Structural requirements and test procedures for TG20 compliant prefabricated structural transom units

CADS

Revision History

Date	Version	Description	Author
19/11/2013	0.1	First draft	RCH
06/03/2014	1.0	Issued to NASC	CADS
18/12/2015	2.0	Extensively revised in light of pilot implementation	CADS
01/07/2016	3.0	Renamed and revised in light of further feedback.	CADS
26/07/2016	4.0	Published by NASC.	CADS

Contents

1 Introduction

Prefabricated transom units consist of scaffold tubes with couplers permanently attached at both ends by welding in the manufacturer's fabrication shop. They are available in a limited range of fixed lengths to accommodate the required number of scaffold boards and toe boards between the standards. There are two main types:

- Intermediate board transoms usually fitted with telescopic extension pieces to optionally support boards placed between the inner standards and the building façade. This type are sometimes directly substituted for the traditional board transoms which are usually attached to the ledgers with putlog couplers. They are not credited with special structural properties and therefore are not considered further in this document.

- Structural transom units fitted with special couplers so as to connect in-line directly to the supporting standards and also to support the inner and outer ledgers at right angles to the transom. These structural transoms are the subject of this document.

The main advantages of prefabricated structural transom units (PSTs) may be listed as follows:

- The fixed length and semi-rigid end connections facilitate efficient setting out and self alignment thereby saving labour.

- A reduced number of site fixings saves labour

- The partially fixed connections to the standards permit ledger bracing to be omitted from scaffolds in certain conditions thereby allowing unobstructed walk-through access on all lifts.

The principal feature of prefabricated structural transom units is the integral couplers attached to both ends. These couplers are fundamentally different from other scaffold couplers used in tube-and-fitting scaffolds because they join three tubes rather than two. Also the connection between the transom and the standard is concentric rather than offset. These differences mean that the structural properties of connectivity, strength and stiffness need to be established and taken into account in structural design or at least in the structural analysis behind any `standard' or `compliant' designs for scaffolds utilising prefabricated structural transom units. The current BS and EN product and testing standards for scaffold couplers[1, 2, 3.] do not cover prefabricated transom unit couplers so the NASC has developed this product and testing standard as far as possible consistently with the relevant existing standards. The objective is to ensure that PST products used by the industry have coupler strengths and stiffnesses which are sufficient to justify the structural calculations on which the TG20:13 eGuide is based.

2 Product outline specification

TG20 compliant prefabricated structural transom units (PSTs) consist of 48.3 mm outside diameter scaffold tubes with special couplers welded to both ends so as to permit on-site concentric connection to a pair of standards and also connection of the inner and outer ledgers of the scaffold. Fig 1 illustrates a typical proprietary product but other details may be acceptable provided that they satisfy the structural requirements of this specification.

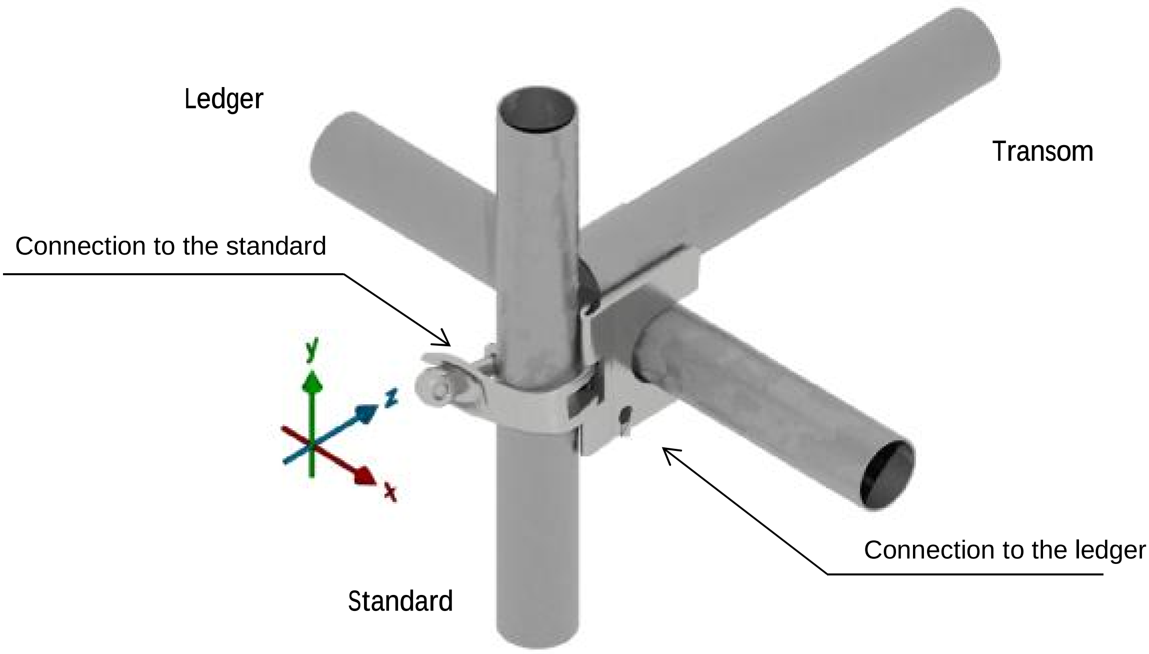


Fig 1 Typical prefabricated structural transom connection showing xyz axes

The assembly of tube and couplers shall be supplied hot-dipped galvanised after fabrication or electro-plated so as to provide the same standard of durability.

2.1 Tube specification

The transom tube shall be a 48.3 mm outer diameter circular hollow section supplied in accordance with one of the following standards:

- Type 4 scaffold tube to BS EN 39:2001
- 48.3 x 3.2 mm CHS grade S355 hot finished steel to BS EN 10210-1
- 48.3 x 3.2 mm CHS grade S355 cold formed steel to BS EN 10219-1

2.2 Coupler specification

The transom couplers shall be fabricated from pressed or drop forged steel and designed by the manufacturer to provide the functionality and durability necessary for safe and efficient site assembly, service, dismantling and re-use. The relevant requirements of BS EN 74-1 shall be satisfied except where varied by this specification.

All bolts/screws shall be maintained free running before erection and then tightened to a torque of 50 Nm unless specified otherwise by the manufacturer. Transoms with couplers fixed by driving wedges shall be tightened by means of impacting the wedge with a 500g hammer until the jarring blow unless specified otherwise by the manufacturer.

The transom couplers shall be designed and consistently fabricated by the manufacturer so as to achieve the structural properties when tested as given in table 1. Welds should be dimensioned, prepared and executed so as to ensure ductile behaviour under loads causing bending and twisting of the coupler. This means that failure in rotation tests should be by excessive distortion of the clamping components rather than fracture of the weld or of the steel adjacent to the welds.

