tectonus

resilient seismic solutions

Offering a step-change in seismic technology

Tectonus Catalogue

Tectonus

Tectonus is a structural solutions company offering earthquake-proofing technology with the innovative Resilient Slip Friction Joint.

The patented RSFJ technology allows buildings to withstand seismic activity by providing friction damping and self-centering function; two characteristics which when combined greatly improve building resilience and minimize the structural damage caused by seismic events. More importantly, the technology does not require post-event maintenance continuing to protect the building's structural integrity for future earthquakes and aftershocks.

This cutting-edge technology is scalable with a compact design, allowing it to be implemented in new and retrofit projects of steel, timber or concrete materials for low to high rise structures.

Resilient seismic solutions

The global impact of earthquakes and aftershocks is growing, and there is an ever-increasing demand to minimize human and economic cost of seismic events.

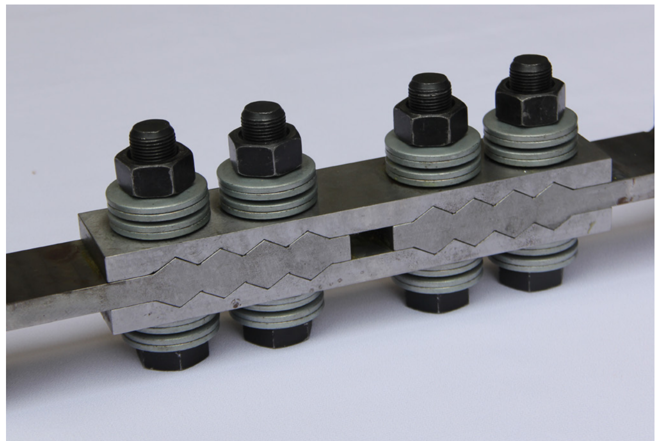
The cost of recent major earthquakes has spurred the development technologies which not only improve survivability, but also minimise damage so that buildings may be reoccupied quickly with little business interruption and repair costs.

The key characteristics of the RSFJ technology, which allow a structure to resist earthquake loads and minimise damage, are:

- **damping**
- **self-centering**
- **no post-event maintenance required for RSFJ connections**

The damage avoidance charactertics of the RSFJ means no post event repair costs, rapid reoccupancy, less business interruption, and protecting the occupants and the structure during aftershocks.

Resilient Slip Friction Joint (RSFJ)



Patented technology

The RSFJ technology provides a unique and innovative solution for improving seismic resilience of structures. With the capacity to dissipate earthquake energy and restore a structure after both primary and aftershock seismic events, this compact joint is exceptionally scalable and can be implemented in all types of new and retrofitted structures of various materials (steel, timber and concrete).

The key patented elements of the RSFJ technology include the unique groove geometry of the plates, high strength bolts with disc springs which together are responsible for the desirable self-centering and damping capabilities.

Tectonus has also applied for patents on other joint types and system aspects of seismic joint technology.

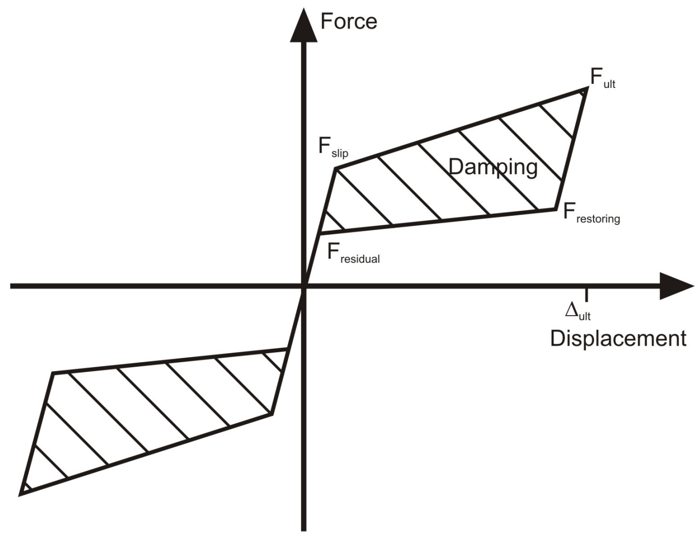
Contents

RSFJ advantages

Conventional seismic solutions were based on "high-damage" concepts; i.e. dissipating seismic energy within the entire structure which ultimately experiences a significant level of damage.

