QUAKETEK

Earthquake Protection Made Easy

About QUAKETEK

History

Our history began in 1987 at Mechtronix Systems Inc. when Joaquim Frazao co-founded the company to develop innovative engineering and manufacturing solutions, primarily for aerospace. Using these aerospace technologies, Mr.Frazao developed friction surfaces to overcome key challenges with respect to corrosion, cold welding and creep in friction based energy dissipation. Under Mr.Frazao's supervision, Mechtronix went on to manufacture thousands of seismic brakes, which today protect more than 200 buildings around the world.

After the sale of Mechtronix, Mr.Frazao founded Quaketek to continue manufacturing the highest quality seismic brakes using the same proven methods. Quaketek has continued to improve the precision and quality of friction devices (seismic brakes and others) with investments in new state of the art equipment, R&D and a dedicated, purpose built manufacturing facility in Montreal, Canada.

Today, our focus is on more than just profit as we are committed to improve earthquake safety, by making seismic technologies more accessible, more affordable and even easier to integrate into any new or existing structure.

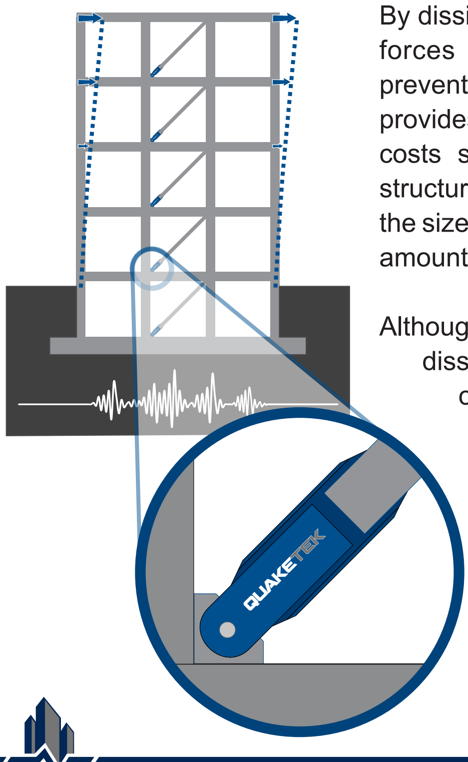
Recognized Performance & Safety

Seismic brakes have undergone extensive testing in some of the most recognized engineering institutions and associations in the world. However, perhaps the most rigorous and important test of the technology was that of the 7.1 magnitude earthquake in Mexico City, September 19th 2017.

While more than 600 buildings collapsed or needed to be torn down, and thousands more suffered serious damage: the Torre Cuarzo performed ideally. There was no damage and not a single broken pane of glass. The 180m tall Torre Cuarzo is protected by more than 450 seismic brakes, each precision manufactured and tested at our Montreal facility to ensure that the seismic brakes would work at the maximum response force required by the engineers and dissipate energy smoothly, quietly and reliably once activated. This result is perhaps the most significant, showing that with good design and reliable friction mechanism, both people and investments can be protected from major earthquakes.

How Do Seismic Brakes Work?

The Seismic Brake transforms and dissipates kinetic energy of an earthquake of specialized components through friction.



By dissipating the energy of an earthquake, forces and displacements are reduced: preventing structural damage. This in turn, provides significant savings in construction costs since the elements supporting the structure can be optimized, thereby reducing the size of steel and concrete sections or the amount of steel rebar in reinforced concrete.

Although any two elements in contact can dissipate energy through friction, getting consistent performance and results is a challenge. After several years of research and with its previous experience in the aerospace industry, the proprietary manufacturing techniques employed at Quaketek allow the seismic brakes to maintain a stable response force without considerable variation even after many cycles, unlike yielding options (e.g. traditional braces, BRBs)

Simple & Reliable

Another major advantage of seismic brakes is that they are not velocity dependent, and behave as force limiters: the force and energy dissipation remain independant of velocity (frequency). This unique feature makes it an easy-to-introduce element to virtually any structural design, since only the axial Displacement and axial response Force are required to begin introducing the seismic brakes.

In contrast, alternative technologies such as base isolation and Viscous damping must be calibrated and designed depending on the induced building velocity, which can add several levels of complexity to any project.

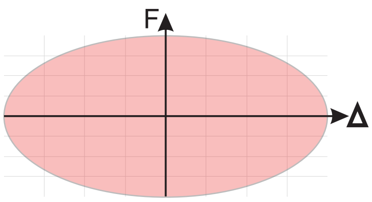
Dissipating Seismic Energy

With energy dissipation independent of velocity, seismic brakes dissipate the largest amount of energy when compared to other existing alternatives. This is possible because the force exerted on the seismic brake is constant after reaching activation. (See Graphic Below). This high energy dissipation and simple design allow for easy integration into almost any type of design.