Structural property	Symbol	Min. value	Units
1: Characteristic slip resistance down the standard (when loaded via the ledger)	F_{sy}	10.00	kN
2: Characteristic slip resistance along the ledger	F_{sx}	1.85	kN
3: Transom to standard – rotation about the ledger axis 3a: - characteristic resistance moment	M_{ksx}	1.75	kNm
3b: - rotational stiffness up to moment = 1.06 kNm	$C_{\varphi sx1}$	45.00	kNm/rad
4: Transom to standard – rotation about transom axis 4a: - characteristic resistance moment	M_{ksz}	1.65	kNm
4b: - rotational stiffness up to moment = 1.00 kNm	$C_{\varphi sz1}$	24.00	kNm/rad
5: Transom to ledger - rotation about the standard axis 5a: - characteristic resistance moment	M_{kly}	0.70	kNm
5b: - rotational stiffness up to moment = 0.42 kNm	$C_{\varphi ly1}$	7.50	kNm/rad

Table 1: Required structural properties for TG20 compliant structural transom couplers

Note: The resistance forces and moments in table 1 are `characteristic' or `5% quantile' values. They are not design values. The stiffnesses are minimum average values for each group of at least 5 tests. Design values based on table 1 are given in table 5.15 of the *TG20:13 Design Guide* as amended 2016.[4]

The test procedures for determining the actual properties of individual specimens of the couplers of a candidate prefabricated structural transom unit product are described in section 3 of this document. The statistical process applied to each group of test results is described in section 4.

3 Test procedures

Specimens for testing shall be unused and randomly selected from a batch of at least 500 samples.

Tests to determine the structural properties of the couplers of prefabricated structural transom units shall be conducted and the results analysed statistically generally in accordance with BS EN 12811-3:2002[2] except where varied by this specification. Section 5 lists the clauses in BS EN 12811-3 which do not apply and those requiring numerical values or options to be selected. Section 4 lists the steps in the revised analysis procedure.

The manufacturer shall declare the guaranteed minimum ultimate tensile strength of the coupler clamping components so that the effect of variations in the material strength of samples may be assessed. The manufacturer is advised to ascertain the actual grade of steel supplied (typically ASTM 450) and not simply rely on specifying the minimum grade for scaffold tube (eg S235) because this may unduly penalise the processed test results for the rotation tests.

Coupler bolts or screws (where used) shall be checked to be free running and tightened to 50 Nm torque or to the manufacturers requirement using a calibrated wrench. Care must be taken to exclude lubricant and other contaminants from the grip surfaces of the connection, especially when it is necessary to lubricate the threads to ensure free running. The design of couplers shall be such that after tightening onto any steel or aluminium tube, there shall be significant effective travel on the nut or wedge. Experience shows that 2 mm of thread or wedge remaining and a minimum gap of 2 mm between the closing flap and the body are suitable limits.

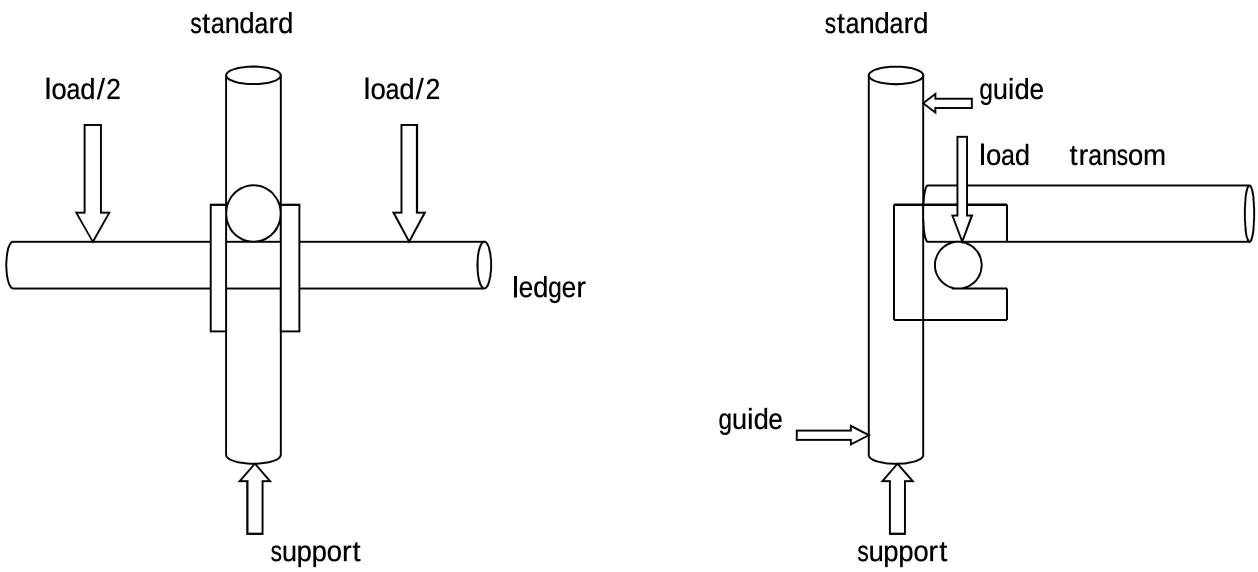
Transoms with couplers fixed by driving wedges shall be tightened by means of impacting the wedge by hand with a 500g hammer until the `jarring blow' unless specified otherwise by the manufacturer. Wedge couplers shall be tested for vibration resistance in accordance with BS EN 12811-3 section 7.4 in addition to the following.

3.1 Characteristic slip resistance down the standard F_{sy}

This test is designed to determine the resistance to slip down the standard [F_{sy} kN] which may govern the maximum safe load on the working platform.

The test arrangement shall be in accordance with the first paragraph of section 7.2.1.2 and fig 5 of BS EN 74-1:2005. The test loads shall be applied to the transverse tube which is the ledger. A short stub length of transom tube shall be tightly fixed in position but not loaded or restrained. At least 5 samples shall be tested. The test procedure shall be carried out in accordance with section 7.2.1.4 of BS EN 74-1. The test results shall be evaluated statistically in accordance with section 7.2.1.5 to determine the 5% quantile or characteristic slip resistance which shall be not less than 10 kN for compliance.

It is not necessary to test for loading in the inverse direction (up the standard).



Elevation in Z direction

Elevation in X direction

Fig 3.1 Diagram of load test type 1

3.2 Characteristic slip resistance along the ledger F_{SX}

This test is designed to determine the resistance to slip along the ledger [F_{sx} kN] which may be critical in cases of high wind forces acting parallel to the scaffold ledgers. In this test the transom and standard members are supported so as to lie in the horizontal plane and a load is applied along the ledger so as to push it through the connection as shown in fig 3.2. The loading should be continued beyond the first maximum for at least 5 mm displacement.