Second generation seismic solutions developed in recent decades have produced the development of "low-damage" concepts where the damage is controlled and limited to replaceable fuses or joints in the structure, which, while lowering the overall structural damage does not allow immediate reentry. This is due to the frequency of aftershocks and often results in significant repair costs (usually at a high cost).

The innovative RSFJ technology represents a third generation solution based on "damage-avoidance" concept. With its maintenance free design the RSFJ provides a cost effective and game changing technology with unlimited potential and benefits.



Hysteresis curve

Effective dissipation of energy
Significantly reducing the seismic load through friction damping and thus improving structural resilience.

Self-centering capacity
Restoring the structure to its designed position after any seismic event.

Continued damage avoidance
Following a seismic event, the RSFJ is ready for any aftershocks that may occur and will remain fully available throughout the lifetime of the structure.

Maintenance free
No element of the RSFJ requires periodic service or post event maintenance.

High initial stiffness
Resistant to wind loads and limiting the drift of structures under seismic events within the serviceable design loads.

Cost-effective
The RSFJ is cost effective to implement and is maintenance-free; eliminating the expensive post-event maintenance and replacement costs required in other technologies.

Applicable to all building materials
Can be implemented in any structure and can form part of any Lateral Load Resisting System (LLRS), connected to steel, timber or concrete structural members.

Retrofit applicable
Due to the ease of connection to existing structural members, the RSFJ can be part of any building retrofit project.

Scalable
The connector is fully scalable and may be custom designed to a variety of structural requirements with applications ranging from storage units to high rise structures.

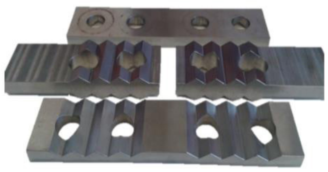
Compact size
The RSFJ is smaller than many comparable seismic connectors with the same load characteristics.

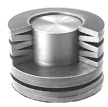
Easy implementation of SAP2000
In SAP2000 the RSFJ load displacement behaviour can be easily modeled (by choosing the Damper-Friction spring type element) accurately representing the cyclic behaviour of the joint.

Simple installation
With implementation as simple as traditional bolted steel plate connections, the RSFJ requires no specialist skills to install.

Structural health monitoring
When used with a displacement sensor, the RSFJ may be installed in an instrumented configuration where displacement monitoring provides high precision measurement of seismic forces in structural element - providing safe remote structure diagnosis even after extreme earthquake events.

RSFJ operation





Disk springs

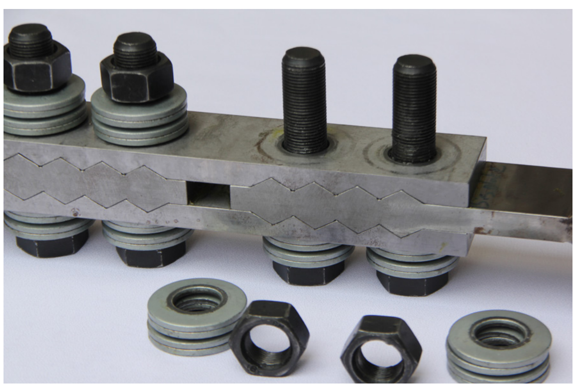
High strength bolts

Cap and slotted plates

The outer cap plates and the centre slotted plates are grooved and clamped together with high strength bolts and disc springs. When the applied joint force overcomes the frictional resistance between the sloped bearing surfaces, the centre slotted plates start to slide and energy will be dissipated through friction during cycles of sliding.

The patented shape of the plate ridges along with the use of disc springs and high strength bolts provide the desirable self-centring characteristic.

The angle of the grooves is designed such that at the time of unloading, the reversing force induced by the elastically compacted disc springs is larger than the friction force acting between the facing surfaces. Therefore, the system is re-centered upon unloading.



The lateral resistance of this new joint is higher than conventional flat plates friction joints for a similar clamping force provided by high strength bolts.

It should be noted that the sliding plates will only travel the length of one groove as their movement is restricted when the disc springs become completely flattened (or locked). Both the length of the groove in the middle plates and the number of disc springs are designed to achieve the required displacement for a targeted ductility.