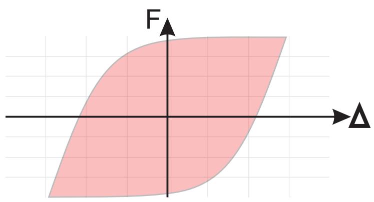
In existing buildings that need to be updated to comply with new and more demanding building codes, the seismic brake is the ideal choice as it requires minimal disruption of operations and minimum modification of existing elements in the places where it's installed.

In new structures, architects and engineers integrating these shock absorbers can innovate and enhance aesthetic appeal, all while providing their customers with benefits such as cost savings in construction material and maximum protection.

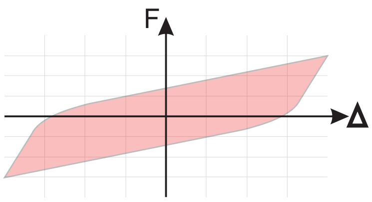
The performance of each of our Seismic Brakes is individually verified as each device is tested at the full response force. Customers can benefit from substantial savings all while ensuring that quality and reliability are never compromised.



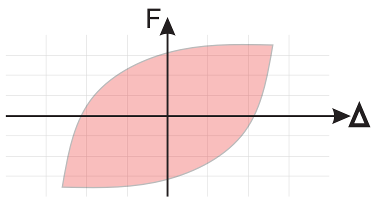
Viscous Damper ①③



Buckling Restrained Brace ②



Base Isolator ①③



Viscoelastic Damper ③

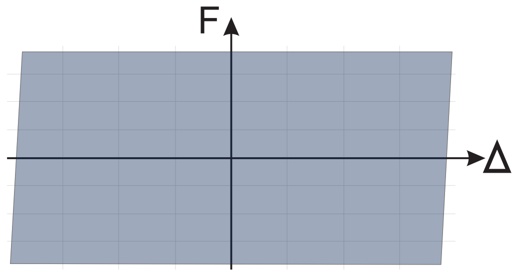
1 – Velocity dependent, adds complexity to design

2 – Must be replaced after 1 time use

3 – Temperature dependant. Require inspection & maintenance access

Comparison of Energy Dissipation of Different Earthquake protection technologies

The area within the hysteretic curve is proportional to the energy absorbed by the device

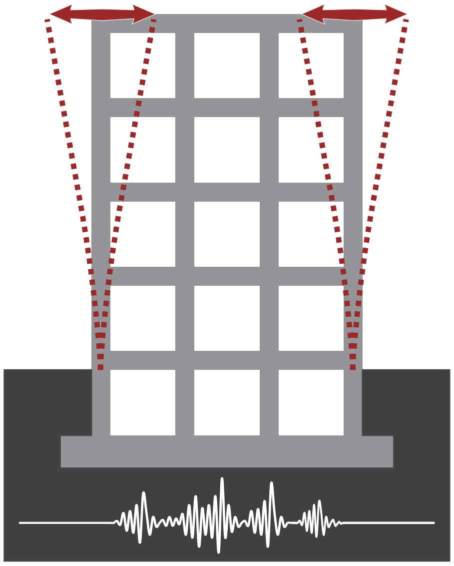


Seismic Brake

Core Benefits

Safety and Security

Although the majority of structures designed under current seismic codes prevent collapse and protect lives, these buildings can be seriously damaged after an earthquake because they make use of ductility for energy dissipation and therefore undergo permanent deformations. Seismic brakes protect the structure against earthquakes without the use of permanent deformations. Buildings can remain operational during and after an earthquake by preventing structural damage, in turn protecting occupants, operations and investments.



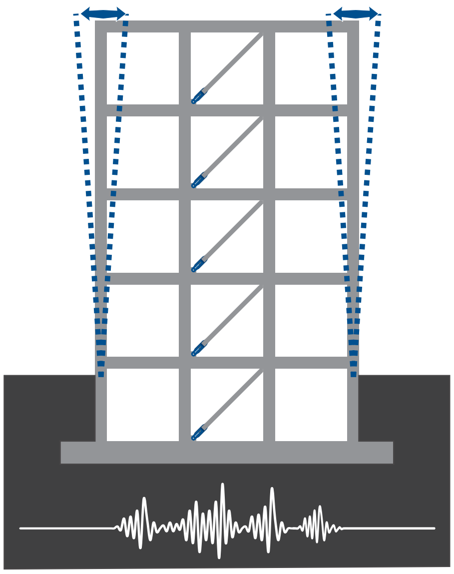
Savings in Construction & Lifetime Costs