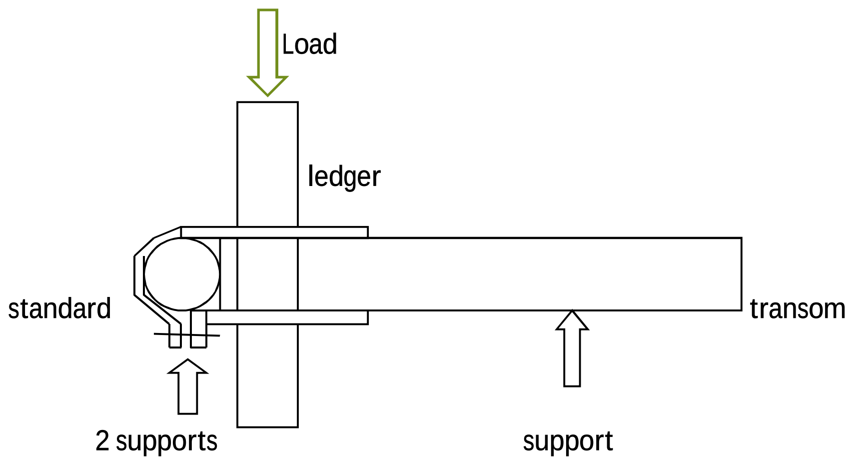


Fig 3.2 Diagram of load test type 2 (elevation in Y direction)

At least 5 samples shall be tested. The test procedure shall otherwise be carried out in accordance with section 7.2.1.4 of BS EN 74-1 except that measurements of movement Δ_1 are not relevant. The test results shall be evaluated statistically in accordance with section 7.2.1.5 to determine the 5% quantile or characteristic slip resistance which shall be not less than 1.85 kN for compliance.

3.3 Transom to standard rotation about the ledger axis

Load test type 3 is designed to determine the characteristic flexural resistance moment of the transom to standard connection in the vertical YZ plane [M_{ksx} in kNm] and the average rotational stiffness [$C_{\varphi sx1}$ in kNm/radian] up to the intended safe moment [$M_{serv,sx}$ = 1.06 kNm].

This test is carried out on samples of PSTs which have been cut in half and connected to a scaffold tube representing a scaffold standard with a short length of scaffold tube representing a scaffold ledger in place but not loaded.

The standard member is set vertical and clamped in position approximately 200 mm above and below the coupler. The short stub ledger is fixed tightly in position but not loaded or restrained. Vertical load is applied to the transom at approximately 400 to 600 mm from the standard axis. These dimensions may be varied within reason to suit the test rig and the available load cell. The moment of the load shall be calculated at the axis of the standard and the coupler rotation calculated from the deflection at the end of the coupler weld furthest from the standard and the distance from that point to the axis of the standard.

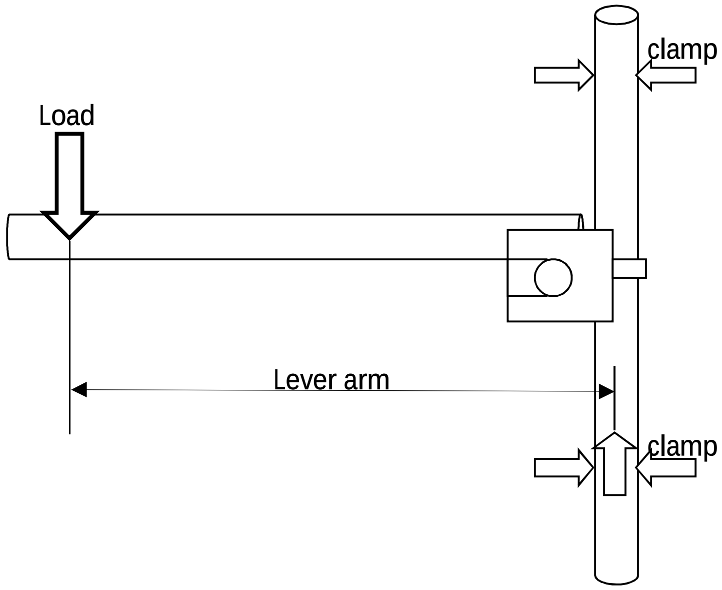


Fig.3.3 Diagram of load test type 3 (X elevation)

At least 5 tests should be carried out with the ultimate load acting downward on the transom in its normal orientation as shown in fig 3.3. It is not necessary to carry out ultimate load tests in the reverse direction because the connection is stronger in reverse and unlikely to be fully loaded in in that direction. The moment-rotation readings shall be plotted and results processed statistically in accordance with section 4 of this specification.

In each test the load should be cycled to +/- the intended safe moment [1.06 kNm] three times followed by downward loading to failure. The failure moment is defined as the first maximum value of the moment-rotation curve or the value of moment for which the energy quotient q_e = 11, whichever occurs first. Note that it is necessary to continue loading well past the maximum value into the descending part of the loading curve to ensure that the maximum has in fact been achieved and for correct evaluation of the energy quotient.

For each test the mode of failure shall be described in the test report together with a photograph.

3.4 Transom to standard rotation about the transom axis

Load test type 4 is designed to determine the characteristic torsional resistance moment of the transom to standard connection in the vertical XY plane [$M_{ksz,nom}$ in kNm] and the average rotational stiffness [$C_{\varphi sz1}$ in kNm/radian] up to the intended safe moment [$M_{serv,sz}$ = 1.00 kNm].

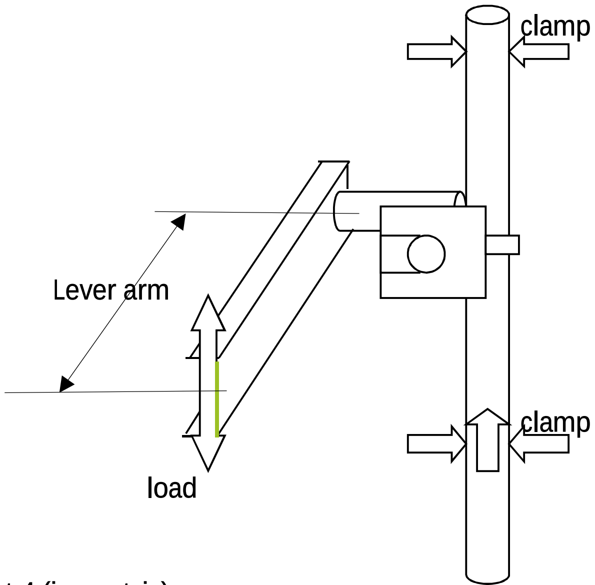


Fig 3.4 Diagram of load test 4 (isometric)

In this test the standard member is vertical and clamped in position approximately 200 mm above and below the coupler. A stub ledger is fixed tightly in position but not loaded or restrained. The transom `stub’ is cut about 50 mm from the coupler and a stiff loading member is welded to its end to extend 500 mm horizontally at right angles. Vertical load is applied to the loading member at approximately 400 mm from the transom axis so as to produce torsion in the coupler. The torsion moment is calculated at the common axis of the standard, transom and coupler and the coupler rotation is calculated from the deflections of a gauge length fixed at right angles to the transom at the end of the coupler weld furthest from the standard or by any acceptable alternative.