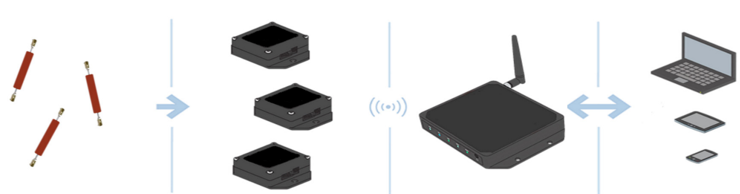
A special high-durable grease is used to control the possible rusting and wearing of the sliding surfaces over the design life of the structure with no maintenance.

Smart RSFJ

Highly precise measurement of the applied force can be determined from the joint displacement, therefore any RSFJ may be instrumented to provide structural health monitoring.

A variety of commercially available sensor technologies may be used to determine the deflection of the joint and the structure, the exact forces to which the joint and the structure have been subjected. These measurement may be used to determine any potential stiffness degradation of building structural elements and as a result evaluate any frame damage.

- Sensors integrated into the RSFJ may be self-powered.
- Information sensed at the sensors may be transmitted by wireless means to a data collection system.
- Data from a single joint may be combined with data from other joints to provide aggregate information about portions of or the entirety of structures.



Potential applications

New build

The RSFJ is an ideal connector to protect new buildings and structures against earthquake damage for the lifetime of the structure.

Applications include:

- **steel, timber and concrete structures (or hybrid of any)**
- **secondary structures such as facades and industrial shelves**
- **low to high rise multistory buildings**
- **architecturally unique designs**

Retrofit projects

The RSFJ is an excellent solution for retrofit projects. With a unique and compact design, the connector can be easily implemented in existing structures.

The RSFJ provides increased seismic resilience for the structure and allows the aesthetic appearance of the building to be preserved.

Application examples

Braced Frame

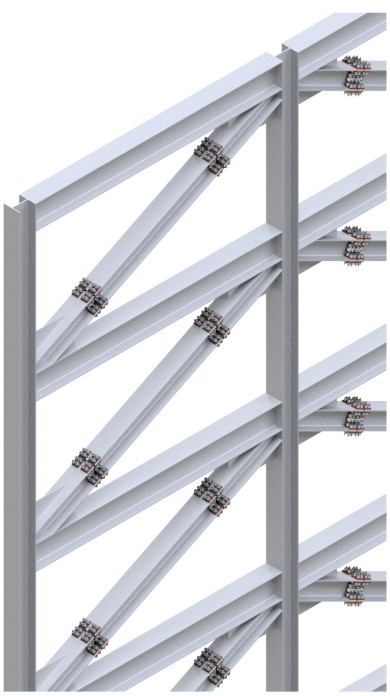
For steel braced frame structure, split diagonal braces have half RSFJ middle plates welded to the ends; cap plates, bolts and springs complete the coupling of the brace members and provide the seismic resisting brace. A RSFJ joint assembly at each brace end doubles the travel.

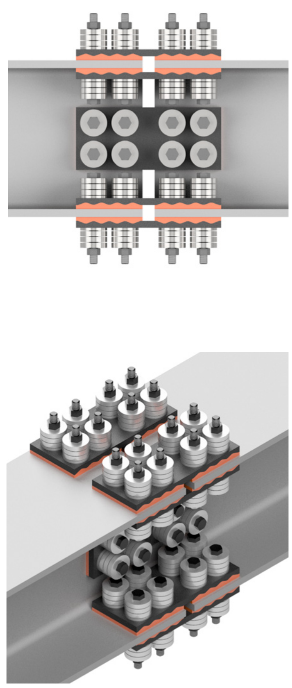
RSFJ application in a **steel braced frame** (RSFJ capacity of 3,000 kN)

