# New Friction-based Seismic Brace: Cost-efficient Alternative to BRB's and EBF's

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## ABSTRACT

To address the demand for high seismic resilient systems while to be cost-efficient, an innovative steel brace incorporating efficient friction dampers and a new anti-buckling mechanism is introduced (branded as DMAX). This new seismic brace provides high damping and ductility for brace applications without experiencing any damage. The high consistency and very low tolerances of the dynamic performance of the presented system have been the significant advantages when compared to other friction-based braces available in the market (providing the best-in-class overstrength factor of 1.15). Its elastic perfectly plastic hysteresis performance makes it an efficient alternative to BRB's and EBF's. To demonstrate the dynamic performance of this new brace as well as its velocity independence (as part of ASCE07-16 requirements), the paper presents the results of a full-scale testing conducted at the Structures Lab of the Auckland University of Technology (AUT) using MTS dynamic actuators. This new system could provide an efficient solution for both new builds and retrofit projects in earthquake prone regions.

## 1 INTRODUCTION

During the last decades there has been a good advancement on the seismic design of structures with a transition from "High-damage" to "Low-damage" concepts to address the need for quick functional recovery. Bracing systems have always been considered as one of the efficient lateral load resisting solutions. While the use of bracing systems such as Eccentrically Braced Frames (EBF's) and Buckling Restrained Braces (BRB's) could provide the required stiffness and ductility for design of structures, the yieldable components in charge of energy dissipation will experience damage and there would be need for maintenance and replacement after severe events. As such, those structures already vulnerable would be at the high risk of aftershocks until the detailed assessments are performed and the necessary remedial actions have been in place.

**Fig. 1:** Sample of low damage bracing systems:
Buckling Restrained Braces - BRB’s (left), and Eccentrically Braced Frames – EBF’s (right)

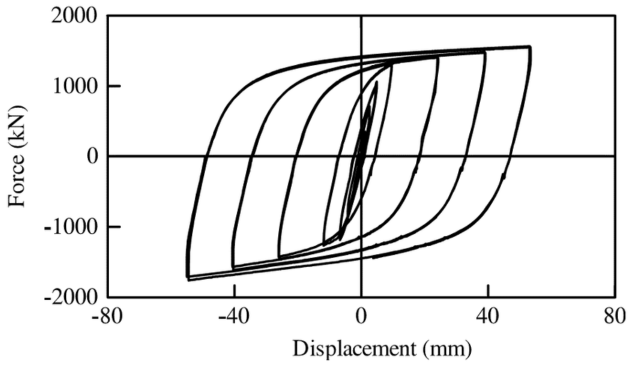


**Fig. 2:** Typical hysteresis performance of BRB’s/EBF’s

The team has already been successful is introducing new advanced bracing solutions (tension-compression and tension-only) for seismic protection of commercial and industrial structures by incorporating the Resilient Slip Friction Joint (RSFJ) technology (Bagheri et al., 2020; Hashemi et al., 2020; Yousef-beik et al., 2021; Zarnani and Quenneville, 2015). Those solutions with self-centring feature have been adopted in several buildings in NZ and overseas such as Lincoln University's Waimarie in Christchurch designed by BECA (awarded top prize for Building Nations Innovation in 2024), Tawa Church retrofitting in Wellington, and Nature Path's office in Vancouver designed by Fast + Epp (tallest fully timber building in a high seismic region).

