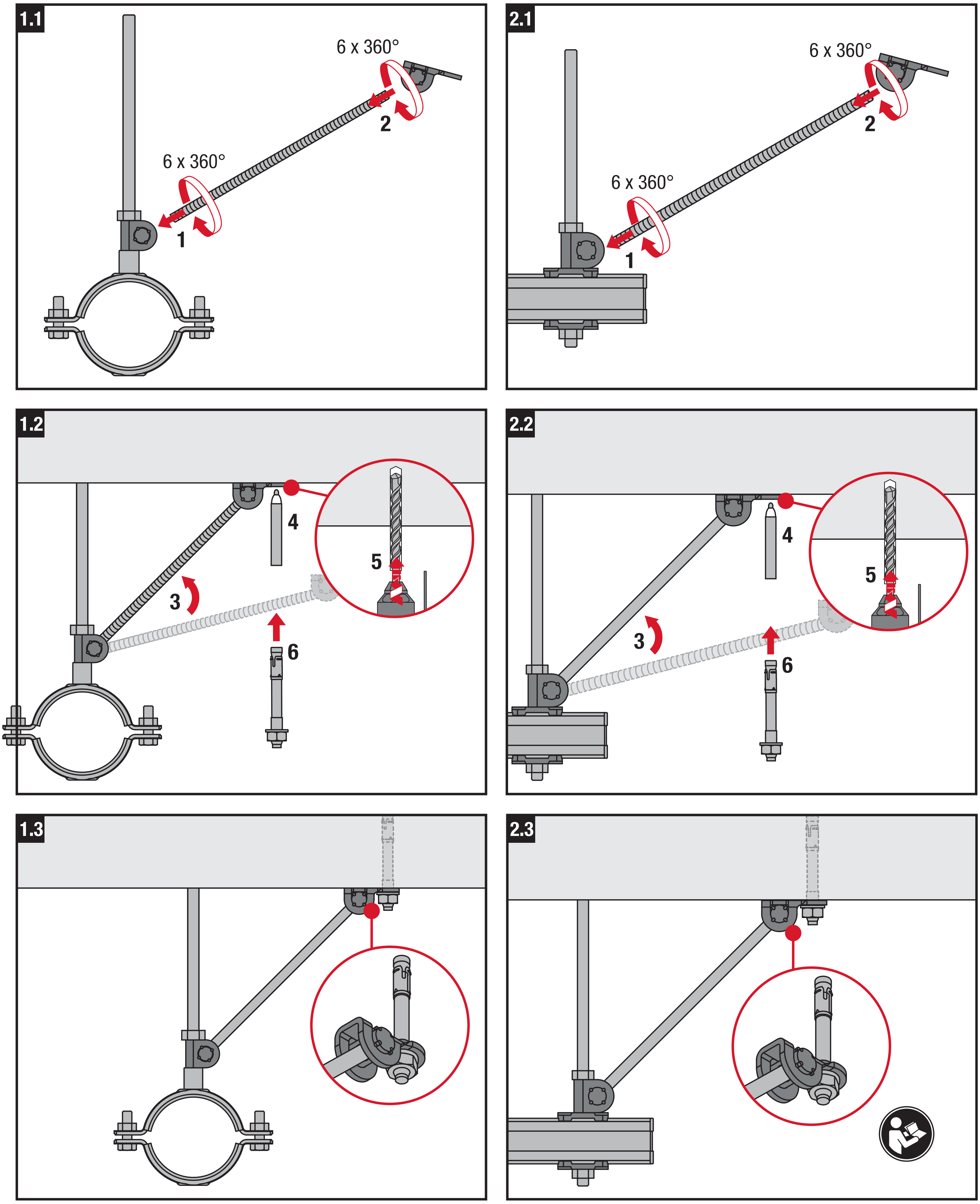
MQS Seismic System





Instruction for use MQS-CH

MQS Seismic System



Instruction for use MQS-RS

MQS Seismic System

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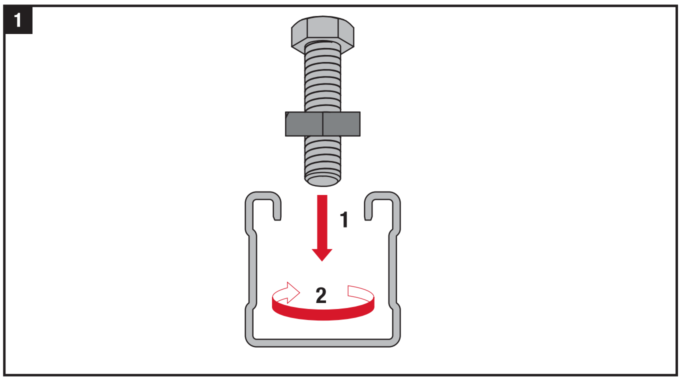

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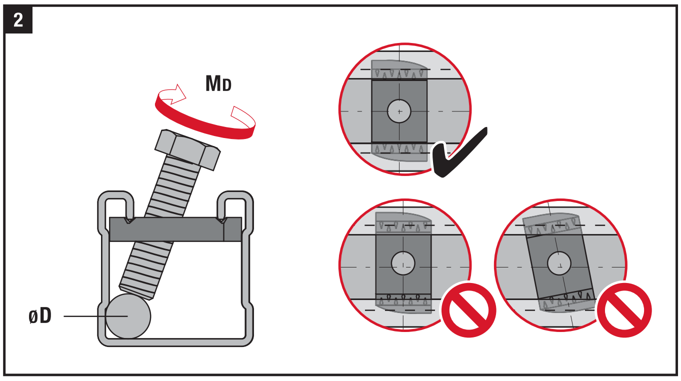

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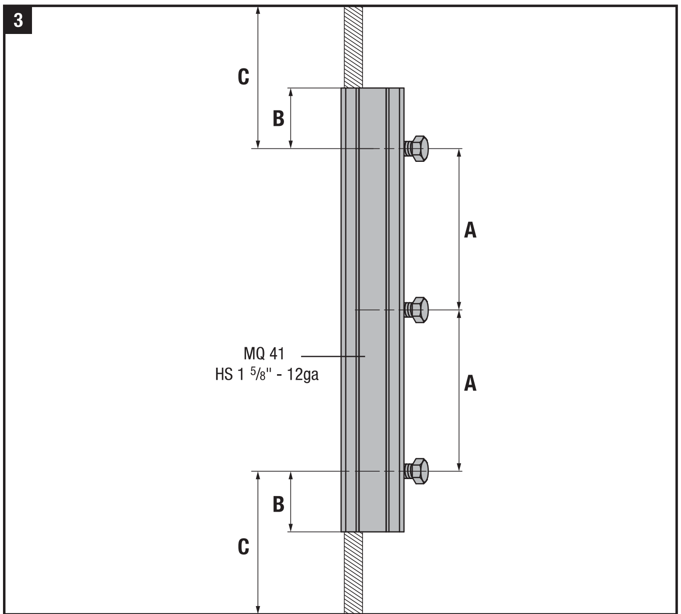

øD	MD	max A	max B	max C
M10 / 3/8"	11 Nm 8ft-lb	330mm / 13"	100mm / 4"	150mm / 6"
M12 / 1/2"		450mm / 18"	100mm / 4"	150mm / 6"
M16 / 5/8"		580mm / 23"	100mm / 4	150mm / 6"

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