Performance of baseplate energy dissipating mechanisms in rocking cold-formed steel storage racking

James Maguire[1,2], Zhenghao Tang[1,2], Charles Clifton[2], Lip Teh[1], James Lim[2]

[1]University of Wollongong, [2]University of Auckland

Introduction

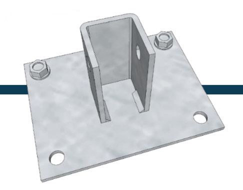
Cold-formed steel storage racking is used for bulk storage of products which are often much heavier than the structure itself. The combination of high loads and light structural members can make the racks susceptible to collapse during earthquake motion.

To increase the resilience of such structures to cross-aisle ground motion, two novel types of energy dissipating baseplates were tested:

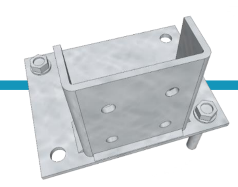
1. Unanchored baseplates that allow the structure to rock; and
2. Friction sliding baseplates that allow rocking while dissipating energy through friction.

Test method

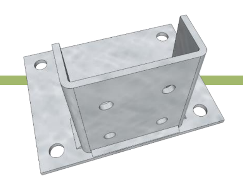
Full scale laboratory testing was conducted on a 3-storey, 2-bay storage rack assembly. The rack assembly was loaded with six 7.7 kN pallets and subjected to static pushover and dynamic snapback testing. The cross-aisle stiffness and dynamic properties of the rack were determined for four baseplate configurations.



Standard Baseplate
Used in New Zealand
3.5 mm plate thickness



Heavy duty Baseplate
Used in non-seismic areas
10 mm plate thickness



Unanchored Baseplate
Allows frame to uplift with no resistance

Friction sliding Baseplate
Allows frame to uplift with friction resistance

Results

The rack was subject to a horizontal load at the top beam level of the center frame. Each baseplate configuration reached a displacement of 100 mm before a quick release was triggered, causing the frame to vibrate freely.

1. Both baseplate systems provide constant restoring force with no stiffness increase (Fig 2). This allows the rack to remain elastic. The restoring force can be controlled for the friction sliding baseplate.
2. Residual displacement suggests permanent rack deformation with heavy duty baseplate (Fig 3).
3. Friction sliding baseplate was very effective at dissipating energy (Fig 4). Free vibration only lasted three cycles before coming to rest.
4. Unanchored baseplate did not dissipate energy effectively. The period was significantly increased using the unanchored baseplate (Fig 4).

Figure 1. Tested storage rack assembly.

Static pushover

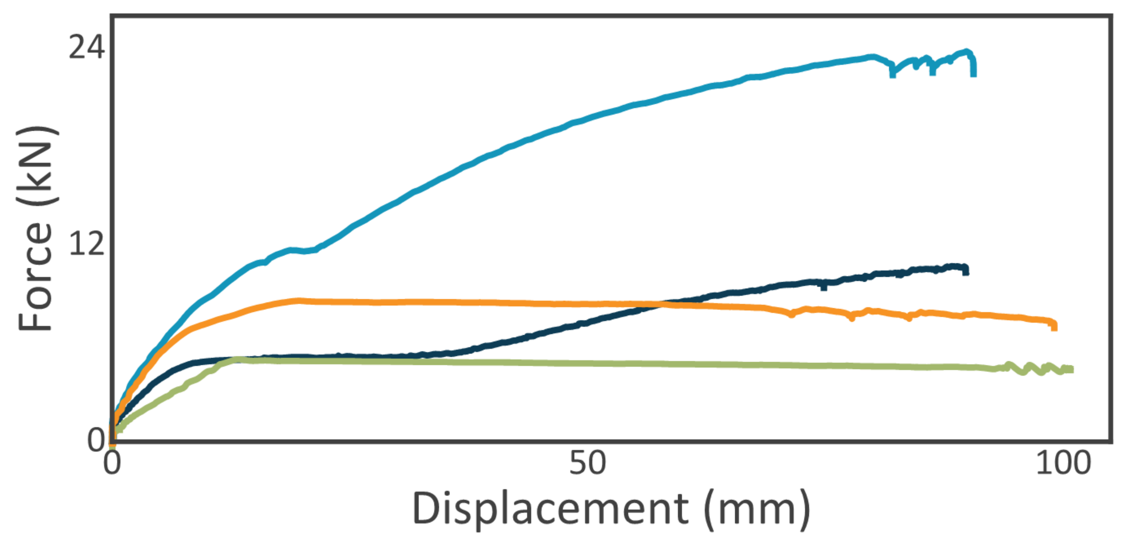


Figure 2. Force-displacement curve for top beam level.