New Construction

- 2-5% savings in Total Project Cost (including device installation) when compared to buildings that dissipate energy through ductility
- No maintenance required, meaning seismic brakes can be enclosed in walls and no increase in operations costs
- Can prevent permanent deformations in structures
- Significantly reduces Building Insurance Premiums, up to 50% depending on the insurer/region

Retrofitting Projects

- 30-60% savings in Total Project Cost when compared to alternatives
- No maintenance required, meaning devices can be enclosed in walls and no increase in operational costs
- Adaptable to virtually any existing structural system: Shear walls, Moment Resisting Frames, Masonry etc. Can be used in Wood, Steel or Concrete buildings
- Minimizes interruptions to Operations during retrofitting through ease and speed of installation



With Seismic Brakes

Lighter & Better Protected Structures

Sustainable Construction

Environment

Dissipating seismic energy through the usage of large ductile sections is inefficient and wasteful. Producing steel releases 4 tonnes of $C0_2$ per tonne of steel produced and concrete is even more polluting, we must be diligent and responsible in our usage of these materials. Every tonne saved by using seismic brakes to dissipate energy instead of ductile or overly stiff members, directly benefits our environment.

Social Responsibility

As urban sprawl continues and populations in seismic areas grow, our communities and therefore buildings must become more resilient. Earthquakes in or near major cities have taught us time and time again that even if buildings do not collapse, damaged buildings means people are displaced and often left homeless. The poorest members of society are often most affected by seismic events and least likely to have safety nets such as earthquake insurance or the ability to leave the affected area. The current principle of collapse prevention through ductility is simply unsustainable!

The low cost and ease of use of seismic brakes, allows governments and societies to simultaneously improve the resilience and environmental responsibility of communities.

Simplicity in Structural Design and Modeling

The seismic brake can be modeled as a “Link”, in most Structural Software, representing a Yielding Restrained Brace, or YRB where the seismic brake acts as a force limiter allowing the brace to behave as a normal structural member under service loads. It is only engaged once the activation is reached, at which point the response force remains constant until reversing direction. The hysteretic loop is therefore rectangular and remains independent of velocity & without relying on yielding.

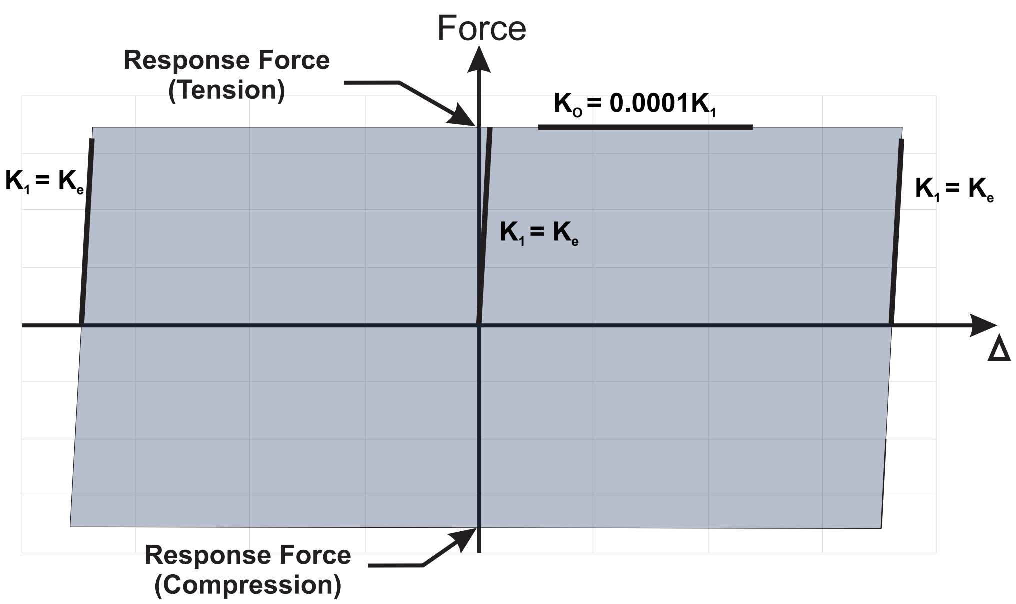
A YRB is modeled as a fictitious yielding brace (elastoplastic element) however instead of yielding, the seismic brake dissipates energy. For a Structural Engineer, this feature provides considerable simplification to the design process.

