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structural load testing report

thermoseam

thermal break fixings
for standing seam roofing

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1 INTRODUCTION

1.01 Standing seam roofing provides an unparalleled degree of weather protection combined with puncture resistance, leading to a very high degree of confidence in the completed roof covering. The key to this reliability is the concealed fixing clip which is folded into the seam when the roof sheets are mechanically locked together. With increasing demands for the thermal performance of roofing systems, any fixing which is a potential thermal bridge is at a disadvantage. A fixing which is both thermally efficient and mechanically secure is therefore required.

1.02 Clearly the strength of any thermal break needs to be tested as materials with low thermal conductivity tend to have a lower tensile strength than the traditional steel fixings. The tensile capacity of the cleat assembly is therefore of great importance.

1.03 The testing programme was designed to determine the strength of the combination of plastic ferrule and metal cleat which is incorporated into the seam upstand.

1.04 The report and testing program were commissioned by Thames Valley Special Products Ltd (TVSP), who designed and constructed the test rig with advice from Allanconsult Ltd. The test regime was determined and supervised by Allanconsult Ltd.

2 Nature of Loading

2.01 ThermoSeam fixings are typically used on a 500mm wide trough at 400mm centres, giving a rate of 5 per square metre. Wind suction is the governing criterion and therefore direct tensile testing was clearly the required consideration.

2.02 Negative air pressure which stresses the fixings arises when airflow accelerates as it encounters an obstacle. As moving air needs to make room for the obstacle the only way it can do this is to either compress or to accelerate; in practice it does both; initially causing an overpressure immediately on the windward side of the obstacle, and thus causing a pressure gradient around the obstacle. This pressure gradient accelerates the airflow, relieving the pressure increase. Invariably the diversion of the airflow over the roof of a building leaves a pocket of reduced pressure above the roof. This reduced pressure or suction is the design criterion for sheet roof fixings.

2.03 The precise interaction between time, pressure, and air velocity is complex and depends on a large number of parameters. In order to facilitate design of practical projects a set of empirical rules and parametric formulae have been devised and codified for the use of Structural Engineers, in British and European standards. Design standards currently use the limit state philosophy and the testing in this report is intended to produce load capacities which can be used with such codes and standards.

2.04 This process isn't clear cut since there are a number of parameters which have to be properly understood for the correct interpretation and application of the results. It will be seen that neither the design load to be applied to the fastener nor the ultimate capacity (or load at the point of failure) can be precisely assessed, and also that the absence of precision is not an obstacle to the provision of practical working capacity values for design.

2.05 The load resistance required is also to be understood in the context of the behaviour of the clip assembly. Wind suction loading occurs as a transient load on a building element as a whole and derives from the pressure difference between one face of the element and the other. In the case of an insulated roof panel the pressure difference is broken down in steps, with each component being subjected to a partial pressure which is a proportion of the overall pressure difference.

2.06 Typically for an enclosed building the dynamic pressure (q) is obtained for the site location and building shape. This is then multiplied by internal and external coefficients to get the surface pressure relative to atmospheric pressure which results from a wind in a particular direction. For the roof structural elements the design case usually arises from considering a negative external pressure combined with a positive internal pressure, resulting in the maximum uplift load on the panel. The panel comprises a series of layers each of which is loaded by a partial pressure on each side. The algebraic sum of these pressures between the inner and outer surfaces is the total pressure difference acting on the panel as a whole.

2.07 To put this another way, there is a pressure gradient across the thickness of the panel and this is in the form of a series of discrete steps. Initially the interstitial pressure will be the ambient average normal air pressure. If there is an external pressure drop of 0.8q (a typical high value) and an internal pressure rise of 0.3q, this gives an overall pressure gradient of 1.2q. A first approximation for a typical standing seam roof would therefore be to take 0.8q as the maximum load effect on the fasteners. However a relatively small deflection in the roofing sheet pan in response to a sudden gust would be to cause a sharp drop in pressure within the air gap beneath the sheet.

