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Connection and Bracing Systems Tested to Allow for Seismic Design Parameters in Australia

Abstract: Given recent geological activity in Australia, it is important that building structures use system components which are qualified and designed to allow for seismic actions. International standards such as ACI 318 (14) for cast-in concrete connections or AS 4100 (5) for bracing of steel structures allow for seismic design methods. Having said this, many innovative connection and bracing systems have features which are not addressed in these standards and therefore need to be tested for seismic performance to close this gap.

Bolted/cast-in systems for concrete and steel connections are regularly used in building structures. International standards can derive the seismic tensile performance for both concrete and steel failure mechanisms. However, with shear performance, although seismic concrete design is covered, the steel failure mechanism needs to be further explored for other features such as serrated washer to plate interaction. A testing program was designed to address this and put this type of connection through seismic shear testing protocol in accordance with ACI 355.2 (2) (equivalent to shear protocol EOTA TR 049 (7) category C1). The results were assessed and used for the seismic design method.

Bracing systems for structures incorporating concrete and steel elements are typically designed using AS 4100 (5). Some of these systems have been seismically tested in accordance with AS/NZS 1170.0 (8) Appendices A and B using Gr500E bar in NZ. A test program was put in place to qualify this type of system using Gr500N bar. The test results were assessed, and the system qualified in Australia with a ductility factor of $\mu = 1.5$.

Keywords: Seismic, Shear, Serrated Washer, Connections, Bracing, Ductility Factor.

1 Introduction

Regulations referenced in the National Construction Code are regularly changing to keep up with the dynamic nature of national and international standards. As such it has been found that recent updates of Australian Standards reflect these changes, one of which addresses seismic activity. For example, the standard AS 3600 – Concrete structures (3) was updated in 2018 and introduced a new chapter on Design for Earthquake Actions (Chapter 14). Similarly, AS 5216 – Design of post-installed and cast-in fastenings in concrete (1) was updated in 2021 and introduced a new Appendix on Design of fastenings under seismic actions (Appendix F). Furthermore, the Australian Standard for Structural design actions AS 1170 part 4 – Earthquake action in Australia (15) was amended in 2018 introducing a new hazard design factor along with updated hazard maps.

Given the increased regulation for seismic design in Australia, it is important that systems used for connections and bracing in structural application are qualified to ensure they that perform accordingly. This paper will explore the qualification for a proprietary bolted/cast-in system for concrete and steel connections (OrbiPlate™) and the testing program it went through to address any gaps in seismic performance. It will also go through the stringent testing program of a proprietary Bracing System used in New Zealand (ReidBrace™) which was qualified for seismic actions and then re-tested and qualified for use in Australian seismic conditions using local Australian materials.

2 Bolted/cast-in system for concrete and steel connections

2.1 Typical bolted/cast-in systems

Typically bolted/cast-in systems for concrete and steel connections comprise of a cast-in element, also referred to as a ferrule and a connection plate or fixture, typically made of steel. These elements are used to connect steel to concrete or concrete to concrete as show in the figure 1.

(a) Steel to concrete connection.

(b) Concrete to concrete connection.

Figure 1. Typical Bolted/cast-in connections

Typically, a standard fixture hole is designed into the steel fixture plate that suits the bolt intended to pass through it and connect into a cast-in ferrule. With this set-up, cumulative construction tolerance may cause problems with lining up the connection or steel fixture plates. OrbiPlate™ is a proprietary bolted/cast-in system which overcomes cumulative construction tolerances and consists of a serrated orbital plate, toothed washer and proprietary serrated flange head bolt. The system relies on a specific hole size in the connection or steel fixture plates to suit the system which will connect into the proprietary cast-in ferrule. Figure 2 depicts the components for the proprietary bolted connection system and Figure 3 depicts its connection to a cast-in ferrule.

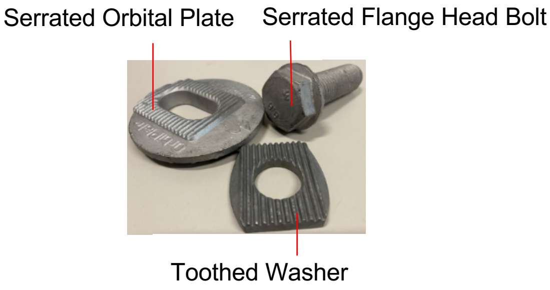


Figure 2. Components for proprietary bolted connection system

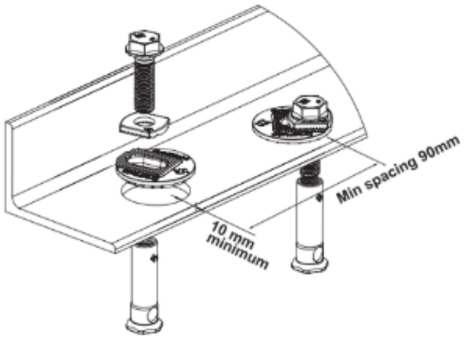


Figure 3. Connection of proprietary bolted system to a cast-in ferrule

2.2 Seismic qualification for bolted/cast-in systems

AS3600 – 2018 section 19.3 provides some guidance on cast-in ferrules and references AS 3850.1, Appendix B for their design. AS 3850.1 uses the Concrete Capacity Design (CCD) method but does not address seismic design methods. Alternatively, AS 5216 – 2021 (1) also uses the CCD method and addresses the seismic design method but only for post-installed fasteners. Therefore, currently the most appropriate standard to use for the seismic calculation of the cast-in ferrule system would be ACI 318M-19 Chapter 17 (14).