The YRB with a seismic brace therefore:

- ➔ Can dissipate more seismic energy and at a lower response force as compared to a ductile brace which would be yielding or buckling
- ➔ Has the same performance in both Tension and Compression
- ➔ Acts as a force limiter at the design response force

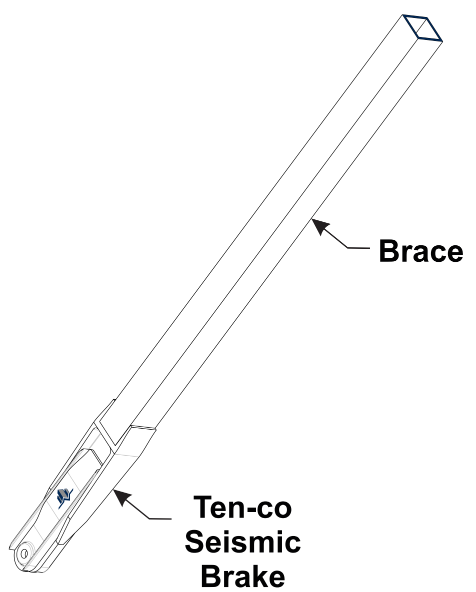
In software, the YRB is simulated as a standard steel brace which will deform, simulated as perfect bi-linear deformation rather than deterioration by ductility. A ductile brace would yield and normally have to be replaced after the earthquake. Although sometimes identified as perfect ductility, in reality the seismic brake protects the brace from plastic deformation, engaging before the brace reaches its elastic limit and dissipating the seismic energy through friction.

Once the earthquake is over, the devices settle back to their original position under the vibration of the building and through the elasticity of the protected structure with essentially no residual drift. The YRB with the seismic brake remains ready for the next earthquake and does not need to be replaced or re-calibrated.



Theoretical YRB Hysteretic Loop

Brace Equipped with Seismic Brake



Core Benefits

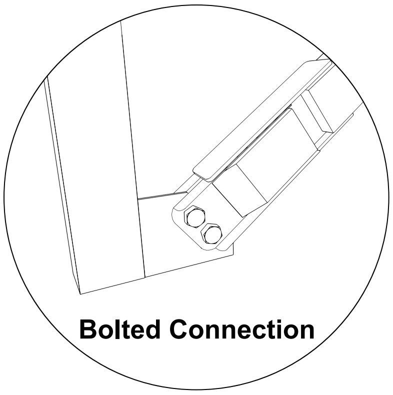
Simple Installation & Short Lead Times

Virtually any project or structure can be equipped with seismic brakes. The system can be adapted to elements of Wood, Steel or Reinforced Concrete. Connection design is simple and straightforward and no more complex than any other braced structure. There are numerous possible configurations and limitless possibilities for customization.

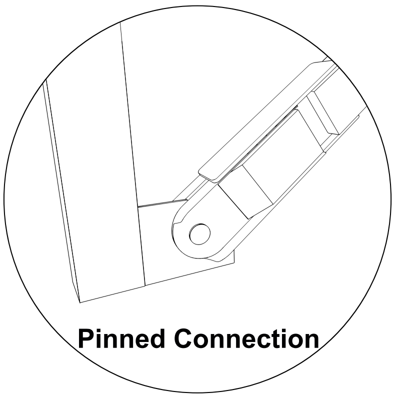
The ease of installation in new and existing buildings allows the devices to be integrated quickly and with minimal intervention. Engineers and builders around the world often select seismic brakes for some of the most challenging projects (such as hospital retrofits) where disruptions to operations are costly and dangerous.

Short Lead Times
With standardized products and rapid customization options, Quaketek can quickly respond to onsite requirements.

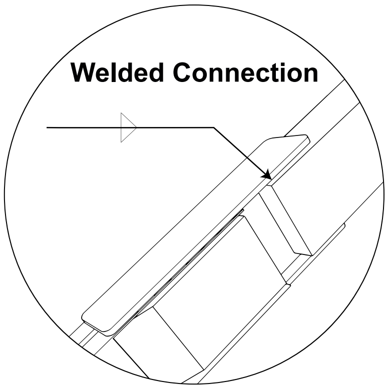
We can provide rapid shipping or for customers that prefer “just in time” deliveries this option is also available.