2.08 The space below the sheeting is nominally ventilated at ridge and eaves. However within the timescale of a typical gust the pressure inside and outside this ventilated zone does not have time to equalise. The result is that the suction on the outer surface immediately produces a small upward deflection of the sheet between fixings, and this generates a balancing suction below the sheet. The short term suction of the wind is therefore passed directly to the substrate, with a neutral effect on the sheeting fasteners. To put this into context the deflection under maximum working load would be of the order of 5mm. A change in volume produced by less than a millimetre is sufficient to produce a balancing pressure reduction which would match the highest wind induced suction likely to be met in practice;

$$PV^{\gamma} = K$$

$$P_2 = \frac{P_1 V_1^{\gamma}}{V_2^{\gamma}}$$

Substituting 100kN/m² as an approximate value for atmospheric pressure (P_1), a conservative value of 1.25 for γ, and then V_1 = say 0.05m³ and V_2 = 0.051 (a 1mm upward movement), we get

$P_2 - P_1 = 2.5\,kN/m^2$ (approx.)

2.09 It follows from this that failure of fastenings could only occur at the edge of a roof. The local external pressure coefficient is also at a maximum in edge regions. Edge regions may be considered for the purposes of this report generally as 10% of the width of the building but for particular cases will need careful evaluation by a Structural Engineer, as the detailed code provisions are complex.

2.10 In limit state terms the load would be multiplied by a partial safety factor of 1.4, and the load capacity would be taken as 0.87 times the characteristic strength of the assembly. This analysis would result in an overall factor of safety in a typical installation of 2 against failure.

2.11 The strength of the fastener here is defined as the limit of proportinalaity of the assembly (fastener and clip). However the *ultimate* load at failure (the maximum load that is needed to separate the sheeting from the substrate) is at least 70% higher. Twenty five cyclic tests were carried out in which the sample assemblies were loaded to 150% of the limit of proportionality and no loss of breaking failure capacity was found after five overload cycles.

2.12 The assessment of the design wind suction must be undertaken by suitably experienced and qualified Structural Engineer, because individual building requirements and wind effects are highly variable.

3 TEST SPECIMENS AND TESTING RIG

3.01 Samples were made comprising a Thermoseam ferrule and metal clip. The ferrule was screwed into a block of timber through a block of PIR insulation board, simulating an actual installation. The ferrule head was engaged into the anchor plate of the fixing clip, which was folded around a steel door hinge to simulate the clamping effect of the welted standing seam.

3.02 In this manner the test measures the resistance of the entire fixing system and not just the Thermoseal component.

3.03 The frame was arranged such that a progressive strain could be applied by a screw jack at one end. Elongation was measured by a Demec dial gauge with a resolution of0.02mm, and the load was recorded by a digital load cell (Mecmesin BFG2500N, calibrated by the manufacturer before testing). The load and strain were simultaneously recorded on video and this was interrogated afterwards. This technique allowed the test to be run as a smooth continuous load application at slow speed without pausing for measurements. Pausing the replay at intervals allowed the recording of stress and strain measurements which were precisely simultaneous.

3.04 The test frame comprised a channel section of folded aluminium plate, which both housed the test specimens and provided a guide, and also transmitted the compressive reaction balancing the tensile force imposed on the test specimen.