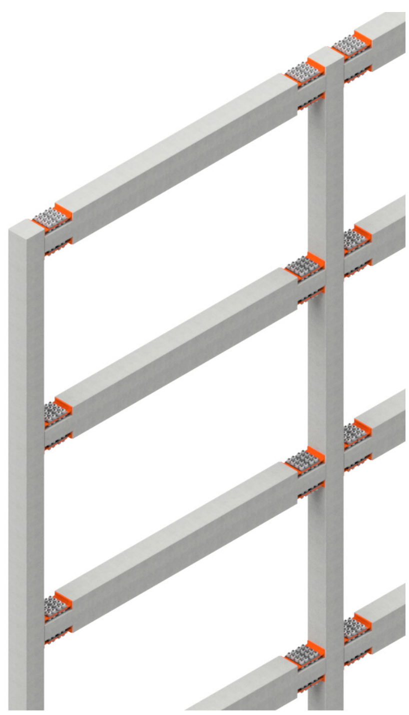
Moment Resisting Frame

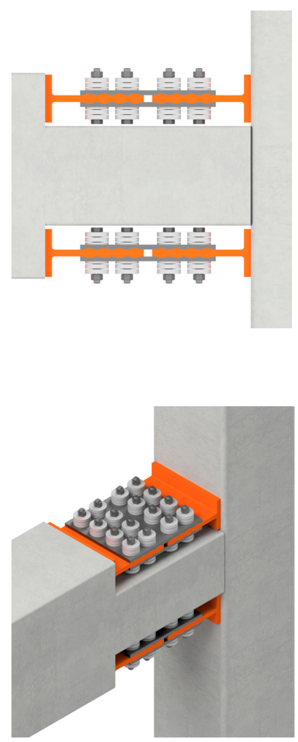
The RSFJ in Moment Resisting Frames are installed at the end of the beams. The initial stiffness of the RSFJ (below the F_{slip} value) provides rigid moment beam connections that contribute to decrease the beam sizes.

RSFJ application in a **concrete moment resisting frame** (RSFJ capacity of 1,500 kN)







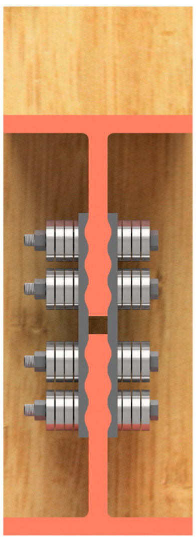


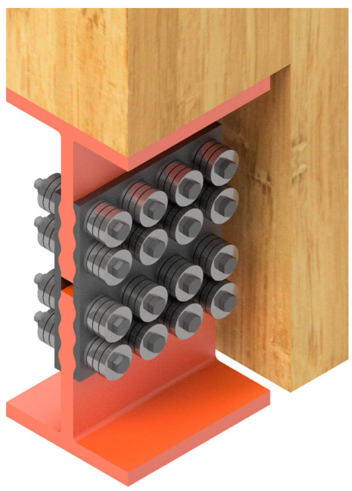
Application examples

Shear wall

RSFJ hold-downs are best installed at the shear wall corners. The bi-directional friction resistance of the RSFJ provides the necessary damping. The RSFJ middle plates are connected to steel plates for ease of connection to the foundation and timber shear wall.

RSFJ application in a **timber shear wall**
(RSFJ capacity of 1,000 kN)





Feature project - Nelson Airport Terminal

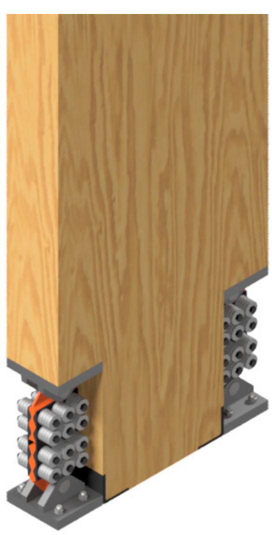
Tectonus is honoured to be selected as a nominated supplier.

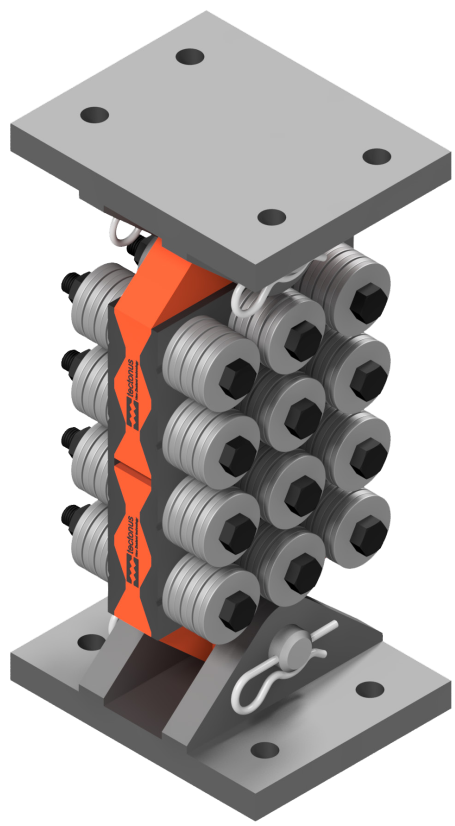
The RSFJ for the NAT project has a tensile capacity of 1000 kN in tension and allows movement of the LVL column in both in and out-of-planes.