2.2.1 Tensile Capacity - Seismic Design & Qualification

With respect to tensile capacity, ACI 318M-19 (14) clause 17.7 provides theoretical calculation methods for steel, concrete and pullout failure modes and provides further reductions factors in clause 17.10 for each failure mode to allow for Seismic conditions.

2.2.2 Shear Capacity - Seismic Design & Qualification

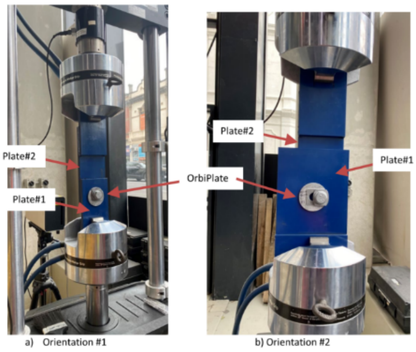
With respect to shear capacity, ACI 318M-19 (14) clause 17.7 provides theoretical calculation methods for steel, concrete and pryout failure modes but does not require any further reduction factors for Seismic conditions according to clause 17.10. Having said this, when considering the unique nature of the proprietary bolted connection system which requires steel interaction between the serrated orbital plate and the toothed washer, it warrants an investigation to explore how seismic conditions would affect this potential failure mode. As such, the most suited seismic testing for shear steel performance is detailed in ACI 355.2 (2), which is referenced in ACI 318M-19 Chapter 17 (14) for post-installed anchors. ACI 355.2 (2) clause 9.6 is equivalent to the seismic shear testing protocol of EOTA TR049 (7) clause 2.3 category C1 shear. Therefore, it was decided to organise seismic shear testing for the proprietary bolt, orbital serrated plate and toothed washer interaction based on EOTA TR049 (7) clause 2.3 category C1 shear.

2.3 Testing Shear Capacity – Serrated Plate & Toothed Washer Seismic Interation

Swinburne University of Technology (SWUT) was commissioned to carry out testing of the proprietary bolted connection system size M16 (ORB2016BGH) and M20 (ORB2020BGH) with different configurations according to C1 seismic shear testing protocol in EOTA TR049 (7) - equivalent to the seismic shear testing protocol in ACI 355.2 (2). The purpose of the test was to assess the seismic shear steel performance of the proprietary bolt, serrated orbital plate and toothed washer under C1 cyclic loading.

2.3.1 Test Setup

The proprietary bolted connection system was tested for seismic shear performance with different sized bolts and plate thickness in the Swinburne SMART Structures Laboratory. Images of the typical test setup are shown in Figure 4. The system was also tested in two different orientations as shown in Figures 5 and Figure 6.



a) Orientation #1

b) Orientation #2

Figures 4, 5 and 6 Reference: Swinburne University, OrbiPlate test report Final (16)

Figure 4. Shear test setup in MTS 250 kN actuator with 2 different orientations

Figure 5. Orientation #1

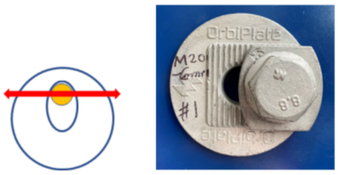


Figure 6. Orientation #2

For Orientation #1, depicted in Figure 5, the bolt was positioned 10mm off centre (half-way of the slot) and the load applied parallel to the slot for the M16 (ORB2016BGH) with 12mm plate and M20 (ORB2020BGH) with 16mm plate. This set-up was used to allow for a more challenging condition on the bolts in bending and on the teeth between the two washers (i.e. between the serrated orbital plate and tooth washer).

For Orientation #2, depicted in Figure 6, the bolt was positioned 20mm off centre (outer-most position on the slot) and the load applied perpendicular to the slot for M20 (ORB2020BGH) with a 6mm plate. This set-up was used to allow for a more challenging condition on the ply in bearing and on the teeth around the big washer (serrated orbital plate).

The proprietary bolted connection system was subject to alternating shear load protocol as per figure 7 and the load levels indicated in Table 1.