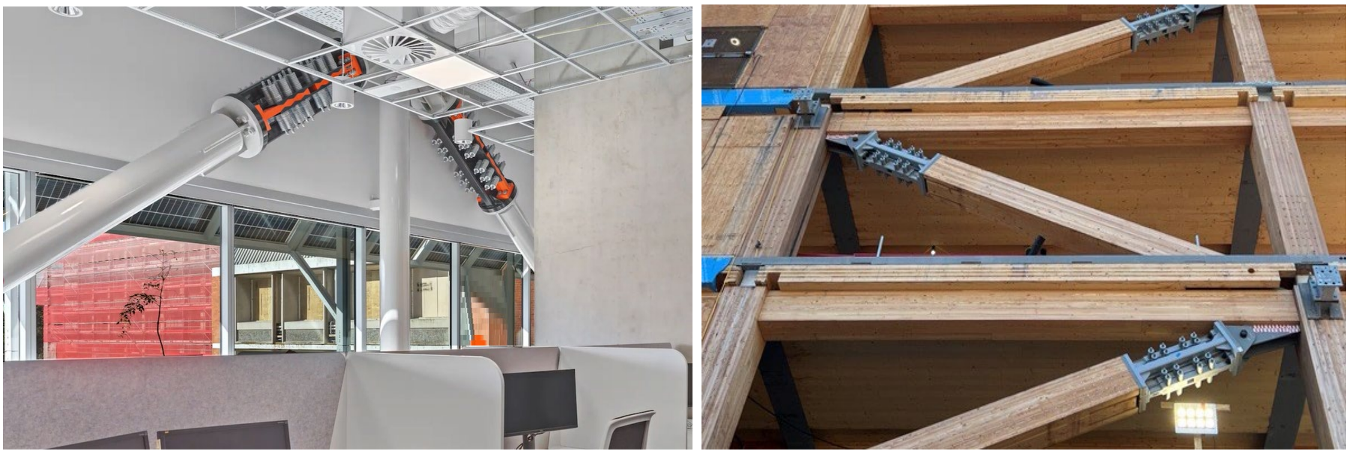

**Fig. 3:** Samples of the Tectonus tension-compression self-centring braces:
Lincoln University's Waimarie in Christchurch (left), and Nature Path's office in Vancouver (right)

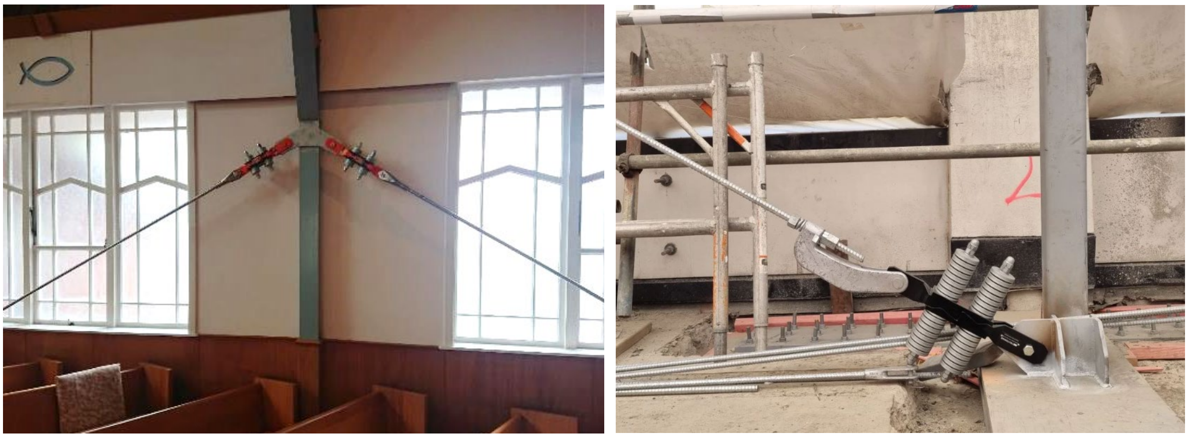

**Fig. 4:** Samples of the Tectonus tension-only self-centring braces:
Tawa Church retrofitting in Wellington (left), and Greys Ave multi-storey bldg extension in Auckland (right)