The RSFJ was designed purposely for this project based on the design requirements provided by the project structural engineer.

The RSFJs provide the LVL column with the capacity to develop a plastic hinge behaviour while all materials remain in the elastic range.

Additionally, the RSFJ does not hinder the contemporary design by fitting seamlessly within the beam.

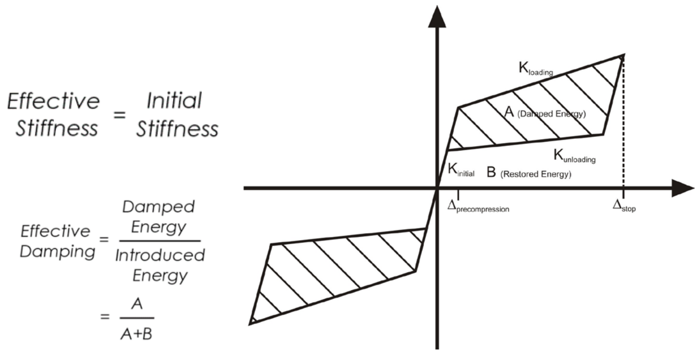




Joint design considerations

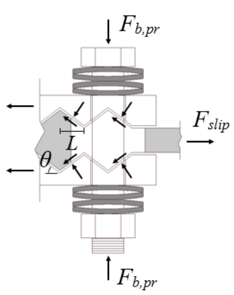
Design procedures have been developed for different possible configurations of RSFJ: symmetric, asymmetric, and combined symmetric-asymmetric.

The flag-shaped hysteresis loop shows the cyclic performance of the joint which can be identified by the slip force (F_{slip}), ultimate resistance (F_{ult}), restoring capacity ($F_{restoring}$), residual resistance ($F_{residual}$), and the joint ultimate displacement (Δ_{ult}).

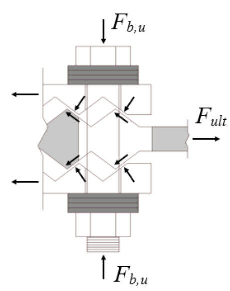


Fully self-centering flag-shaped hysteresis response

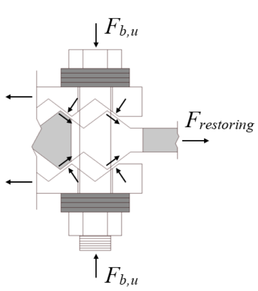
When the applied load is greater than the slip force, the sliding in the joint occurs. Therefore, the design F_{slip} has to be greater than the service loads such as wind forces. By conducting numerical analysis, the optimum sliding force can be determined, ranging between 50% to 75% of the joint ultimate capacity. The difference between the F_{ult} and $F_{restoring}$ indicates the frictional resistance that needs to be overcome during unloading to allow the joint to return to its original position. The magnitude of the restoring force is also a critical factor accounted in a resilient seismic design to provide re-centring of the structure.



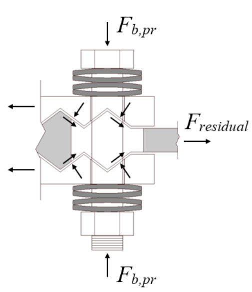
At rest before slip



At ultimate loading



At ultimate unloading



At restored position

Structural analysis using SAP2000

The RSFJ can be easily integrated in the structural analysis and design software SAP2000. It allows the designer to accurately calibrate the parameters according to the requirements of the project.

In SAP2000 the RSFJ load displacement behaviour can be easily modelled by choosing the Damper-Friction spring type link element.