4 TEST RESULTS AND CONCLUSIONS

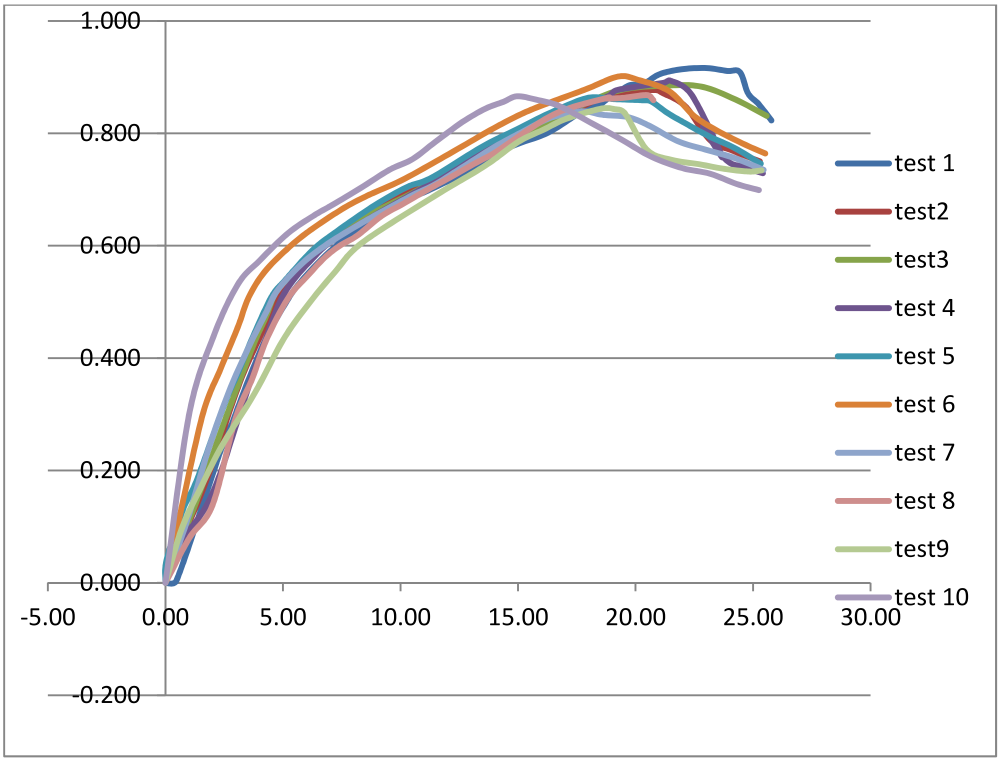
4.01 In all tests carried out the first serviceability limit was reached when the metal cleat started to buckle locally at the slot provided for thermal movement. Ultimate failure also occurred first in the metal cleat. It was found that at cleat failure there was permanent deformation in the plastic flange of the Thermoseam coupler, but the coupler remained firmly attached to the cleat.

4.02

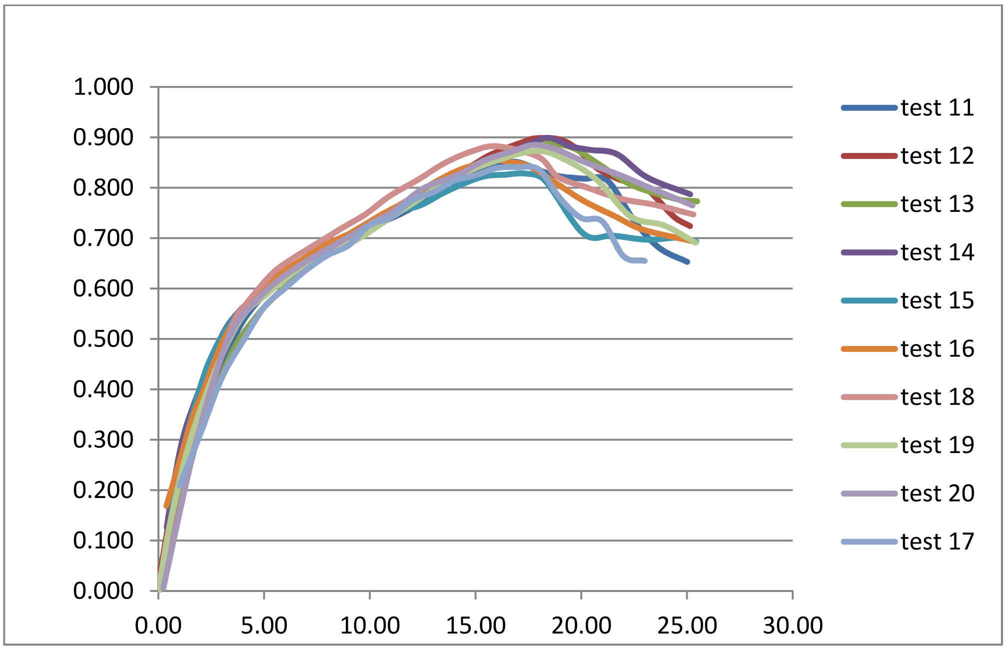
The photograph above shows a cleat on the point of failure, whilst the isolating ferrule is successfully resisting being pulled through the screw hole.