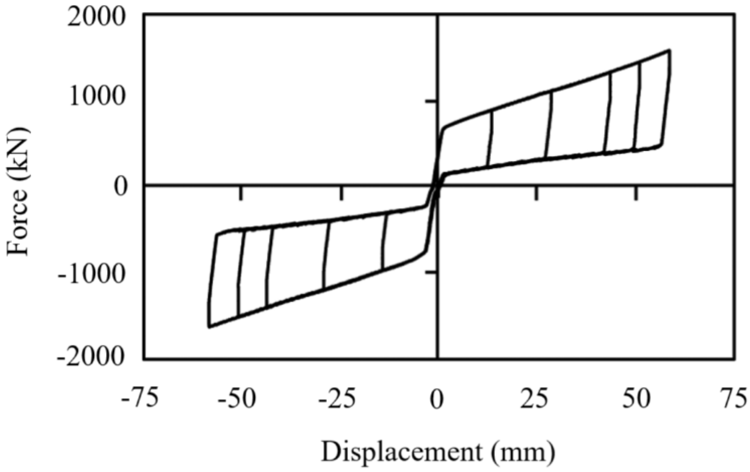


**Fig. 5:** Typical flag-shape hysteresis performance of the Tectonus self-centring braces

This paper presents a new friction-based seismic brace (branded as DMAX) with similar hysteresis performance of BRB and EBF (with no re-storing capacity) to be as cost-efficient with the additional advantages of providing the best-in-class overstrength factor of 1.15 (with savings on the capacity design of the adjacent members and foundation) and experiencing no damage during the earthquake events.

## 2 NEW FRICTION-BASED SEISMIC BRACE (BRANDED AS DMAX)

The DMAX is a steel brace supplied end to end (Fig. 6), incorporating the Tectonus DFFJ friction damper. The DMAX brace provides high damping and ductility for brace applications without experiencing any damage. The high consistency and very low tolerances of the dynamic performance of DMAX have been the significant advantages when compared to other friction-based dampers available in the market (providing the best-in-class overstrength factor of 1.15). Its elastic perfectly plastic hysteresis performance makes it an efficient alternative to BRB's and EBF's. It should be noted, providing lateral stability for friction-based braces has always been a challenge because the initiation of friction sliding in the damper appears as a plastic hinge resulting in the brace global buckling at the damper location. The lateral stability of the DMAX brace is provided by an external jacket as a robust anti-buckling mechanism (a proprietary design). To demonstrate the dynamic performance of DMAX brace as well as its velocity independence (as part of ASCE07-16 requirements), this paper presents the testing results of the DFFJ friction damper test as well as a full-scale testing of DMAX brace which have been conducted at the Structures Lab of the Auckland University of Technology using MTS dynamic actuators. The unique performance of the Tectonus DFFJ friction damper (implemented in several projects) has already been demonstrated and witnessed by an independent Chartered Professional Engineer, technical member of the NZSEE.

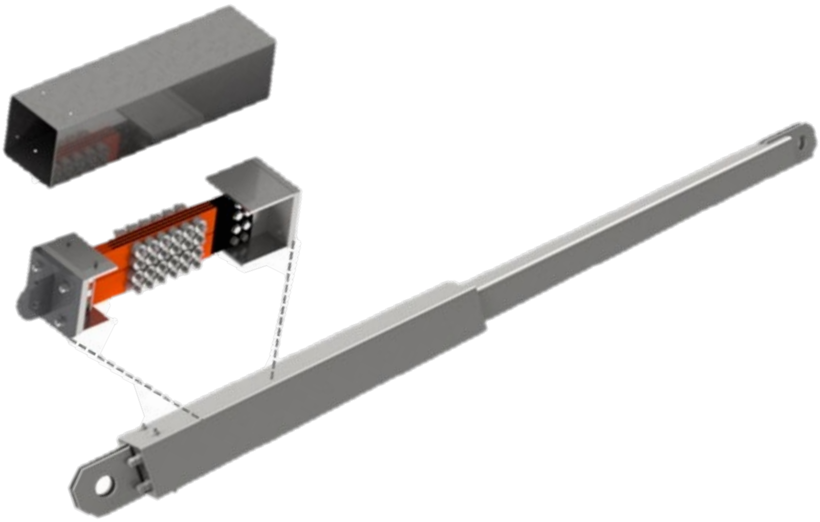

**Fig. 6:** DMAX seismic brace equipped with DFFJ friction damper and anti-buckling jacket

## 3 EXPERIMENTAL PROGRAM AND VALIDATION

### 3.1 DFFJ friction damper test

The testing has been conducted at the Structures Lab of the Auckland University of Technology (AUT), located at City Campus. The ambient temperature was recorded at approximately 18°C. The maximum target displacement of the joint was set at 25mm in tension and compression. The loading protocol was specified as per EN15129 providing a rigorous testing regime to verify the dynamic performance of the DFFJ. The number and amplitudes of the loading cycles are detailed as follows.