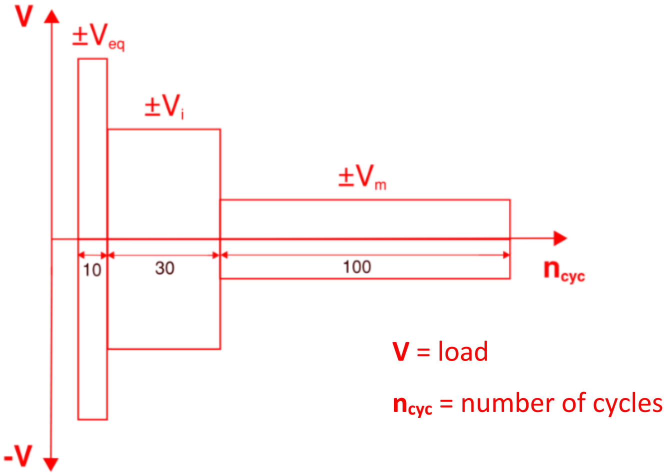


Figure 7. Cyclic shear loading protocol - Figure 2.8 from TR049 (7)

The derivation of the load levels in Table 1 were based on equations 2.9 to 2.11 from TR049 (7) as follows,

$$V_{eq} = 0.35*A_s*f_{uk} \qquad (1)$$

Where

A_s = [mm^2] – effective stressed cross section area of steel element in the shear plane;

f_{uk} = [N/mm^2] – characteristic steel ulitmate tensile strength (nominal value) iof the finished

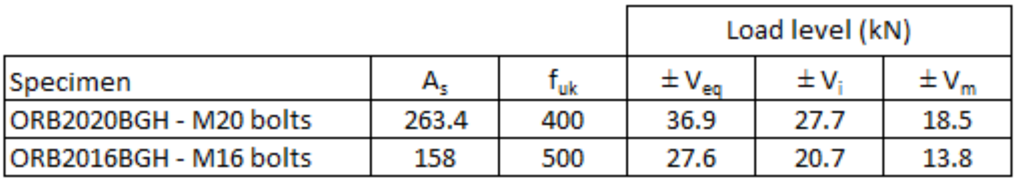
product;

$$V_i = 0.75*V_{eq}\ [N] \qquad (2)$$

$$V_m = 0.5*V_{eq}\ [N] \qquad (3)$$

Note: The effective stressed cross section area (A_s) and the characteristic steel ultimate tensile strength (f_{uk}) were both based on the cast-in ferrule.

Table 1. C1 cyclic loading level for connection system with two different bolt sizes.

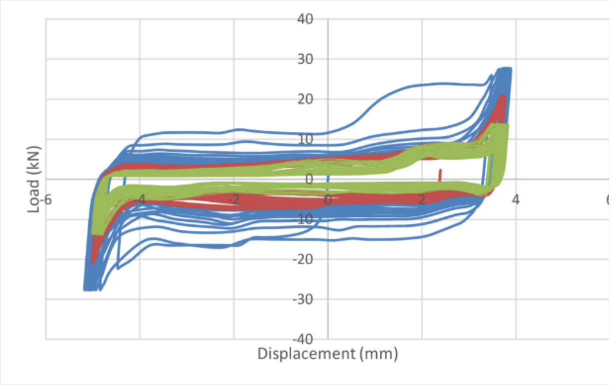


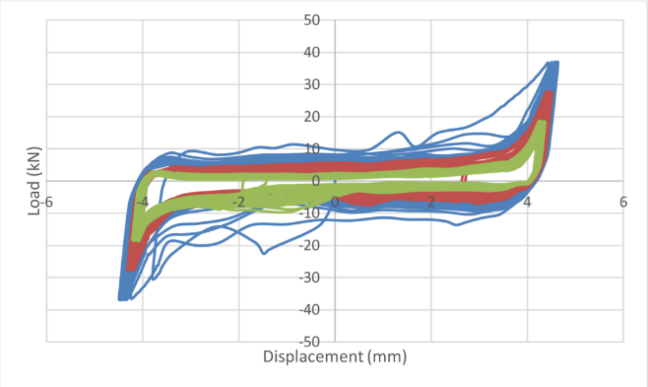
			Load level (kN)		
Specimen	A_s	f_{uk}	$\pm V_{eq}$	$\pm V_i$	$\pm V_m$
ORB2020BGH - M20 bolts	263.4	400	36.9	27.7	18.5
ORB2016BGH - M16 bolts	158	500	27.6	20.7	13.8

Table 1 Reference: Swinburne University, OrbiPlate test report Final (16)

2.3.2 Test Results

All fifteen test specimens were subjected to a complete program of alternating shear protocol depicted in figure 7. Examples of the load-displacement curves for the cyclic shear tests on the test specimens are shown in Figure 8 and 9.





Legend: 🟦 = *10 cycles at V_{eq}* 🟥 = *30 cycles at V_i* 🟩 = *100 cycles at V_m*

Figure 8. Cyclic shear M16 bolts, 12mm plt.

Figure 9. Cyclic shear M20 bolts, 16mm plt.