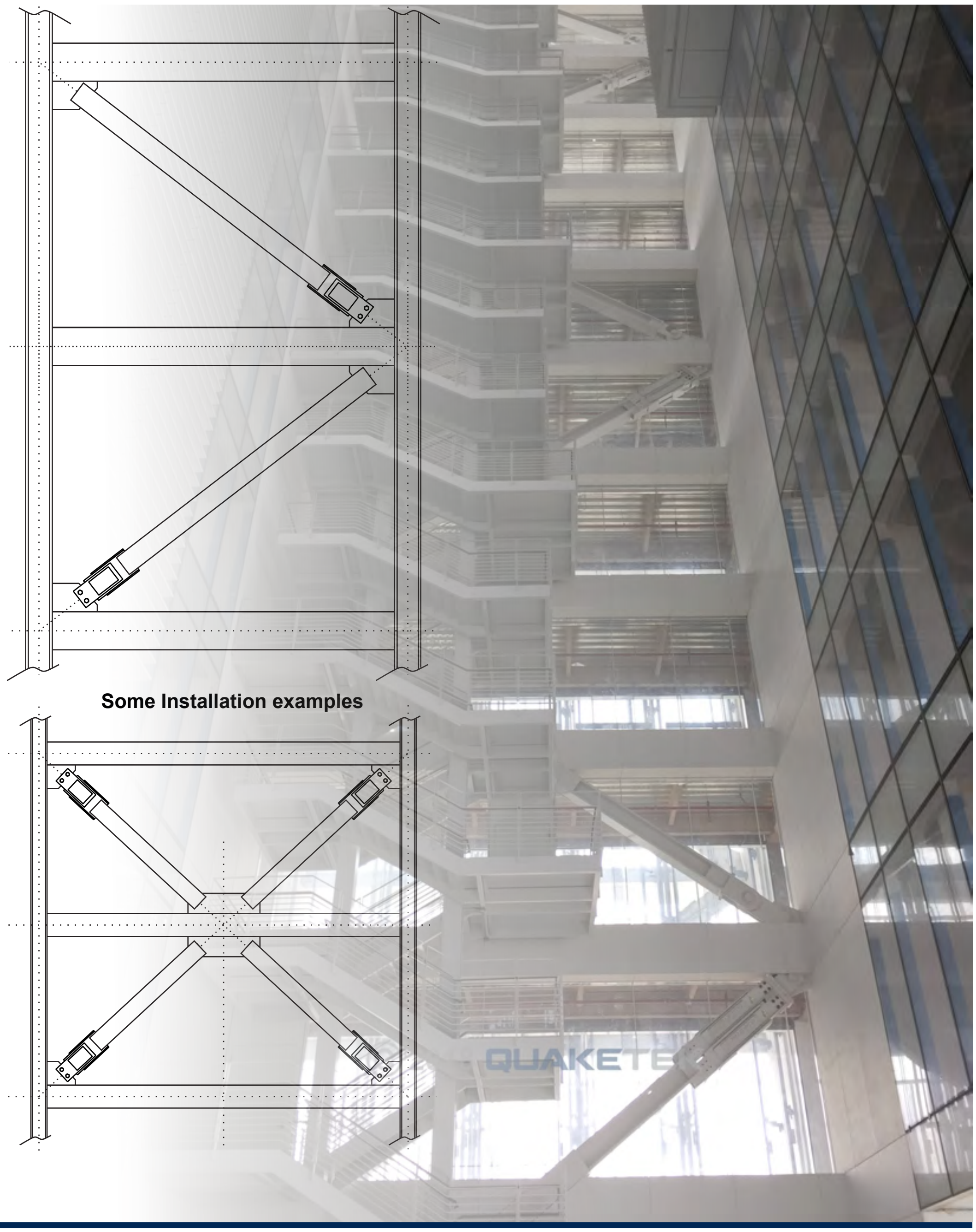
Bolted Connection



Pinned Connection



Welded Connection



Some Installation examples

Commercial Applications

Torre Cuarzo

Mexico City, Mexico

Standing at 180m on the Paseo Reforma in Mexico City the Torre Cuarzo uses over 450 Seismic Brakes. The seismic brakes protect the Torre Cuarzo against some of the strongest earthquakes in the world.

Asset protection

With 47,000 m2 of high end finishings and thousands of occupants, the Torre Cuarzo is a very valuable asset. YRB equipped with Seismic brakes enable the building to have the highest level of seismic protection without increasing the cost of construction.