- 5 cycles at +/- 6.25mm (25% of the maximum displacement)
- 5 cycles at +/- 12.5mm (50%)
- 10 cycles at +/- 25mm (100%)

The testing program included 4 different tests with the following sequences and frequencies. The quasi-static tests were performed at 5 full cycles and the dynamic tests as per the above loading protocol:

- Test #1: Quasi-static at 0.1Hz
- Test #2: Quasi-static at 0.2Hz
- Test #3: Dynamic at 1.0Hz
- Test #4: Dynamic at 2.0Hz

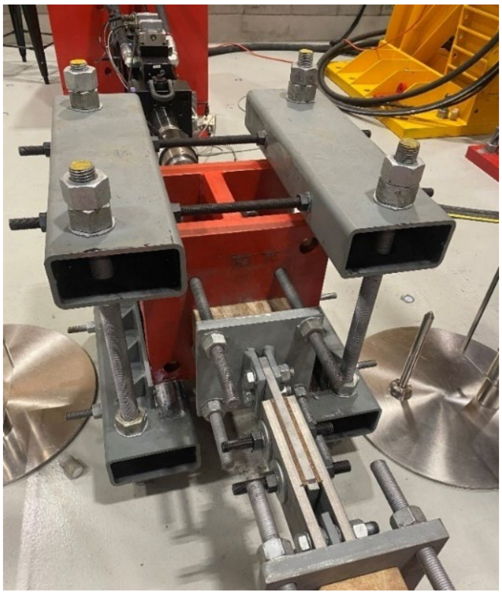

**Fig. 7:** Component test setup using 250kN MTS actuator

The results of the friction damper quasi-static performances (Tests #1 & 2) and dynamic performances (Tests #3 & 4) are presented in this section. As shown in Figs. 8 and 9, there is no performance degradation for any of the quasi-static and dynamic testing and the damper hysteresis behaviour is fully repeatable. As per the performance comparison between the quasi-static and dynamic testing, it can be deduced that the performances are compatible demonstrating the response of the device is independent of velocity and frequency of excitation as well as the reliability of the DFFJ performance even after several severe events. It should be noted that the slack observed in the performance is due to the clearance at the bolts connecting the damper to the end brackets which would be mitigated by tighter clearances or use of pin connections.