Figures 8 & 9 Reference: Swinburne University, OrbiPlate test report Final (16)

Following completion of the cyclic shear protocol, the proprietary bolted connection system was tested to failure in shear to determine the residual shear capacity. From the total fifteen test specimens, 5 were tested in Orientation #1 for M16 bolts with 12mm plates, 5 were tested in Orientation #1 for M20 bolts with 16mm plates and 5 were tested in Orientation #2 for M20 Bolts with 6mm plates. Table 2 provides a summary of the residual shear test results tabulating the number of tests, average residual shear load ($V_{res,m}$) and the mode of failure (MoF) as follows.

Table 2. Summary of residual shear test results

Test Set-up	**No. of tests**	**Mode of failure (MoF)**	**Average Residual shear load, $V_{res,m}$ (kN)**
Orientation #1 – M16 bolts with 12mm plates	5	Tooth washer split	71.1
Orientation #1 – M20 bolts with 16mm plates	5	Tooth washer split	91.8
Orientation #2 – M20 bolts with 6mm plates	5	Bolt shear	150.8

As stipulated by Cl 3.1.2 TR049 (7), the reduction factor on characteristic shear capacity from static loading is calculated as shown in Table 3

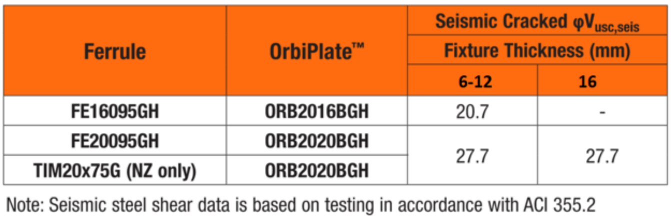
Table 3. Reduction factor calculation on characteristic shear capacity per Cl 3.1.2 TR049

Test Set-up	**$V_{res,m}$ (kN) (from table 2)**	**V_{eq} (kN) (from table 1)**	**Ratio of $V_{res,m}/V_{eq}$**	**$\alpha_{v,C1}$ (reduction factor)**
Orientation #1 – M16 bolts with 12mm plates	71.1	27.9	254.84% > 160 %	1
Orientation #1 – M20 bolts with 16mm plates	91.8	36.9	248.78% > 160 %	1
Orientation #2 – M20 bolts with 6mm plates	150.8	36.9	408.67% > 160 %	1

Tables 2 and 3 Reference: Swinburne University, OrbiPlate test report_Final (16)

All specimens completed the C1 alternating shear protocol in EOTA TR049 (7) with the average residual shear load for 5 specimens in each test series exceeding more than 1.6 times the applied V_{eq} for cyclic protocol, demonstrating the suitability of the serrated orbital plate and toothed washer interaction for the proprietary bolted connection system for seismic shear C1 category performance defined in EOTA TR049 (7). According to Clause 3.1.2 in EOTA TR049 (7), no reduction to static shear load is required if $a_{v,C1} = 1$. As such, Table 4 provides the seismic design table which reflects the proprietary connection system shear performance.

Table 4. Seismic Design Table $\phi V_{usc,seis}$ (kN) where $\phi = 0.75$ and based on $f'c \geq 32MPa$



Ferrule	OrbiPlate™	Seismic Cracked $\varphi V_{usc,seis}$	
		Fixture Thickness (mm)	
		6-12	16
FE16095GH	ORB2016BGH	20.7	-
FE20095GH	ORB2020BGH	27.7	27.7
TIM20x75G (NZ only)	ORB2020BGH		

Note: Seismic steel shear data is based on testing in accordance with ACI 355.2

Table 4, Reference: Ramset, OrbiPlate Design Guide (12)

3 Bracing System for concrete-steel structures

3.1 Typical bracing systems

Typically, bracing systems are used to brace the roof and wall elements of lightweight structures. They comprise of a rod, turnbuckle, eyelet, and cleat connection point and are frequently used on steel structures which are cladded with prefabricate concrete elements. An example of structural cross bracing is shown in Figure 10.