This function accurately represents the cyclic behaviour of a RSFJ provided its parameters are properly calibrated in accordance with the design parameters of the joint, which are:

- slip force
- loading stiffness
- maximum loading force
- maximum uploading force
- residual force
- ultimate displacement

RSFJ limitless possibilities

RSFJ hysteresis responses

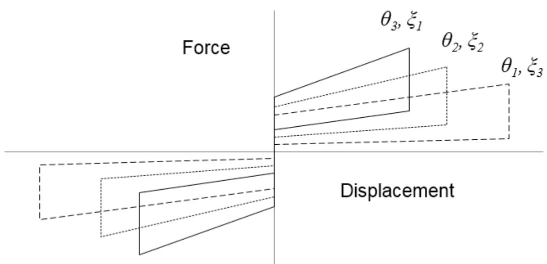
The following cyclic hysteresis responses below illustrate the effect of connection parameters on joint performance comprising the variations in magnitude of the slip force, ultimate capacity, restoring force, residual resistance, joint displacement and hysteresis damping ratio ranging from 10% to 15% (ξ_{hyst}).

The connection design parameters consist of the angle of the groove, coefficient of friction (CoF), number of disc springs in series and parallel, number of bolts, and the initial prestressing force of the bolts.

As shown in the diagrams below, by adopting a higher CoF (through different material arrangements for the sliding surfaces) and increasing the clamping force (by using more bolts), the frictional resistance may be adjusted through a wide range.

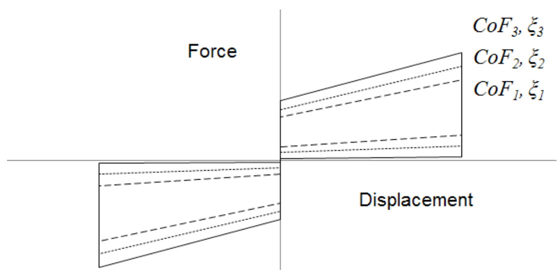
By comparing the connection parameters effect on the hysteresis damping ratio, it can be determined that only the groove angle has a detrimental effect on the ξ_{hyst}. Increasing the CoF, number of disc springs in parallel, and also the prestressing force result in a larger ξ_{hyst} while increasing the number of disc springs in series and number of bolts have no effect.

1. Groove Angle



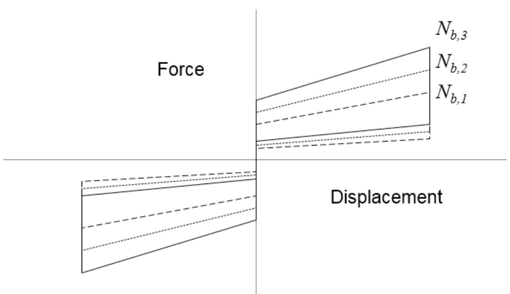
$(\theta_i < \theta_{i+1};\ \xi_{hyst,i} < \xi_{hyst,i+1})$

2. Coefficient of friction



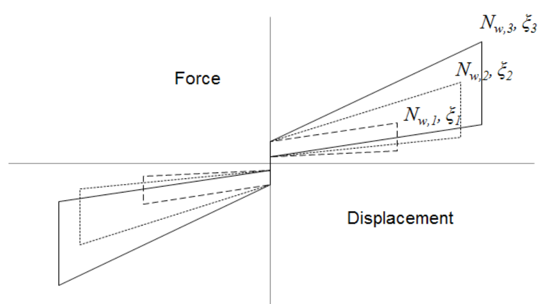
$(CoF_i < CoF_{i+1};\ \xi_{hyst,i} < \xi_{hyst,i+1})$

3. Number of bolts



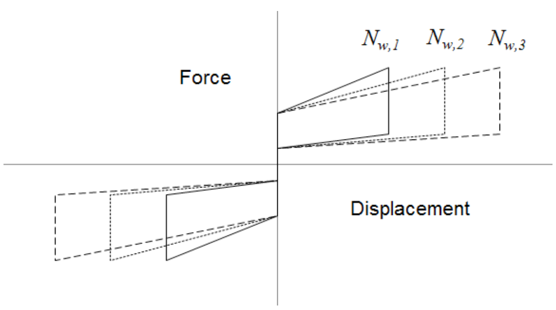
$(N_{b,i} < N_{b,i+1};\ \xi_{hyst,i} = \xi_{hyst,i+1})$