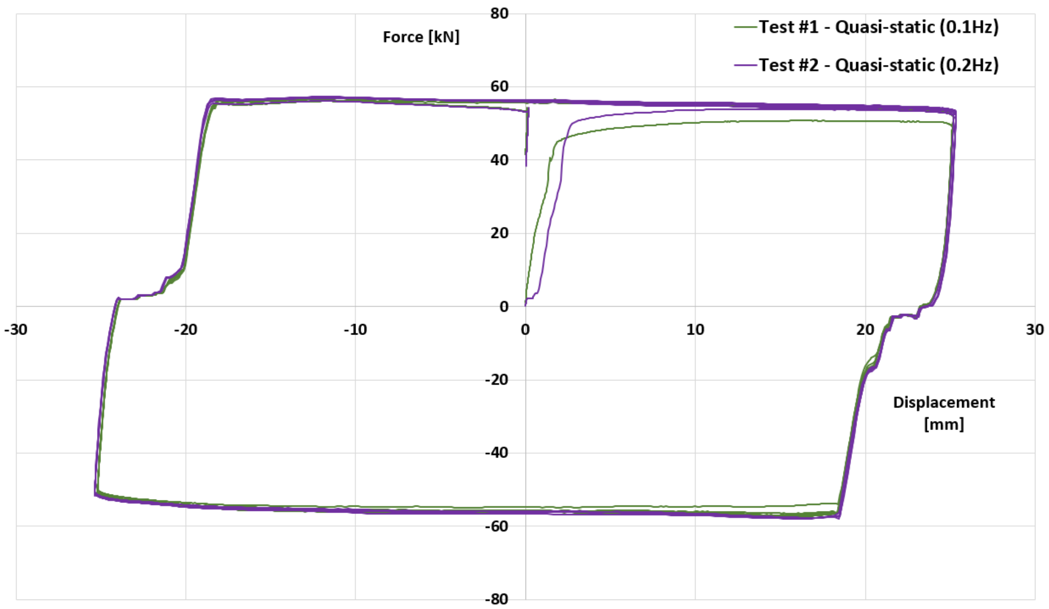


**Fig. 8:** Quasi-static performance of DFFJ (Tests #1 & 2)

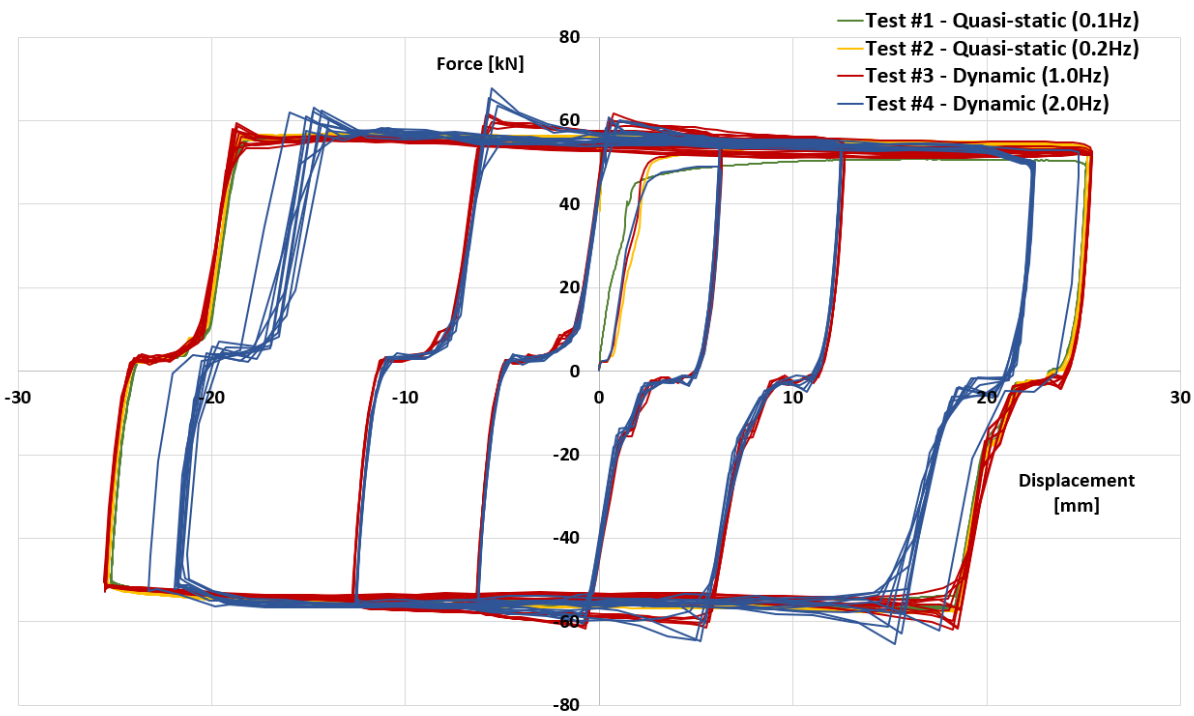


**Fig. 9:** Comparison of dynamic and quasi-static performances

### 3.2 DMAX brace assembly test (as per ASCE7-16)

To demonstrate the dynamic performance of DMAX brace entire assembly, a full-scale testing has been conducted at the Structures Lab of the Auckland University of Technology (AUT) using an MTS dynamic actuator. The loading protocol was specified as per ASCE07-16 providing a stringent testing regime (at the frequency of 0.2Hz). The number and amplitudes of the loading cycles have been:

- 10 cycles at +/-17mm (37.5% of the maximum displacement)
- 5 cycles at +/-34mm (75%)
- 3 cycles at +/-45mm (100%)


**Fig. 10:** Dynamic testing of DMAX brace with a capacity of 310kN

The DMAX brace tested had a capacity of about 310kN. The result of the dynamic performance is presented in Fig. 11 demonstrating the compatibility of the hysteresis curves after simulated severe events without any stiffness and strength degradation. It should be noted that the performance tolerances are below +/-15% resulting is a very low overstrength factor critical for having an efficient capacity design of the adjacent members and foundation, in particular for retrofitting projects.

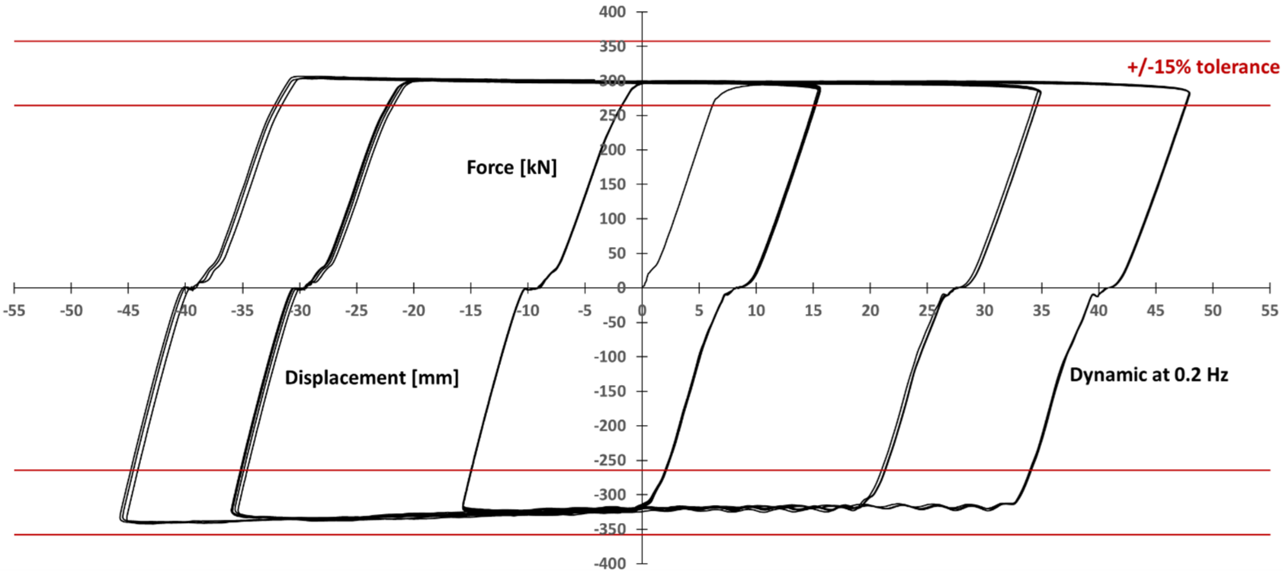


**Fig. 11:** High-consistent dynamic performance of DMAX brace with a tolerance lower than +/-15% (as per ASCE07-16)

In addition, as part of the ASCE07-16 requirements to demonstrate the velocity independence of the brace performance, a quasi-static testing was conducted at the full stroke on the same brace at a frequency of 0.02Hz (10 times slower than the dynamic test). As shown in the comparison plot (Fig. 12), the performances are quite compatible verifying another unique feature of the DMAX brace.