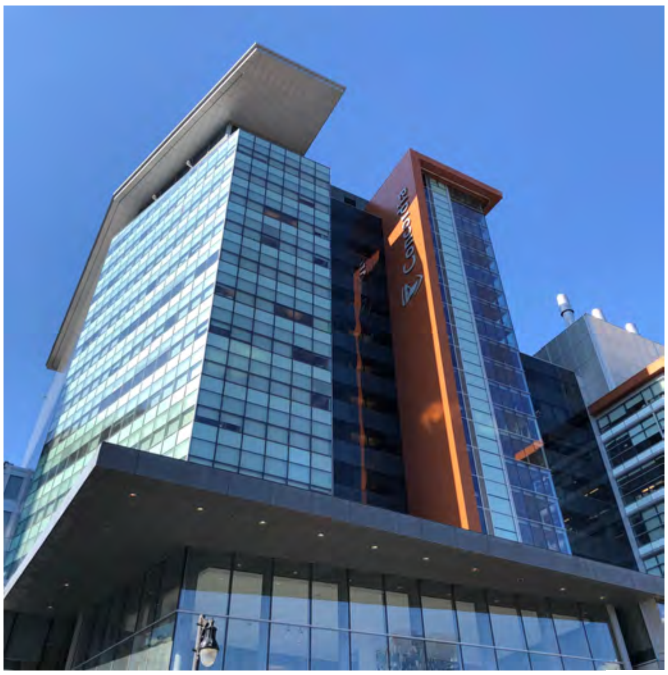
In September of 2017 a 7.1 Magnitude earthquake shook Mexico city damaging neighboring buildings while the Torre Cuarzo remained damage free in that earthquake and the aftershocks that followed, without a single broken pane of glass.

Institutional Applications

Concordia University

Montreal, Canada

The Engineering and Business pavilions of the Concordia University make use of seismic brakes to avoid excessive deformations and to ensure that students and faculty remain protected in the event of an earthquake. Concordia's library building was the first building in North America to use damping devices and the first application of seismic brakes in the world.



St-Odile Elementary School

Montreal, Canada

This audacious retrofit brought the old building back to recent seismic code requirements. Students' life can now be protected in the event of a major earthquake.

ACC Sharp Memorial Hospital

San Diego, U.S.A

To ensure that operations remain uninterrupted during and after a major earthquake, Sharp Memorial Hospital uses YRB equipped with seismic brakes to protect people and sensitive medical equipment.

Guide for Structural Design with Yielding Restrained Braces

Support

This introductory guide* has been created to simplify the integration of Yielding Restrained Braces (YRB) into your project. A YRB is formed by the brace plus seismic brake assembly. With this approximation, engineers can quickly develop advanced models of resilient structures. If at any moment you find yourself with questions regarding any of the steps, please don't hesitate to contact our engineering team at design@quaketek.com or by visiting our website at www.quaketek.com

Step 1 – Create the model

With a pre-dimensioned model of the structure without YRBs, proceed to calculate shear force at the base and in every storey based on code requirements. Export the lateral stiffness per floor and lateral forces applied. Most software easily export this data into a tabular format. This calculation can also be performed manually if preferred.

Step 2 – Force per floor

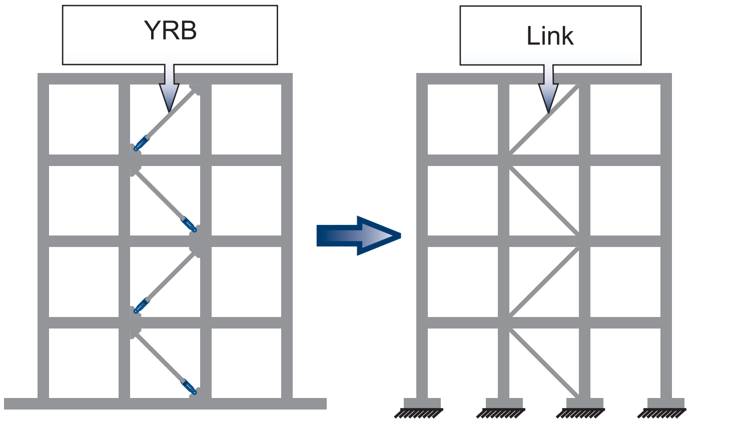
To select the response force, we must first determine what portion of the storey shear will be taken by the YRBs and what portion by the frames (or other lateral resisting system present). The objective is to increase the capacity of the building to resist earthquake forces without increasing accelerations and therefore forces in elements. It's therefore necessary to assign an optimum shear to the YRBs that minimizes response forces & moments exerted on the frame by maximizing the energy dissipated by the seismic brakes.

Optimum Response Force

This optimum shear to be given to the YRBs determines the Optimum response force for each device. Optimum Shear has been found to be less than 50% of the plastic storey shear (pinned structures tend to have a higher optimum force).