4. Number of washers (in parallel)



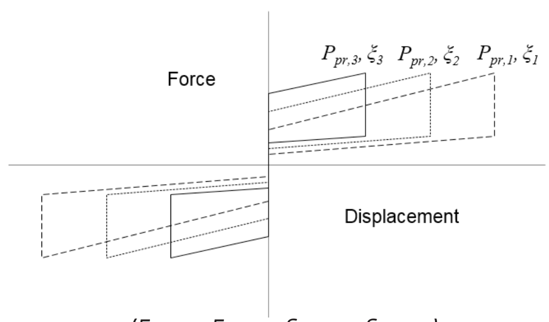
$(N_{w,i} < N_{w,i+1};\ \xi_{hyst,i} > \xi_{hyst,i+1})$

5. Number of washers (in series)



$(N_{w,i} < N_{w,i+1};\ \xi_{hyst,i} = \xi_{hyst,i+1})$

6. Prestressing force



$(F_{pr,i} < F_{pr,i+1};\ \xi_{hyst,i} < \xi_{hyst,i+1})$

Case studies

RSFJ component testing

In order to experimentally investigate the hysteretic behaviour of the RSFJ, a series of joint component tests were conducted. The following figures show the components and the assembly of the manufactured specimen which was a symmetric double acting RSFJ (comprised of two centre slotted plate and two cap plates). All plates were manufactured using mild steel grade 350. Two 20*50*220 mm mild steel stiffeners were welded to the cap plates to restrain them against out of plane bending. The disc springs that have been used in the test have a maximum capacity of 110 kN and a maximum deflection of 1.8 mm at the flat state. Two high resistant 8.8 bolts with nine spring washers in series per side were used.

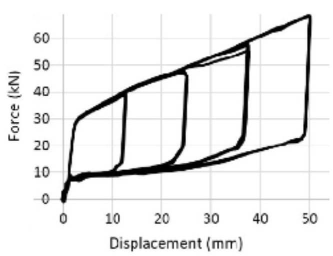
Cap and centre slotted plates

Disc springs

RSFJ at rest

RSFJ after slip

The displacement schedule with an average loading rate of 0.5 mm/s was applied to the specimen with different prestressing forces and different deflections. The schedule which is based on the previous experiments carried out on the similar slip friction connections includes four reverse cycles at 20%, 40%, 67% and 100% of the maximum targeted displacement. A sample hysteresis response of the joint is shown below demonstrating the damping and self-centring capacity of RSFJ.



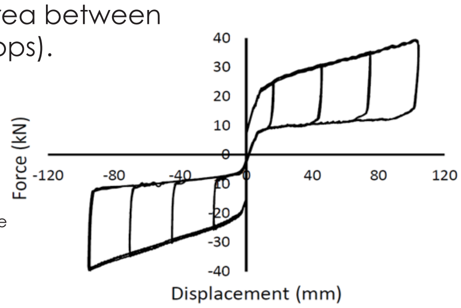
Hysteresis response of the joint component testing

Testing RSFJ on a timber shear wall

The configuration tested shown in the image below use two identical RSFJ units.

As shown, the RSFJ hold-downs were installed in the notches at the bottom corners of the CLT wall. The RSFJ configuration was composed of two centre slotted plates and two cap plates.

The RSFJ was designed and built to be able to accommodate a maximum displacement of 65 mm in tension and 15 mm in compression. This was due to the relatively higher displacement demand in tension compared to the one in compression in a hold-down connector. As shown, the load-deformation behaviour of the shear wall reinforced with RSFJs represents "flag-shaped" hysteresis curves which imparts the self-centering behaviour as well as energy dissipation (the bounded area between the hysteretic loops).



overall hysteresis response of the shear wall

Large-scale shear wall testing using RSFJ as hold-downs

RSFJ product tables

While the RSFJ is theoretically capable of an infinite configuration variety, Tectonus has designed a number of standard configurations which suit many purposes. Should your application not be covered by these standard configurations please contact Tectonus to discuss a custom design.

The standard configurations are categorised based on a combination of the groove angle maximum deflection.