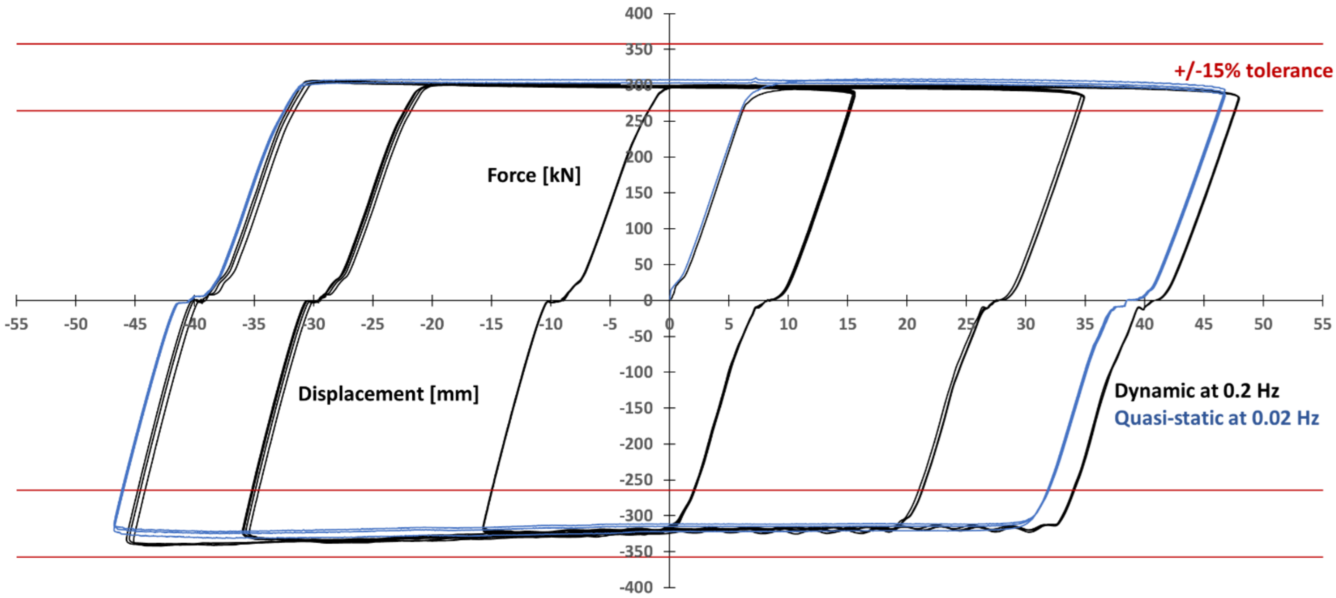


**Fig. 12:** Demonstration of velocity independence by comparing the quasi-static & dynamic performances

## 4 PROPOSED EQUIVALENT SEISMIC FORCE REDUCTION FACTOR

As per the case studies conducted by the research team comparing the DMAX brace with conventional braces in conceptual structures, the following equivalent seismic force reduction factors are proposed corresponding to different international codes and standards. More details regarding the structural modelling and analysis can be found in the paper published by Lal et al. (2025) in the proceedings of this conference.

**Table 1:** Proposed equivalent seismic force reduction factor corresponding to different international codes

| | NEW ZEALAND (NZS 1170.5) | CANADA (NBCC) | USA (ASCE7) |
|---|---|---|---|
| **Ductility** | **3.5 (μ)** | **4.8 ($R_dR_o$)** | **8 (R)** |
| **Overstrength** | **1.15** | **1.15** | **1.15** |

## 5 CONCLUSIONS

An innovative new seismic brace is introduced with high consistency and very low tolerances of the dynamic performance. Its elastic perfectly plastic hysteresis performance as well as the best-in-class overstrength factor of 1.15 make it a cost-efficient alternative to BRBs and EBFs. The results of a full-scale testing conducted at the Structures Lab of the Auckland University (AUT) verified the unique performance of this new bracing system with no velocity dependence (as part of ASCE7-16 requirements) to provide an efficient solution for both new builds and retrofit projects in earthquake prone regions.

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