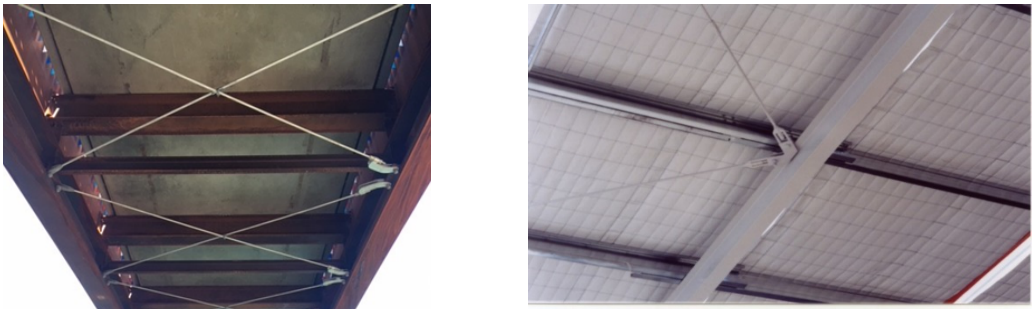


Figure 10. Typical Structural Cross Bracing

Generic bracing relies on tensioning the rod by using a turnbuckle mechanism which tightens the system ensuring the structure is square. The ReidBrace™ System is a proprietary bracing system which provides a different and more user-friendly mechanism to tension the rod. The rod for this system is Gr500E threaded bar used in New Zealand which complies with AS/NZS 4671 and has been seismically tested in accordance with AS/NZS 1170.0 (8) Appendices A & B. In Australia, the rod is made of Grade 500N threaded bar which also complies with AS/NZS 4671. Figure 11 provides detail of the system components and Figure 12 depicts the assembly of the components with the rod made from AS/NZS 4671 Grade 500E or Grade 500N bar.

1. Reid™ Tension Spring
2. Reid™ Tab Washer
3. RBRACE
4. RBRACE-END
5. ReidBar™ nut x 2
6. Pin and Clip

Figure 11. System Components *Figure 12. Assembly*

Figures 11& 12 Reference: Ramset, ReidBrace Design Guide (13)

3.2 Seismic qualification for bracing systems

NZS3404 Steel structures (6), standard for NZ, provides detail on seismic design in section 12, however it limits the yield stress of the steel to no greater than 450 MPa in Table 12.4, thus setting the aforementioned proprietary bracing system outside of the scope of this standard. As such, the proprietary bracing system was tested at University of Auckland (UoA) in New Zealand using the prototype testing method as per AS1170.0 (8) Appendix B & NZS 3404 (6) Cl 17.5.[refer ASEC 2020 paper 'Seismic test program on proprietary tension only bracing system: ReidBrace™ , Emanuele Naccini, A/Prof Charles Clifton (1)]

Similarly, AS4100 Steel structures (5), standard for AUS, provides detail on earthquake design in section 13 which also has limitations on the maximum yield stress of the steel. Given, AS4100 (5) Cl 17.5 also has a prototype testing method, the seismic test results of the proprietary bracing system tested at the UoA can be used for Australian conditions. To do so, it was required to validate that the AS/NZS 4671 (4) Grade 500N threaded bar used in the proprietary bracing system for Australia will perform equivalent to the AS/NZS 4671 Grade 500E threaded bar used in the proprietary bracing system for New Zealand. Melbourne Testing Services (MTS) were commissioned to carry out monotonic tensile testing on the proprietary bracing system used with AS/NZS 4671 (4) Gr500N threaded bar. Following this, Swinburne University of Technology (SWUT) assessed the test results from the UoA and MTS

3.2.1 Cyclic Testing (Seismic) using Grade 500E threaded bar

The Cyclic Testing (Seismic) was carried out by UoA on the proprietary bracing system for sizes RB12, RBA16, RB20 and RB25 using the system components with AS/NZS 4671 (4) Grade 500E threaded bar. It was used to determine the performance of the proprietary bracing system under repeated tension and compression load cycles resembling seismic load conditions. These tests were also displacement controlled with displacement levels set at each cycle ranging from 0.75μ to 6.0μ, where μ is the calculated yield displacement. All samples performed extremely well under cyclic loading, with none of the samples reaching ultimate capacity at the target level of displacement. Figure 13 shows the test set-up for the cyclic testing and Figure 14 provides results on one of the sizes graphing tensile stress vs deformation.

The components and the Gr500E threaded bar were also subject to freeze testing. They were frozen and loaded to failure. The load was applied at the maximum speed of the actuator (10 mm/s) to simulate rapid tensile loading during an earthquake. The typical temperature for testing was -10°C but some tests were also conducted at -5°C. Figure 15 depicts the test set-up for the freeze testing.