4.03 A sample set of results is appended to this report. Typical load/extension curves are illustrated below.

4.04



4.05



4.06 First yield of the cleat begins at a characteristic load of 0.52kN. The characteristic ultimate tensile capacity of the combined assembly is 0.82kN. The design characteristic strength of the cleat has been assessed conservatively, in view of these results, as 0.452kN which is the characteristic strength divided by the appropriate partial factor of safety, 4.07 The design value for use with ultimate (factored) wind loads is **450N**, the strength of the assembly in all cases being limited by the cleat. Hysteresis tests found that samples tested to the 520N threshold returned to their original length when unloaded and showed no loss of strength or stiffness on re-loading.

4.08 The metal cleat has been in use for many years and no failures have been reported.

5 DESIGN FOR USE IN BUILDINGS IN UK AND EIRE

5.01 The governing criterion is the local suction at edges of a roof. This should always be assessed by a qualified and experienced Structural Engineer. The following general guide gives an indication of typical results for differing degrees of wind exposure. It is necessarily general and will prove conservative in many instances.

5.02

England, Wales & Southern Ireland	Exposure and / or height	General spacing	Spacing 1st 1.5m or 10% of roof slope length, whichever is greater, with seam spacing of 500m;
	Suburban / urban up to 10m high	5/m²	400mm
	Fairly open country and or up to 15m high	5/m²	225mm
	Open country, no obstructions, 30m high	5/m²	200mm
Northern Ireland and lowland Scotland inc Edinburgh	Suburban / urban up to 10m high	5/m²	350mm
	Fairly open country and or up to 15m high	5/m²	200mm
	Open country, no obstructions, 30m high	5/m²	175mm