Each product configuration generates a specific hysteresis curve which can be easily identified by the values provided in the tables. This flag-shaped behaviour can then be incorporated into SAP2000 for structural modeling and analysis under cyclic loading, as described in the *RSFJ limitless possibilities section (pg 9)*.

Note: For the illustrated hysteresis curves, F_{slip} could be set by the designer (typically as 50% of F_{ult})

Category 30

For Category 30,

- $F_{residual} = 0.46*F_{slip}$

Groove angle of 30° - Deflection up to 20 mm

Product Code	Number of bolts per splice	Ultimate capacity, F_{ult} (kN)	Restoring capacity, $F_{restoring}$ (kN)
RJWS-30-1	1	178	80
RJWS-30-2	2	357	160
RJWS-30-3	3	535	240
RJWS-30-4	4	714	320
RJWS-30-6	6	1070	481
RJWS-30-8	8	1427	641
RJWS-30-10	10	1784	801
RJWS-30-12	12	2141	961
RJWS-30-15	15	2676	1202
RJWS-30-N	N	178*N	80*N

Category 25

For Category 25,

- $F_{residual} = 0.41*F_{slip}$

Groove angle of 25° - Deflection range 20 to 40 mm

Product Code	Number of bolts per splice	Ultimate capacity, F_{ult} (kN)	Restoring capacity, $F_{restoring}$ (kN)
RJWS-25-1	1	149	59
RJWS-25-2	2	297	118
RJWS-25-3	3	446	176
RJWS-25-4	4	594	235
RJWS-25-6	6	891	353
RJWS-25-8	8	1188	470
RJWS-25-10	10	1485	588
RJWS-25-12	12	1782	706
RJWS-25-15	15	2228	882
RJWS-25-N	N	149*N	59*N

Category 20

For Category 20,

- $F_{residual} = 0.34*F_{slip}$

Groove angle of 20° - Deflection range 40 to 60 mm

Product Code	Number of bolts per splice	Ultimate capacity, F_{ult} (kN)	Restoring capacity, $F_{restoring}$ (kN)
RJWS-20-1	1	122	38
RJWS-20-2	2	244	77
RJWS-20-3	3	366	115
RJWS-20-4	4	488	154
RJWS-20-6	6	731	230
RJWS-20-8	8	975	307
RJWS-20-10	10	1219	384
RJWS-20-12	12	1463	461
RJWS-20-15	15	1829	576
RJWS-20-N	N	122*N	38*N

FAQ

What is the RSFJ?

The Resilient Slip Friction Joint (RSFJ) is a patented structural joint that absorbs seismic actions through friction and possesses the ability to return to its original position, thereby providing both damping and self-centring in one compact device.

What configuration can the RSFJ have?

The RSFJ can be configured to absorb translational and rotational movements. This can be achieved independently, or in combination if desired.

How big or how small can the RSFJ be?

The RSFJ is scalable in size, depending on required parameters such as force resisted and movement allowed.

In what LLRS can the RSFJ be used?

The RSFJ can be used in all types of LLRS as it replaces the traditional connections. It can be used in low, medium and high-rise buildings of any construction materials.

Where is the RSFJ manufactured?

The RSFJ was developed in New Zealand and can be manufactured anywhere under a strict manufacturing control by Tectonus.

Can the RSFJ be part of a structural health monitoring system?

Yes. The movement of the RSFJ can continuously be monitored, which is related to the force applied to the RSFJ. This offers a unique opportunity to measure the force and movement in the structure, and make decision on the condition of the structure following a seismic event.

Does the RSFJ require any maintenance or repairs?

The RSFJ does not require any maintenance or repair measures if the force imposed on the RSFJ during the earthquake is below its Fult capacity. This is different from other seismic passive devices or systems which rely on yielding of the material or a mere friction damping. Dampers that yield during an earthquake need to be replaced to resist the after-shocks, if the time allows. This can be extremely expensive (involving high risks) and is not usually considered in a project cost. These extensive repairs can render the recovery uneconomical and force the building to be demolished.

Does Tectonus provide engineering assistance/consulting?

Yes. Tectonus' expert consultants work with you to determine the best RSFJ and its connection options for your project to ensure the highest standard of seismic resilience.

Notes:

Contact us with any additional queries

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