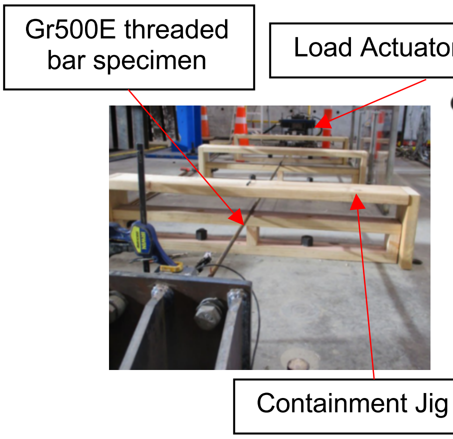


Figure 13. Cyclic Test Set-up

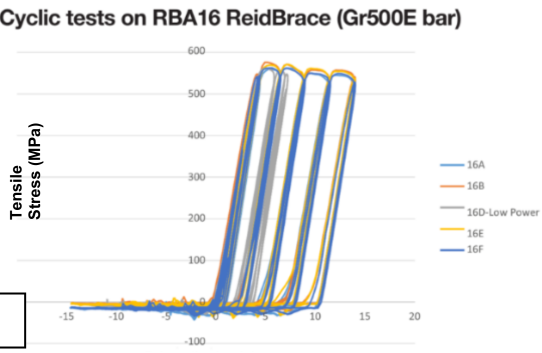


Figure 14. Graph of Tensile Stress vs Deformation

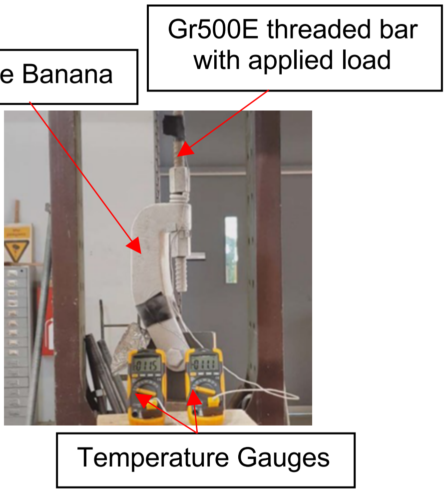


Figure 15. Freeze Testing Set-up

Figures 13, 14 & 15 Reference: Naccini, E., Clifton, C. A/Prof. (10)

3.2.2 Monotonic Tensile Testing using Grade 500E threaded bar

Finally, the components and Grade 500E threaded bar was subjected to monotonic tensile testing at the UoA. The Gr500E propriety brace system averaged an ultimate tensile strength R_m > 600 MPa for sizes 12mm to 25mm and recorded a uniform elongation above 10% at peak load, as per AS/NZS 4671 (4). Figure 16 depicts the test set-up and Figure 17 shows the tensile stress vs strain graph for one of the sizes subjected to the monotonic tensile testing.

Figure 16. Test Set-up

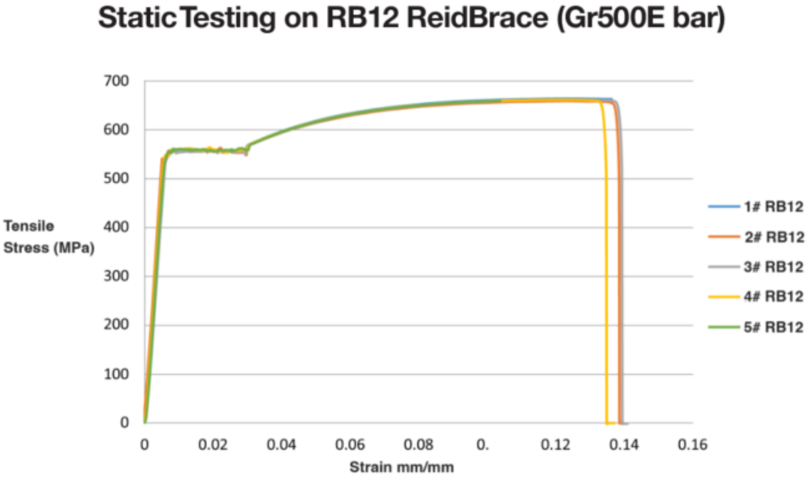


Figure 17. Gr500E Brace System Stress vs Strain

Figures 16 and 17 Reference: Naccini, E., Clifton, C. A/Prof. (10)

3.3 Monotonic Tensile Testing using Grade 500N threaded bar

MTS were commissioned to perform tensile testing on the proprietary bracing system using Grade 500N threaded bar. The test was a destructive test and was carried out on 12mm, 16mm, 20mm, 25mm and 32mm set sizes. A plane Gr500N threaded bar was also tested as a ‘control’ comparison. The testing was to be undertaken in accordance with the principles of AS 1391:202 Metallic Materials – Tensile Testing – Method of Test at Room Temperature and AS/NZS 4671:2019 Steel for reinforcement of concrete (4).

3.3.1 Test Set-up – Monotonic Tensile Test Gr500N threaded bar

There were 5 repeat samples for each of the 5 proprietary bracing system sizes. They were all assembled at the MTS laboratory following the proprietary bracing system’s installation instructions. Figure 18 depicts the 5 sizes of the proprietary bracing system assembled in readiness for testing. In preparation for testing, gauge marks were indented along the free length of the Gr500N threaded bar for determination of uniform elongation A_{gt}.

To facilitate tensile testing of the proprietary brace assemblies, a pair of test specific high strength cleat plates were designed and manufactured to accommodate axial loading of the assemblies for each size.

Each test specimen was set up in a calibrated testing machine and contact extensometer to measure and record strain of the Gr500N threaded bar as shown in Figure 19. Upon reaching the expected tensile strength value, the extensometer was removed, and strain was subsequently calculated using the testing machine crosshead for the remainder of the test.