At least 5 tests should be carried out with the ultimate load acting downward on the loading rig with the transom in its normal orientation and at least 5 tests in the opposite sense because of the non-symmetry of the coupler in this mode. The moment-rotation readings shall be plotted and the results processed statistically separately for upward and downward loading in accordance with section 4. The lesser of the results for upward and downward loading shall be adopted as final.

In each test the load should be cycled to +/- the intended safe moment [1.00 kNm] three times followed by loading to failure. The failure moment is defined as the first maximum value of the moment-rotation curve or the value of moment for which the energy quotient q_e = 11, whichever occurs first. Note that it is necessary to continue loading well past the maximum value into the descending part of the loading curve to ensure that the maximum has in fact been achieved and for correct evaluation of the energy quotient.

For each test the mode of failure shall be described in the test report together with a photograph.

3.5 Transom to ledger rotation about the standard axis

Load test type 5 is designed to determine the characteristic flexural resistance moment of the transom to ledger connection in the horizontal XZ plane [M_{kly} in kNm] and the average rotational stiffness [$C_{\varphi ly1}$ in kNm/radian] up to the intended safe moment [$M_{serv,ly}$ = 0.42 kNm].

This test is carried out on samples of PSTs which have been cut in half and connected to a scaffold tube representing a scaffold ledger with a short length of scaffold tube representing a scaffold standard in place.

The ledger member is set vertical and clamped in position approximately 200 mm above and below the coupler. The short stub standard is fixed tightly in position but not loaded or restrained. Vertical load is applied to the transom at approximately 400 to 600 mm from the ledger axis. These dimensions may be varied within reason to suit the test rig and the available load cell. The moment of the load shall be calculated at the axis of the ledger and the coupler rotation shall be calculated from the deflection at the end of the coupler weld furthest from the standard and the distance from that point to the axis of the ledger.

If the connection is unsymmetrical in this loading condition, at least 5 tests should be carried out with the load acting downward on the transom and at least 5 tests in the opposite sense. The moment-rotation readings shall be plotted and results processed statistically separately for upward and downward loading in accordance with section 4. The lesser of the results for upward and downward loading (if applicable) shall be adopted as final.

In this test there may be a tendency for the coupler to slip up or down the ledger before the ultimate torsion moment is achieved. This can be avoided by fixing a light collar round the ledger to provide the necessary restraint without affecting the moment resistance of the coupler itself. A pilot test is advisable to trouble-shoot any problems.

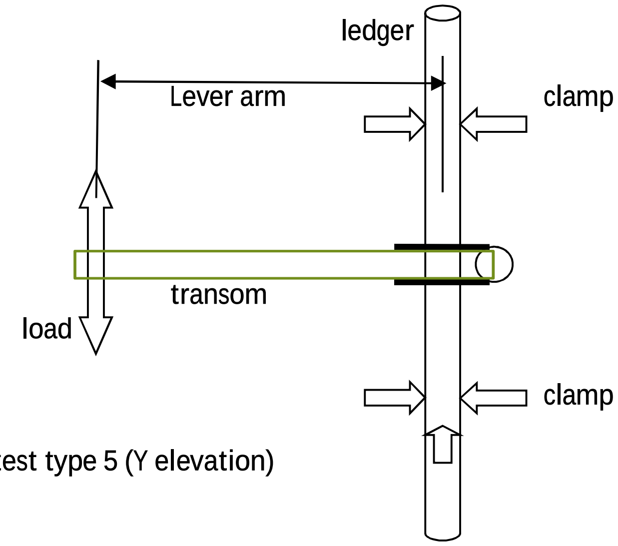


Fig 3.5 Diagram of load test type 5 (Y elevation)

In each test the load should be cycled to +/- the intended safe moment [0.42 kNm] three times followed by loading to failure. The failure moment is defined as the first maximum value of the moment-rotation curve or the value of moment for which the energy quotient q_e = 11, whichever occurs first. Note that it is necessary to continue loading well past the maximum value into the descending part of the loading curve to ensure that the maximum has in fact been achieved and for correct evaluation of the energy quotient. For each test the mode of failure shall be described in the test report together with a photograph.

4 Procedure for calculating results of rotation tests

This is an abbreviated summary of the procedure in BS EN 12811-3 section 10 to which reference should be made in case of doubt. However the sequence has been changed slightly to be more logical and consistent with that adopted for the first product test made for TG20:13[5]. In each test the load should be cycled to +/- the intended safe working moment M_{serv} three times followed by loading to failure. It is not necessary to replicate M_{serv} exactly as long as the corresponding actual values are recorded and used in the calculations.

4.1 Average serviceability stiffness

The stiffness up to the intended safe moment shall be calculated for each test generally in accordance with BS EN 74-1 clause 7.4.1.4.1 interpreted here as:

K_{serv} = Abs{ [$+M_{serv}$ – ($-M_{serv}$)]/[θ_{+Mserv} – (- Θ_{-Mserv})]}

where:

$+M_{serv}$ = Value of the actual recorded positive moment at the end of the third cycle approximating to the intended safe moment.

$-M_{serv}$ = Value of the actual recorded negative moment approximating to the intended safe moment in the third cycle.