For an initial design, you can have a pretty accurate result using **1/4** of the storey shear, if you're designing a building that is expected to have nonlinear deformations. If you're designing to the highest level of performance, fully operational or operational, you're better off using **1/3** of the storey shear. This rule of thumb applies for both retrofitting and new projects. Divide this optimum shear ($V_{optimum}$), by the number of YRB you want to have in every floor to find the seismic shear each device will handle (V_{YRB}). There are no constraints in the number of devices you can use per floor. Architectural constraints often dictate this number and where they are to be located.

***The methods described herein contain assumptions and parameters valid only for Quaketek tension-compression seismic brakes. This guide has been developed based on observed characteristics of Quaketek seismic brakes and is likely invalid for other devices or other Quaketek products. Additional assistance and guidance are available upon request.**



Actual Structure **Software Model**

Step 3 – Locating the seismic brakes

Proceed to locate the YRB "links" in the model created in **step 1**. Where possible, place them where they best control lateral deformations, or in locations architecture has made available. They can be placed without horizontal or vertical continuity.

Location Flexibility

To take advantage of this flexibility in device placement, you must ensure two things for this analysis:

1. That the proportion of the shear allocated to the YRB is the same at every floor (eg. 1/3), increasing towards the building's base when small differences do exist, and

2. That the relationship between the lateral stiffness of the braces (K_{braces}) and whole storey's stiffness (K_{braces} + $K_{bare\ frame}$) remains fairly constant throughout the building's height, generally around 0.7 and increasing towards the building's top when small differences do exist. This check is usually performed at the end of the elements detailed design phase

This ensures that the devices activate at the beginning of the seismic excitation, (before the structure starts developing plastic behaviour) and helps optimize the dynamic response.

Guide for Structural Design with Yielding Restrained Braces

Step 4 - Parameters of the YRB "Links"

Since the braces with Devices are modeled as simple "Links", it is necessary to provide the software with the characteristics of said link. Thus, the YRB equipped with a seismic brake is modeled as a steel brace that follows Wen's model for Plastic-Elastic materials just as any steel element would (i.e. a steel bar, an H profile, I or Tubular).

What cross-section to use on the YRB "link"?

What cross-section to use on the YRB "link"? The cross sectional area determines the initial axial and lateral stiffness. Therefore, take the optimum shear per YRB (V_{YRB}) and divide it by the angle the brace has with the floor. You will then have the response force per device, the Optimum response force. Find an area that has a yielding force at 1.3x this response force, as recommended by international standards.

Let's say that, in **step 1**, in a given floor, you obtained a shear force of 3600kN, and that, **in step 2**, you decided to allocate

Assuming 4 YRB at the floor, ϴ = 30° and A36 steel,

$$V_{optimum} = V_{floor} \times \frac{1}{3} = 3600\text{ kN} \times \frac{1}{3} = 1200\text{ kN}$$

$$V_{optimum / YRB} = \frac{V_{optimum}}{\#\,YRB} = \frac{1200\text{ kN}}{4} = 300\text{ kN}$$

$$\frac{V_{optimum / YRB}}{\cos(30^0)} = \frac{300\text{ kN}}{\cos(30^0)} = \text{Response force} = 346\text{ kN}$$

$$346\text{ kN} \sim 350\text{ kN}$$

Note

This Response force should be modified if it's not at least 30% higher than other service loads (e.g. wind). This is because we don't want the brakes activated unnecessarily. At the end of the elements detailed design phase, when choosing the real brace the brake is attached to, the buckling check must be at 1.3x response force

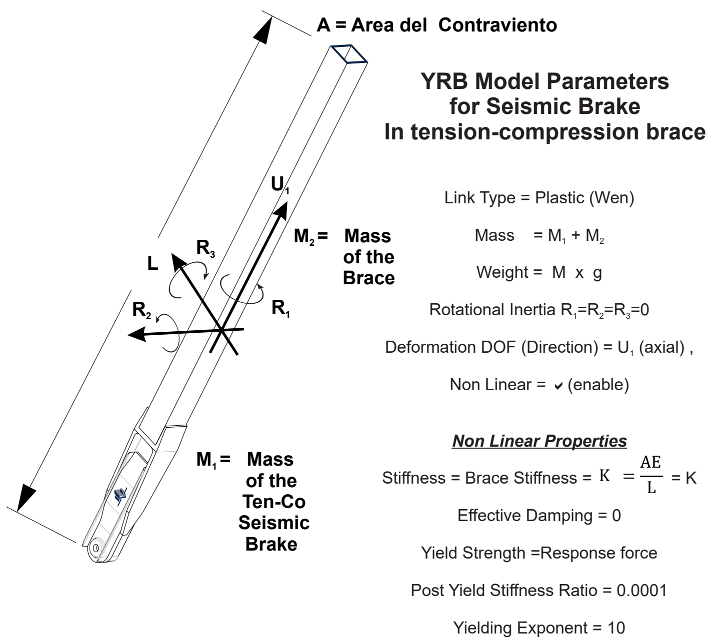
Axial Stiffness

Axial stiffness is introduced to the "link" as the initial stiffness and given by:

