O
one of the world’s greatest unsolved mysteries of our time lies in a
courtyard outside of the Central
Intelligence Agency (CIA) headquar-
ters in Langley, Virginia. It’s a sculpture called
Kryptos, and although it’s been partially solved,
contains an inscription that has puzzled the
most renowned cryptanalysts since being erected
in 1990. Meanwhile, in another part of the DC
Beltway about 15 miles to the southeast, another
great mystery is being deciphered at the American
and Iron Institute (AISI) headquarters. The mys-
tery, structural behavior of cold-formed steel
(CFS) clip angles, has puzzled engineers since the
great George Winter helped AISI publish its first
Specification in 1946. In particular, engineers have
struggled with how thin-plate buckling behavior
influences CFS clip angle strength under shear and
compression loads. Additionally, there has been
considerable debate within the AISI Specification
Committee concerning anchor pull-over strength
of CFS clip angles subject to tension.

The primary problem has been the lack of test
data to explain clip angle structural behavior.
Even with modern Finite Element Analysis (FEA)
tools, without test data to help establish initial
deforations and boundary conditions, FEA
models have proven inaccurate. Fortunately, joint
funding provided by AISI, the Steel Framing
Industry Association (SFIA), and the Steel Stud
Manufactures Association (SSMA) has provided
the much-needed testing that has culminated
in AISI Research Report RP15-2, Load Bearing
Clip Angle Design, that summarizes phase one
of a multi-year research study. The report sum-
marizes the structural behavior and preliminary
design provisions for CFS load bearing clip angles
and is based on testing that was carried out in
2014 and 2015 under the direction of Cheng Yu,
Ph.D. at the University of North Texas. Yu’s team
performed 33 tests for shear, 36 tests for compres-
sion, and 38 tests for pull-over due to tension.
Clip angles ranged in thickness from 33 mils (20
ga.) to 97 mils (12 ga.), with leg dimensions that
are common to the CFS framing industry. All of
the test set-ups were designed so that clip angle
failure would preclude fastener failure.

For shear, it was found that clips with smaller
aspect ratios (L/B<0.8) failed due to local buck-
ling, while clips with larger aspect ratios failed
due to lateral-torsional buckling. Shear test results
were compared to the AISC Design Manual for
coped beam flanges, but no correlation was
found. Instead, a solution based on the Direct
Strength Method (DSM) was employed that uti-
ized FEA to develop a buckling coefficient for the
standard critical elastic plate-buckling equation.
Simplified methods were also developed to limit
shear deformations to ¼ inch. For compression, it
was found that flexural buckling was the primary
failure mode. Test results were compared to the
b Gusset plate design provisions of AISI S214, North
American Standard for Cold-Formed Steel Framing
– Truss Design, and the axial compression member
design provisions and web crippling design provi-
sions of AISI S100, North American Specification for
the Design of Cold-Formed Steel Structural Members,
but no good agreement was found. Therefore, an
alternate solution was developed that utilized column
theory in conjunction with a Whitmore Section approach
that yielded good agreement with test results. It was further
found that using a buckling coefficient of 0.9 in the critical elastic buckling
stress equation will produce conservative results.

Finally, for pull-over due to tension, it was found
that clip angle specimens exhibited significant
deforations before pulling over the fastener heads
(essentially the clip turns into a strap before pull-
over occurs). However, regardless of this behavior,
tested pull-over strength results were essentially
half of AISI S100 pull-over equation E4.4.2-1.

Thanks to AISI Research Report RP15-2, there is a clearer understanding of the CFS clip angle
structural behavior mysteries that have puzzled
engineers for many years. However, just as the
CIA’s Kryptos remains only partially solved, some
aspects of clip angle behavior remain a mystery.
For instance, how are the test results influenced
by the fastener pattern? All of the test data to date
has used a single line of symmetrically placed
screws. This is something that does not occur for
many practical CFS framing situations and will
need additional research. Another glaring research
hole is the load versus deflection behavior of clip
angles under tension. As briefly mentioned above,
the existing pull-over testing has demonstrated
that excessive deflections can be expected before
pull-over actually occurs. Obviously, most prac-
tical situations will dictate a deflection limit of
something like ½ inch or ¼ inch, but today we
don’t have the test data to develop a solution.
Fortunately, AISI in conjunction with its CFS
industry partners continues to fund research on
CFS clip angle behavior that will answer these
questions, and possibly many more.

Decrypted Cold-Formed
Steel Connection Design

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