θ_{+Mserv} = Value of recorded rotation at $+M_{serv}$

Θ_{-Mserv}) = Value of recorded rotation at $-M_{serv}$

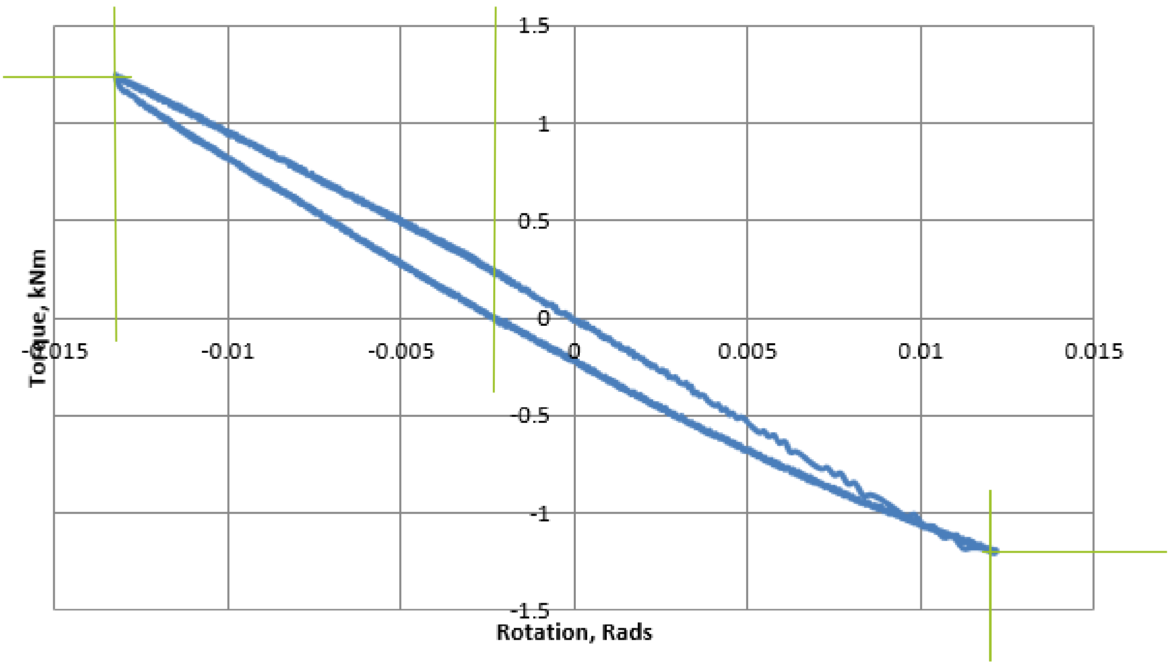


Fig 4.1 Typical moment/rotation graph for third cycle loading

Note:

The above stiffness calculation includes for any looseness present in the third cycle.

The typical moment/rotation graph shows the +/- M_{serv} values and corresponding rotations together with the unloading rotation (see 4.2 below) as indicated by the green lines.

The average stiffness for each test type is taken as the mean value of the stiffnesses of all the tests in the group.

4.2 Unloading stiffness

The unloading stiffness K_u is determined for each test from the third cycle moment/rotation graph:-

K_u = $\text{Abs}\{M_{serv}/(\Theta_{+Mserv} - \theta_u)\}$

where:

M_{serv} is the maximum moment in the cycle approximating to the required safe moment

Θ_{Mserv} is the rotation at M_{serv} as recorded by the instrumentation

θ_u is the residual rotation after unloading as recorded by the instrumentation

The unloading stiffness is required for the calculation of the energy quotient for the assessment of the nominal/adjusted failure moment.

4.3 Ultimate failure moment and reduced moment

The failure moment M_u is defined as the first maximum value of the moment-rotation curve or the value of moment for which the energy quotient q_e = 11, whichever occurs first.

The moment/rotation curve to failure for each test shall be recorded and the following quantities obtained or calculated for each test and tabulated:

M_u The failure moment in kNm

E_{lo} Energy dissipated by loading measured by the area under the loading curve up to failure. Software may be used to fit a polynomial curve to the ultimate loading graph and to calculate the area under the curve. Alternatively it is sufficiently accurate to calculate by manual approximation dividing the area into trapeziums and triangles.

E_{lu} = $0.5*M_u^2/K_u$
= Energy dissipated by unloading measured by the area under the unloading curve up to failure.

q_e Energy quotient (a measure of the ductility of the connection) calculated as $q_e = E_{lo} / E_{lu}$. If $q_e > 11$, in principle it may be necessary to estimate a reduced value of M_u corresponding to $q_e = 11$. Experience indicates that this is unlikely. The correction for ductility is here made to each test result in the same way as the correction for component strength instead of applying an average value at the end of the calculation.

Υ_{R2} Partial safety factor for limited ductility calculated as $\Upsilon_{R2} = 1.275 - 0.025q_e$ but not < 1.0 and not > 1.25

ξ_a Ratio of the guaranteed material strength to the actual material strength of the failure component as measured by coupon test or estimated by Brinnell hardness test but not greater than 1.0

$M_{u,red}$ Reduced/adjusted failure moment calculated as $M_{u,red} = M_u . \xi_a / \Upsilon_{R2}$

4.4 Characteristic resistance moment

For each result in the group calculate:

$y = \text{Log}_n (M_{u,red})$

For the set of results calculate:-

y_m Average of the values of y in the result set.

y_d Deviation of each value of y from the mean $y_d = y - y_m$

S_y Standard deviation of the values of y in the result set

$S_y = \text{Sqrt}\{\text{Sum of } y_d^2 \text{ values/(no of results -1)}\}$

$k_{s,k}$ 5% quantile (confidence) factor taken from table 4 in BS EN 12811-3.
For 5 results set, $k_{s,k} = 2.46$

y_5 the 5% quantile: $y_5 = y_m - k_{s,k}S_y$

$M_{k,nom}$ value of characteristic resistance moment $M_{k,b} = e^{y5}$

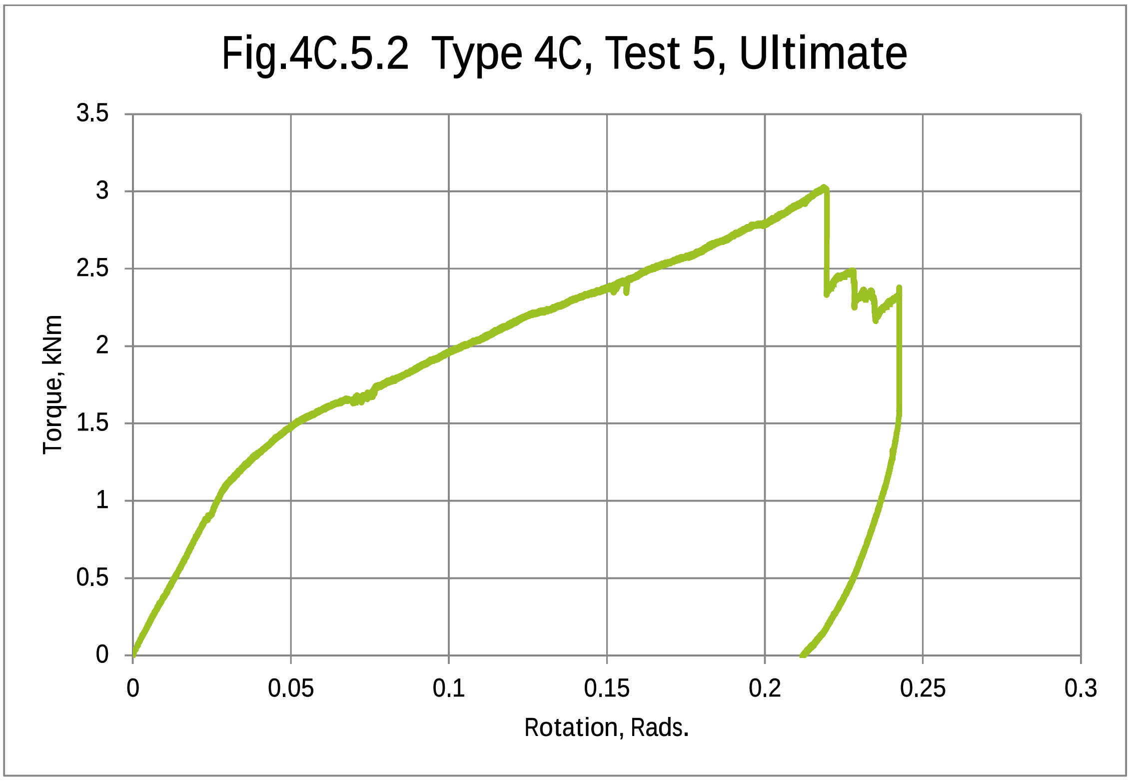


Fig 4.3a Typical moment / rotation graph showing well-defined maximum moment
(type 4 test)