Figure 18. Proprietary bracing assembled

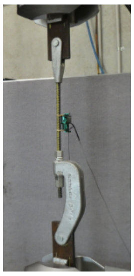


Figure 19. Test Setup

Figures 18 and 19, Reference: Melbourne Testing Services, test report MTS-21-1064 (17)

3.3.2 Test Results – Monotonic Tensile Test Gr500N threaded bar

The Gr500N propriety brace system recorded a minimum tensile strength R_m > 540 MPa for sizes 12mm to 32mm and recorded a uniform elongation above 5% at peak load, as per AS/NZS 4671 (4). Figure 20 shows the Tensile Stress vs Strain graph for one of the sizes subjected to the monotonic tensile testing. The average yield stress, tensile strength, and uniform elongation between the proprietary brace systems assemblies and the Gr500N control bar samples was found to be nominally identical.

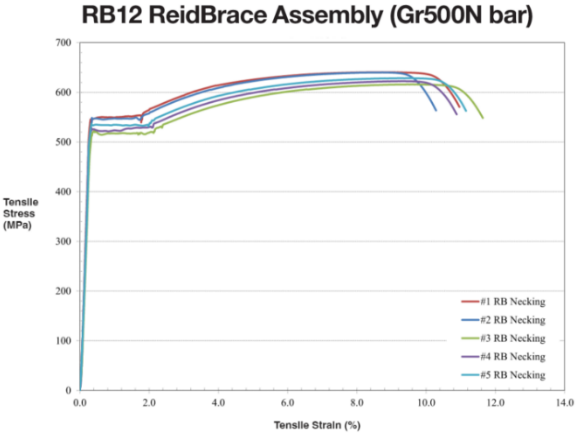


Figure 20. Brace System Stress vs Strain

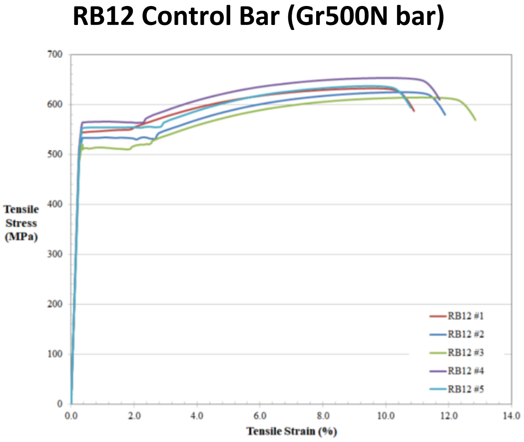


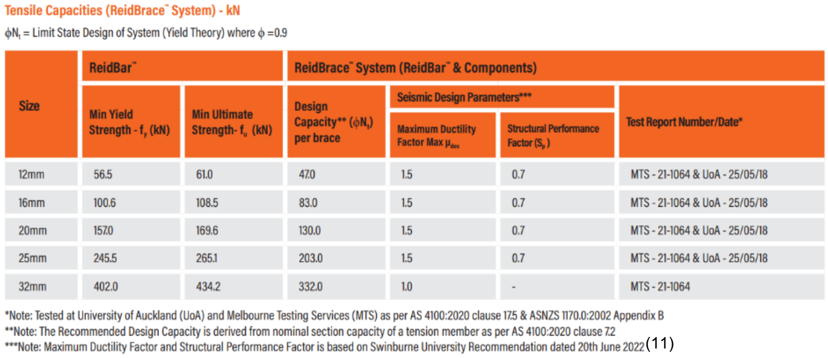
Figure 21. Control Bar Stress vs Strain

Figures 20 and 21, Reference: Melbourne Testing Services, test report MTS-21-1064 (17)

3.4 Assessment from SWUT of MTS and UoA Testing

SWUT reviewed the testing documentation from both UoA and MTS. For the Cyclic testing at UoA, all the cycles performed were designed to reach a maximum inelastic elongation of the system equal to six times the yield elongation of the bar. Up to this level of displacement the bar is still within the yield plateau and therefore the behavior of the Gr500E bar is comparable with the behavior of Gr500N bar. Furthermore, SWUT reviewed the MTS test results and considered the worst performing sample and its ratio between ultimate and yield displacements. From this, the performance of the proprietary bracing system using Gr500N threaded bar for sizes 12mm to 25mm was assessed with a maximum ductility factor (μ) of 1.5 also considering a structural performance factor (Sp) equal to 0.7.