Assuming: E = 200GPa
L = 7m

$$K = \frac{AE}{L} = \frac{0.0063\text{m}^2 \times 200\text{ GPa}}{7\text{m}} = 180{,}000\text{ kN / m}$$

Now, you have all parameters needed to introduce the links in the model. Regardless of the software you use, the parameters are always similar and should be comparable to this image:



Step 5 - Ready to run the Analysis

Once the links have been integrated into the model, the building is ready for the analysis based on local seismic code requirements. Parameters introduced until this stage are enough to perform any static or dynamic analysis.

Verify that your software can read the links' non-linear parameters in any load case. In case it cannot, please look at the box "load cases".

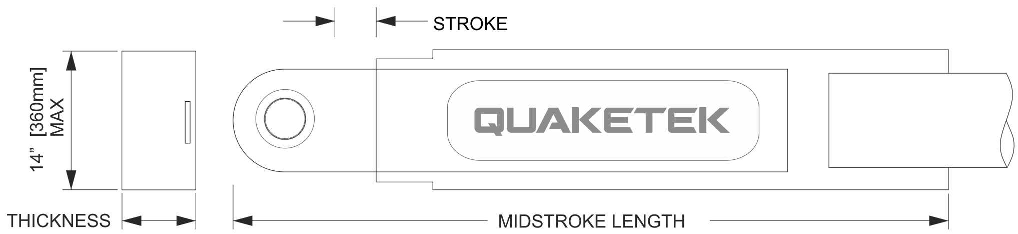
Step 6 - Reiterating for the Final Model

If, after running the analysis, the lateral displacements do not meet your expectations with respect to building performance, then you can iterate, either adding more "Links" per floor, increasing response forces, or stiffening building elements. Response forces and lengths are custom built based on the requirements of your model.

Load cases

Some softwares cannot read the seismic brakes' non-linear parameters when using linear cases. To easily overcome this, create a non-linear case for the seismic load. You can use the lateral forces saved form **step 1** and apply them to a user load pattern. This new, non-linear case's results, are to be used when performing detailed element design. Please don't hesitate to contact our Engineering team to receive assistance on this topic at design@quaketek.com

Sample Seismic Brake



Note

Seismic brakes are custom tailored for building application per engineering requirements. Many elements of the seismic brake can be customized. The mounting end can be adapted according to the connection design (i.e. Welded, Bolted or Pinned), thickness can be customized to fit within walls.

To obtain device dimensions for your project please contact our design team design@quaketek.com.

Designed and manufactured in Canada

Buckling Check

Though the devices perform equally well in Tension and Compression, it's still necessary to check that the brace of the YRB will not buckle. For this check, the cross-sectional area to be used is that of the actual Brace and its length is the length "L" which includes the total YRB length (brace length plus the length of the seismic brake and connections).

Lateral stiffness ratio

Let's assume that for the YRB in this example (with a testing response force of ~350kN) you have chosen a HSS 6X6X1/2 because it passes buckling checks, it's thick enough for welding and readily available. As mentioned in **step 3**, the relationship we are interested in monitoring is:

Lateral stiffness of the selected brace (HSS 6x6x1/2)

$$K_{brace} = \frac{AE}{L}\cos^2(\Theta) = \frac{0.0063\text{m}^2 \times 200\text{ GPa}}{7\text{m}} \times \cos^2(30^0) = 135{,}000\text{ kN / m}$$

Lateral stiffness of storey braces

$$135{,}000\text{ kN / m} \times 4 \text{ braces} = 540{,}000\text{ kN / m}$$

Let's assume that in **step 1**,
storey stiffness (bare frame) was 150,000 kN / m, then

$$\frac{K_{braces}}{K_{braces} + K_{bare\ frame}} = \frac{540{,}000\text{ kN / m}}{540{,}000\text{ kN / m} + 150{,}000\text{ kN / m}} = 0.78$$

This ratio should remain fairly constant at every storey (+/- 15%), greater than 0.5, and around 0.7. Ensure that in a given storey the ratio is always higher than the storey below when differences do exist.

General Information

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