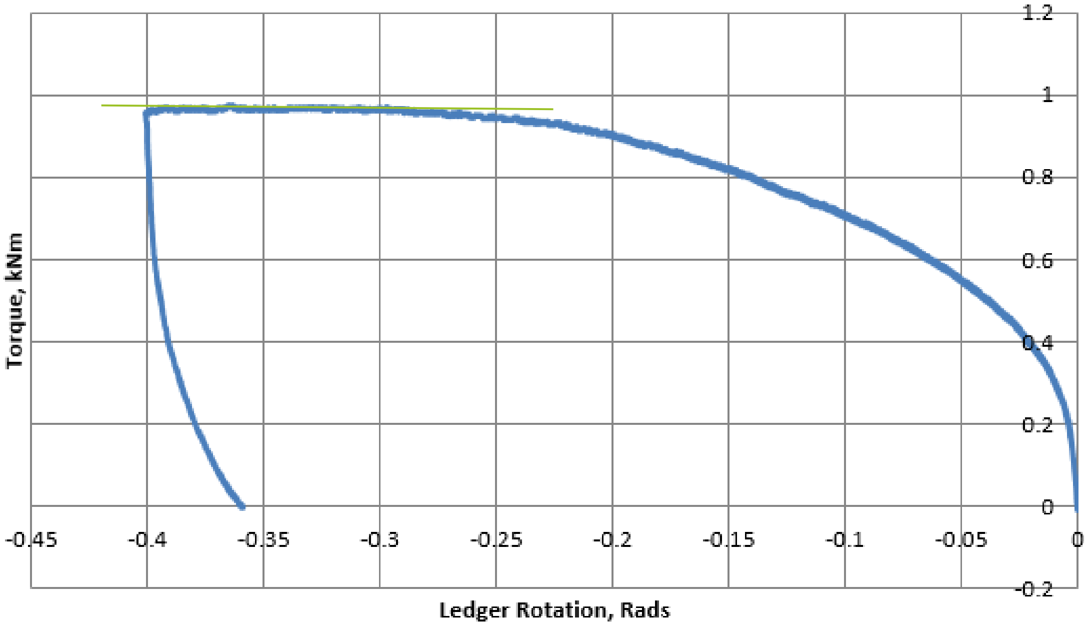


Fig 4.3b Typical moment/rotation graph showing sustained maximum moment plateau.
(type 5 test)

5 BS EN 12811-3 qualifications

Clause reference	Qualification
6.3.2	Not applicable
7.2.2.1	γ_m = 1.1 γ_f = 1.5
7.3	Not applicable
7.4	Applicable to wedge couplers only
7.5	Not applicable
8.0	Not applicable
10.1 Table 2:	
step 1.6	Not applicable
10.6	Not applicable
10.7	
equations 8, 10, 11	Not applicable
Table 3 item 1	Not applicable
Annex A	Optional. The quotient q_e for the dissipation of energy may also be determined by approximate graphical methods.

6 Optional proforma for processing results and summary

Analysis of tests on ……… …….. prefabricated structural transoms for compliance with NASC TG20:13

Issued: ………… By …………

Summary

Test type	Test type / structural property	Symbol	Units	Test value	Required min. value	Status
1	Characteristic resistance to slip down the standard when symmetrically loaded via the ledger	F_{sy}	kN	####	10.0	####
2	Characteristic resistance to slip along the ledger	F_{sx}	kN	#	1.85	#
3	Transom to standard connection – rotation about the ledger (X) axis					
	- characteristic resistance moment	M_{ksx}	kNm	#	1.75	#
	- mean stiffness up to moment M_{serv} = 1.06 kNm	$C_{\varphi sx1}$	kNm/rad	#	45.0	#
4	Transom to standard connection – rotation (twist) about the transom (Z) axis					
	- nominal characteristic resistance moment	M_{ksz}	kNm	#	1.65	#
	- mean stiffness up to moment M_{serv} = 1.00 kNm	$C_{\varphi sz1}$	kNm/rad	#	24.0	#
5	Transom to ledger connection – rotation about the standard (Y) axis					
	- nominal characteristic resistance moment	M_{kly}	kNm	#	0.70	#
	- mean stiffness up to moment M_{serv} = 0.42 kNm	$C_{\varphi ly1}$	kNm/rad	#	7.50	#

Test type 1 Characteristic slip resistance down the standard

Test no	F_{s2} (kN)	F_{s1} (kN)	F_s (kN)	$Y = \log_n F_s$	$Y_d = Y - Y_{mean}$	Y_d^2
1	######	####	####	####	######	######
2	#	#	#	#	#	#
3	#	#	#	#	#	#
4	#	#	#	#	#	#
5	#	#	#	#	#	#
			Y_{mean} =	#	$\sum Y_d^2$ =	#

From EN 12811-3 Annex B:

Standard deviation $S_y = \mathrm{Sqrt}\{\sum Y_d^2/(N-1)\}$ = #

Log_n of 5% quartile $Y_s = Y_{mean} - k_{sk} * S_y$ = ##### – 2.46*#.## = #####

Logarithmic transformation: e^{Ys} = ##.## kN

Characteristic slip force = ## kN > 10.0 kN required

Notes:

N is the number of test results in the sample

F_{s2} is the maximum value of slip force when the deformation between the coupler and the standard is between 1 and 2 mm

F_{s1} is the maximum value of slip force when the relative deformation of the ledger and standard is between 0 and 7 mm

F_s is the lesser of F_{s1} and F_{s2}.