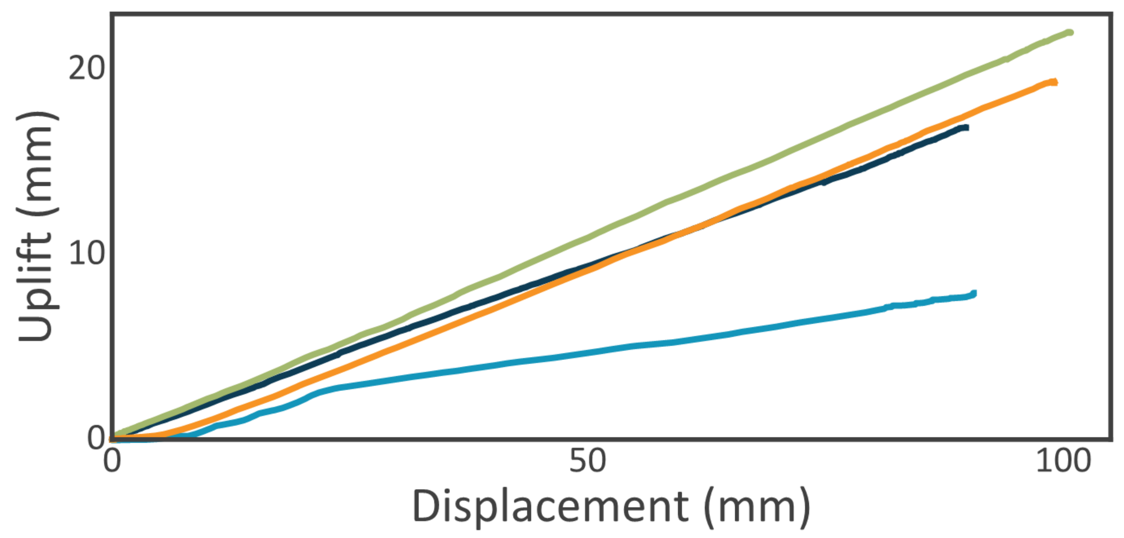


Figure 3. Base uplift against horizontal displacement. Unanchored system behaves as a rigid frame, heavy duty system shows frame deformation.

Dynamic snapback

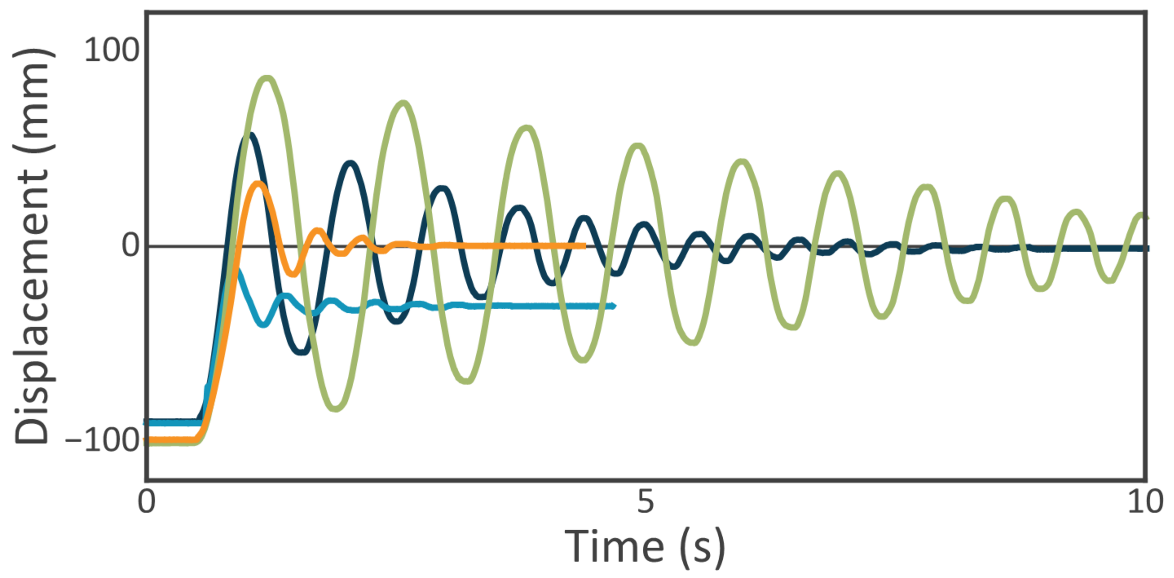


Figure 4. Horizontal displacement measured at the top beam level during free vibration.

Table 1. Rack period and energy dissipation for the first three cycles, from Fig 4.

Baseplate	Period (s)	Damping
Standard	1.01, 0.91, 0.77, ...	26%, 29%, 33%, ...
Heavy duty	0.50, 0.47, 0.44, ...	72%, 51%, 40%, ...
Unanchored	1.37, 1.23, 1.12, ...	15%, 18%, 15%, ...
Friction sliding	0.58, 0.47, 0.38	75%, 43%, 70%

Conclusions

- Unanchored and friction sliding baseplates had less resistance to uplift at large displacements, allowing the rack to remain elastic.
- The unanchored system behaved as a rigid rocking frame, but did not effectively dissipate energy.
- The friction sliding baseplate system was very effective at dissipating energy while allowing the system to remain elastic and self-centering.

Future research will determine baseplate performance when subjected to cross-aisle ground motions. This will be achieved through numerical modelling and shaking table tests.

Additional questions:

- What is the effect of baseplate configuration in larger racks where higher mode responses have greater influence?
- Are current design methodologies well suited to take advantage of these flexible baseplate systems?

Contact Information

James Maguire University of Wollongong
E jrm978@uowmail.edu.au **M** +64 274 221 698

QuakeCoRE
NZ Centre for Earthquake Resilience

Acknowledgements

Thanks to the University of Auckland lab staff for their assistance.
Funding provided by QuakeCoRE. Materials provided by Dexion.