Table 5. Seismic Design Table – for Australian Conditions



Tensile Capacities (ReidBrace™ System) - kN

ϕN_t = Limit State Design of System (Yield Theory) where ϕ =0.9

Size	ReidBar™		ReidBrace™ System (ReidBar™ & Components)			
	Min Yield Strength - f_y (kN)	Min Ultimate Strength- f_u (kN)	Design Capacity** (ϕN_t) per brace	Seismic Design Parameters***		Test Report Number/Date*
				Maximum Ductility Factor Max μ_{des}	Structural Performance Factor (S_p)	
12mm	56.5	61.0	47.0	1.5	0.7	MTS - 21-1064 & UoA - 25/05/18
16mm	100.6	108.5	83.0	1.5	0.7	MTS - 21-1064 & UoA - 25/05/18
20mm	157.0	169.6	130.0	1.5	0.7	MTS - 21-1064 & UoA - 25/05/18
25mm	245.5	265.1	203.0	1.5	0.7	MTS - 21-1064 & UoA - 25/05/18
32mm	402.0	434.2	332.0	1.0	-	MTS - 21-1064

*Note: Tested at University of Auckland (UoA) and Melbourne Testing Services (MTS) as per AS 4100:2020 clause 17.5 & ASNZS 1170.0:2002 Appendix B

**Note: The Recommended Design Capacity is derived from nominal section capacity of a tension member as per AS 4100:2020 clause 7.2

***Note: Maximum Ductility Factor and Structural Performance Factor is based on Swinburne University Recommendation dated 20th June 2022(11)

Table 5 provides the seismic design table which reflects the performance of the proprietary bracing system using Gr500N bar for Australian conditions.

Table 5, Reference: Ramset, ReidBrace Design Guide (13)

4. Conclusion

The design of the proprietary bolted connection system using an orbital serrated plate with a toothed washer, proved to be more than adequate to allow for cyclic/seismic shear loading, in accordance with testing to EOTA TR049 (7) clause 2.3 category C1 shear (also equivalent to testing in accordance with ACI 355.2 (2) clause 9.6 seismic shear). It is worth noting that the displacement behavior tended to be twice that what you would expect with a typical bolted connection through a standard fixture hole. For example, a standard M20 bolt the fixture hole is 22mm, however for the OrbiPlate system you have the hole through the serrated washer being 22mm and you also have the orbital serrated plate mating against the fixture hole in the plate and this accumulates in displacement. The mating fixture hole was set at the higher side of its tolerance leading to a more conservative test. Nevertheless, the cyclic/seismic shear loading met the requirement as stated above and the displacement of the fixture holes can be mitigated with similar methods used for standard bolted connections if required (e.g. annulus gap fillers etc..). All other failure modes subject to seismic actions can be addressed using theoretical models published in ACI 318M-19 Chapter 17 (14), including tensile capacities for concrete cone and pullout along with shear capacities for concrete breakout, steel (bolt & ferrule) and pryout of the cast-in element. The testing confirmed that the tooth washer interaction with the orbital serrated plate is suitable for the seismic shear loads it was measured against, which have been converted to a shear design capacity of the system in the corresponding design guide titled – OrbiPlate™ Design Guide July 2023 Issue – AU & NZ (12).

For the proprietary bracing system using a rod from AS/NZS 4671 (4) Gr500N threaded bar, testing at UoA, and MTS have demonstrated the system's suitability to allow for earthquake conditions in Australia with a ductility factor(μ) of 1.5 for sizes 12mm to 25mm and structural performance factor (Sp) of 0.7 as recommended by SWUT. These seismic design parameters have been tabulated along with the design capacity per brace and published in the corresponding design guide titled – ReidBrace Design Guide July 2023 – AU ONLY (13).

5. Acknowledgement

Swinburne University of Technology, Melbourne Testing Services, University of Auckland, Reid Construction Systems, Ramset.

6. References

1. Standards Australia, AS 5216:2021 Design of post-installed and cast-in fastenings for use in concrete
2. American Concrete Institute, ACI 355.2-19 Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary.
3. Standards Australia, AS 3600:2018 Concrete structures
4. Australian/New Zealand Standard™, AS/NZS 4671:2019 Steel for reinforcement of concrete
5. Standards Australia, AS 4100:2020 Steel structures
6. Standards New Zealand, NZS 3404: Part 1 and 2:1997 (A2) Steel Structures Standard
7. EOTA, Technical Report TR 049 August 2016 Post-installed fasteners in concrete under seismic action
8. Australian/New Zealand Standard™, AS1170.0:2002 Structural design actions Part 0: General principles
9. Standards Australia, AS 3850.1:2015 (A1) Prefabricated concrete elements Part 1: General requirements
10. Naccini, E., Clifton, C. A/Prof. "ASEC 2020 paper 'Seismic test program on proprietary tension only bracing system: ReidBrace™".
11. Swinburne University, ReidBrace final opinion letter 20 June2022
12. Ramset, OrbiPlate Design Guide July 2023 Issue – AU & NZ
13. Ramset, ReidBrace Design Guide July 2023 – AU ONLY
14. American Concrete Institute, ACI 318M-19 Chapter 17 – Anchoring to concrete
15. Standards Australia, AS1170.4-2007 A1 & A2 (R2018) Part 4 Earthquake actions in Australia
16. Swinburne University, OrbiPlate test report Final November 2021
17. Melbourne Testing Services, test report MTS-21-1064 December 16th 2021