Y is the natural logarithm of F_s

Y_{mean} is the mean of all the values of log_nF_s

Y_d is the deviation of each value of Y from Y_{mean}

Y_d^2 is the square of each deviation

K_{sk} is the quantile factor taken from EN 12811-3 table 4. For N = 5 results K_{sk} = 2.46

Test type 2 Characteristic slip resistance along the ledger

Test no	F_s (kN)	$Y = log_nF_s$	$Y_d = Y - Y_{mean}$	Y_d^2
1	#.#	#.####	#.####	#.#####
2	#	#	#	#
3	#	#	#	#
4	#	#	#	#
5	#	#	#	#
#	#	#	#	#
	Y_{mean} =	#	$\sum Y_d^2$ =	#

From EN 12811-3 Annex B:

Standard deviation $S_y = Sqrt\{\sum Y_d^2/(N-1)\}$ = #.####

Log_n of 5% quartile $Y_s = Y_{mean} - k_{sk}*S_y$ = #.#### – #*# = #

Logarithmic transformation: e^{Ys} = # kN

Characteristic slip force = #.## kN > 1.85 kN required

Notes as for type 1 tests except:

F_s = F_{s2} = is the maximum value of slip force when the deformation between the coupler and the ledger is between 1 and 2 mm

F_{s1} is not relevant to this test

K_{sk} is the quantile factor taken from EN 12811-3 table 4. For 5 results K_{sk} = 2.46

Test type 3 Transform to standard connection - rotation about the ledger (X) axis.

Test type 3 unloading stiffness taken from third cycle

Test no.	M_{serv} kNm	Θ_{+Mserv} radians	θ_u radians	$\Theta_{+Mserv} - \theta_U$ radians	Stiffness K_u KNm/rad
2	+#.###	-#.#####	-#.#####	#.#####	###.#
3	+#	-#	-#	#	#
4	+#	-#	-#	#	#
5	+#	-#	-#	#	#
6	+#	-#	-#	#	#
				$K_{u,mean}$ =	#

Notes:

M_{serv} is the maximum moment in the cycle approximating to the required serviceability moment (1.06 kNm)

Θ_{Mserv} is the rotation at M_{serv} as recorded by the instrumentation

θ_u is the residual rotation after unloading as recorded by the instrumentation

K_u is the deduced unloading stiffness = Abs{M_{serv}/(Θ_{+Mserv} - θ_u)}

Test type 3 serviceability loading stiffness taken from the third cycle

Test no.	$+M_{serv}$ kNm	$-M_{serv}$ kNm	Θ_{+Mserv} radians	Θ_{-Mserv} radians	Stiffness K_{serv} KNm/radian
2	+#.###	-#.###	-#.#####	+#.#####	##.#
3	+#	-#	-#	+#	#
4	+#	-#	-#	+#	#
5	+#	-#	-#	+#	#
6	+#	-#	-#	+#	#
				$K_{serv,mean}$ =	#

$K_{serv,mean}$ = # kNm/radian > 45.0 kNm/radian required.

Notes:

The loading stiffness is calculated in accordance with EN 74-1 section 7.4.1.4.1 and therefore includes `looseness'

K_{serv} = Abs{ [$+M_{serv}$ – ($-M_{serv}$)]/[θ_{+Mserv} – (- Θ_{-Mserv})]}

Test type 3 ultimate moments and reduction factors

Test No.	M_u kNm	E_{unload}	$E_{loading}$	q_e	γ_R	f_{ua} N/mm^2	f_{uk}/f_{ua}	$M_{k,nom}$ kNm	Y = Log_n M_{knom}	Y_d	Y_d^2
2	#.##	#.###	#.###	#.##	#.###	###	#.###	#.###	#.####	#.####	#.####
3	#	#	#	#	#	#	#	#	#	#	#
4	#	#	#	#	#	#	#	#	#	#	#
5	#	#	#	#	#	#	#	#	#	#	#
6	#	#	#	#	#	#	#	#	#	#	#
								Y_{mean} =	#	$\sum Y_d^2$ =	#

From EN 12811-3 Annex B:
Standard deviation S_y = Sqrt{$\sum Y_d^2/(N-1)$} = #.####
Log_n of 5% quartile Y_s = $Y_{mean} - k_{sk}*S_y$ = #.#### – 2.46*#### = #.###
Logarithmic transformation: e^{Ys} = #.### kNm
Characteristic resistance moment = #.## kNm > 1.75 kNm required
Notes:
M_u is the maximum moment recorded in the test
From EN 12811-3 section 10.5:-
E_{unload} is the energy of unloading = $0.5*M_u^2/K_u$
$E_{loading}$ is the energy of loading measured by the area under the loading curve up to the point of maximum moment. In this case it is estimated by dividing the curve into 3 or 4 line segments and calculating the areas of the trapeziums and triangle so formed.
q_e is the energy quotient = $E_{loading}/E_{unload}$
γ_R partial safety factor or reduction factor for non-ductile behaviour.
If q_e <= 1.00, γ_R = 1.25
Else if q_e >= 11, γ_R = 1.00
Else: γ_R = $1.275 - 0.025q_e$

From EN 12811-3 section 10.7:
f_{uk} is the minimum ultimate tensile strength required by the specification for the steel used to fabricate the pressing. In this case the steel specified is #### to ### for which f_{uk} = ### N/mm^2 and f_{yk} = ### N/mm^2 [edit to suit material specified]
f_{ua} is the ultimate tensile strength estimated by Brinell Hardness tests.
f_{uk}/f_{ua} = ξ_y per equation 12 is the reduction factor allowing for steel strength variation but not > 1.00
$M_{k,nom}$ = nominal value of ultimate moment after multiplying M_u by ξ_y and dividing by γ_R

From EN 12811-3 section 10.8 and Annex B:
Y is the natural logarithm of $M_{k,nom}$
Y_{mean} is the mean of all the values of $\log_n M_{k,nom}$
Y_d is the deviation of each value of Y from Y_{mean}
Y_d^2 is the square of each deviation
K_{sk} is the quantile factor taken from EN 12811-3 table 4. For 5 results K_{sk} = 2.46

Test type 4 Transom to standard connection – rotation (twist) about the transom (Z) axis

Test type 4 unloading stiffness taken from third cycle

	Test no.	M_{serv} kNm	Θ_{+Mserv} radians (average)	θ_u radians (average)	$\Theta_{+Mserv} - \theta_U$ radians	Stiffness K_u KNm/rad
Normal tests	##	+#.###	+#.####	+#.####	#.####	###.#
	#	+#	+#	+#	#	#
	#	+#	+#	+#	#	#
	#	+#	+#	+#	#	#
	#	+#	+#	+#	#	#
					$K_{u,mean}$ =	#
Inverted tests	#	+#.###	-#	-#	#.####	#
	#	+#	-#	-#	#	#
	#	+#	-#	-#	#	#
	#	+#	-#	-#	#	#
	#	+#	-#	-#	#	#
					$K_{u,mean}$ =	#

Notes:

M_{serv} is the maximum moment per coupler in the cycle approximating to the required serviceability moment (1.00 kNm)

Θ_{Mserv} is the rotation at M_{serv} as recorded by the instrumentation.

θ_u is the residual rotation after unloading as recorded by the instrumentation

K_u is the deduced unloading stiffness = $Abs\{M_{serv}/(\Theta_{+Mserv} - \theta_u)\}$

Test type 4 serviceability loading stiffness taken from the third cycle

	Test no.	$+M_{serv}$ kNm	$-M_{serv}$ kNm	Θ_{+Mserv} Radians	Θ_{-Mserv} Radians	Stiffness K_{serv} KNm/radian
Normal tests	#	+#.###	-#.###	+#.####	-#.####	##.#
	#	+#	-#	+#	-#	#
	#	+#	-#	+#	-#	#
	#	+#	-#	+#	-#	#
	#	+#	-#	+#	-#	#
					$K_{serv,mean}$ =	#
Inverted tests	#	+#	-#	-#.####	+#.####	##.#
	#	+#	-#	-#	+#	#
	#	+#	-#	-#	+#	#
	#	+#	-#	-#	+#	#
	#	+#	-#	-#	+#	#
					$K_{serv,mean}$ =	#

$K_{serv,mean}$ = ##.# kNm/radian > 24.0 kNm/radian required.

Notes:
The loading stiffness is calculated in accordance with EN 74-1 section 7.4.1.4.1 and therefore includes `looseness':
K_{serv} = Abs{ [+M_{serv} – (-M_{serv})]/[θ_{+Mserv} – (- Θ_{-Mserv})]}

Test type 4 ultimate moments and reduction factors – normal tests

Test No.	M_u kNm	E_{unload}	$E_{loading}$	q_e	γ_R	f_{ua} N/mm^2	f_{uk}/f_{ua}	$M_{k,nom}$ kNm	Y = Log_n M_{knom}	Y_d	Y_d^2
#	#.##	#.###	#.###	##.#	#.##	###	#.###	#.##	#.####	#.####	#.####
#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#
								Y_{mean} =	#.####	∑ Y_d^2 =	#.####

From EN 12811-3 Annex B:
Standard deviation S_y = Sqrt{∑ Y_d^2/(N-1)} = #.####
Log_n of 5% quartile Y_s = Y_{mean} – k_{sk}*S_y = #.#### – 2.46*#.#### = #.####
Logarithmic transformation: e^{Ys} = #.### kNm
Characteristic resistance moment = #.## kNm > 1.65 kNm required
Notes: as for test type 3

Test type 4 ultimate moments and reduction factors – inverted tests

Test No.	M_u kNm	E_{unload}	$E_{loading}$	q_e	γ_R	f_{ua} N/mm^2	f_{uk}/f_{ua}	$M_{k,nom}$ kNm	Y = Log_n M_{knom}	Y_d	Y_d^2
#	#.##	#.###	#.###	##.#	#.##	###	#.###	#.##	#.####	#.####	#.####
#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#
								Y_{mean} =	#.####	∑ Y_d^2 =	#.####

From EN 12811-3 Annex B:
Standard deviation S_y = Sqrt{∑ Y_d^2/(N-1)} = #.####
Log_n of 5% quartile Y_s = Y_{mean} – k_{sk}*S_y = #.#### – 2.46*#.#### = #.####
Logarithmic transformation: e^{Ys} = #.### kNm
Characteristic resistance moment = #.## kNm > 1.65 kNm required
Notes: as for test type 3

Test type 5 Transom to ledger connection - rotation about the standard (Y) axis

Test type 5 unloading stiffness taken from third cycle

Test no.	M_{serv} kNm	Θ_{+Mserv} radians	θ_u radians	$\Theta_{+Mserv} - \theta_U$ radians	Stiffness K_u KNm/rad
2	+#.###	-#.#####	-#.#####	#.#####	###.#
3	+#	-#	-#	#	#
4	+#	-#	-#	#	#
5	+#	-#	-#	#	#
6	+#	-#	-#	#	#
				$K_{u,mean}$ =	#

Notes:

M_{serv} is the maximum moment in the cycle approximating to the required serviceability moment (0.42 kNm)

Θ_{Mserv} is the rotation at M_{serv} as recorded by the instrumentation

θ_u is the residual rotation after unloading as recorded by the instrumentation

K_u is the deduced unloading stiffness = Abs{M_{serv}/(Θ_{+Mserv} - θ_u)}

Test type 5 serviceability loading stiffness taken from the third cycle

Test no.	$+M_{serv}$ kNm	$-M_{serv}$ kNm	Θ_{+Mserv} radians	Θ_{-Mserv} radians	Stiffness K_{serv} KNm/radian
2	+#.###	-#.###	-#.#####	+#.#####	##.#
3	+#	-#	-#	+#	#
4	+#	-#	-#	+#	#
5	+#	-#	-#	+#	#
6	+#	-#	-#	+#	#
				$K_{serv,mean}$ =	#

$K_{serv,mean}$ = ##.# kNm/radian > 7.5 kNm/radian required.

Notes:

The loading stiffness is calculated in accordance with EN 74-1 section 7.4.1.4.1 and therefore includes `looseness'

K_{serv} = Abs{ [$+M_{serv}$ – ($-M_{serv}$)]/[θ_{+Mserv} – (- Θ_{-Mserv})]}

Test type 5 ultimate moments and reduction factors

Test No.	M_u kNm	E_{unload}	$E_{loading}$	q_e	γ_R	f_{ua} N/mm^2	f_{uk}/f_{ua}	$M_{k,nom}$ kNm	Y = Log_n M_{knom}	Y_d	Y_d^2
2	#.##	#.###	#.####	#.##	#.###	###	#.###	#.###	#.####	#.####	#.####
3	#	#	#	#	#	#	#	#	#	#	#
4	#	#	#	#	#	#	#	#	#	#	#
5	#	#	#	#	#	#	#	#	#	#	#
6	#	#	#	#	#	#	#	#	#	#	#
								Y_{mean} =	#	$\sum Y_d^2$ =	#

From EN 12811-3 Annex B:

Standard deviation S_y = Sqrt{$\sum Y_d^2$/(N-1)} = #.####

Log_n of 5% quartile Y_s = $Y_{mean} - k_{sk} * S_y$ = #.#### – 2.46*#### = #.###

Logarithmic transformation: e^{Ys} = #.### kNm

Characteristic resistance moment = #.## kNm > 0.70 kNm required

Notes: As test type 3

END of calculations to process test results.

References

1. BS EN 74-1:2005 *Couplers, spigot and baseplates for use in falsework and scaffolds. Part 1: couplers for tubes- requirements and test procedures*

2. BS EN 12811-3:2002 *Temporary Works Equipment - Part 3: Load testing*

3. BS 1139-2.2:2009 *Metal Scaffolding. Couplers - Aluminium couplers and special couplers in steel. Requirements and test methods*

4. TG20 *DesignGuide* National Access and Scaffolding Confederation. 2013 revised 2016

5. Godley M H R. *Structural tests on Readylock transoms.* Oxford Brookes University report OBU 404 for the National Access & Scaffolding Confederation, February 2013