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test 1		test 2		test 3		test 4		test 5		test 6		test 7		test 8		test 9		test 10	
mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
0.47	0.004	0.11	0.046	0.23	0.041	0.55	0.065	0.05	0.041	1.55	0.294	0.94	0.113	1.02	0.080	0.70	0.097	1.00	0.298
2.37	0.238	1.06	0.113	0.89	0.100	1.67	0.132	0.76	0.132	2.33	0.379	1.81	0.235	2.00	0.138	1.51	0.170	2.04	0.438
2.79	0.279	1.97	0.208	1.54	0.170	2.33	0.194	1.33	0.182	3.07	0.454	2.67	0.337	2.97	0.291	2.46	0.248	3.08	0.531
3.53	0.361	2.66	0.297	2.18	0.248	2.93	0.271	2.49	0.316	3.54	0.508	3.57	0.422	3.69	0.363	3.79	0.337	4.02	0.574
4.27	0.434	3.35	0.376	2.83	0.323	3.69	0.368	3.12	0.377	4.21	0.553	4.27	0.480	4.30	0.433	5.03	0.434	5.21	0.622
5.06	0.494	4.17	0.451	3.75	0.424	4.06	0.409	3.66	0.432	5.15	0.593	4.76	0.520	5.21	0.506	6.16	0.500	6.29	0.653
5.70	0.533	4.85	0.514	4.28	0.474	5.03	0.513	4.50	0.508	6.08	0.625	5.73	0.565	6.06	0.547	7.21	0.553	7.12	0.673
7.00	0.590	5.68	0.563	4.71	0.518	6.35	0.581	5.08	0.538	7.51	0.665	6.75	0.599	6.78	0.579	8.36	0.605	8.28	0.702
8.49	0.639	7.74	0.632	5.39	0.549	7.23	0.612	6.26	0.592	8.59	0.689	8.25	0.638	7.42	0.600	11.40	0.687	9.53	0.735
10.06	0.677	10.20	0.694	6.59	0.600	8.98	0.656	7.27	0.625	10.03	0.716	10.28	0.685	8.16	0.618	13.59	0.742	10.51	0.754
11.47	0.704	12.66	0.740	7.49	0.624	11.04	0.705	8.87	0.671	11.34	0.746	11.42	0.708	9.20	0.653	15.02	0.785	11.49	0.785
13.54	0.747	14.56	0.777	9.08	0.664	12.66	0.747	10.26	0.704	12.80	0.781	12.50	0.736	10.13	0.675	16.06	0.806	12.63	0.820
14.75	0.777	15.81	0.805	10.87	0.702	14.48	0.788	11.32	0.721	14.14	0.813	14.01	0.776	11.04	0.697	17.06	0.826	13.62	0.844
16.22	0.800	17.31	0.839	12.95	0.758	15.45	0.810	13.51	0.777	15.56	0.842	15.16	0.802	12.09	0.721	18.55	0.844	14.38	0.856
17.38	0.830	18.68	0.865	14.95	0.788	16.70	0.837	14.95	0.807	17.86	0.878	16.28	0.826	13.10	0.745	19.11	0.843	14.96	0.866
17.97	0.846	19.76	0.874	16.46	0.825	18.78	0.865	16.34	0.836	19.26	0.901	17.22	0.836	13.91	0.763	19.54	0.836	15.76	0.860
18.35	0.848	20.84	0.877	17.66	0.849	19.22	0.877	17.86	0.862	20.12	0.895	17.88	0.839	14.66	0.784	20.48	0.771	16.73	0.849
18.55	0.853	21.14	0.872	19.36	0.877	21.20	0.890	18.68	0.863	21.43	0.875	18.59	0.833	15.43	0.806	21.51	0.753	18.05	0.820
19.33	0.878	22.12	0.848	21.30	0.885	21.46	0.894	19.02	0.861	22.46	0.832	19.66	0.829	16.40	0.831	22.71	0.745	19.44	0.788
19.41	0.878	23.17	0.788	22.81	0.883	22.38	0.869	20.23	0.859	23.42	0.806	20.56	0.814	17.35	0.847	23.73	0.737	20.69	0.758
19.79	0.886	24.14	0.769	24.26	0.860	23.69	0.758	20.65	0.857	24.55	0.782	21.80	0.786	18.88	0.864	24.83	0.732	22.00	0.738
20.30	0.887	25.29	0.750	25.58	0.831	22.87	0.812	21.37	0.836	25.52	0.764	22.98	0.771	18.75	0.862	25.36	0.734	23.18	0.728
20.91	0.903					23.82	0.754	22.07	0.819			24.21	0.756	19.45	0.863			24.29	0.710
21.42	0.910					24.57	0.740	23.16	0.794			25.45	0.735	20.49	0.868			25.25	0.699
22.17	0.915					25.42	0.729	24.21	0.774					20.76	0.859				
23.05	0.916							25.33	0.746										
23.91	0.911																		
24.44	0.909																		
24.79	0.871																		
25.24	0.852																		
25.78	0.823																		

test 11		test 12		test 13		test 14		test 15		test 16		test 17		test 18		test 19		test 20	
mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN
0.00	0.000	0.01	0.021	0.46	0.056	0.39	0.126	0.26	0.035	0.38	0.169	0.25	0.020	0.00	0.000	0.00	0.000	0.23	0.006
1.19	0.224	1.14	0.277	1.21	0.217	0.70	0.207	1.00	0.247	0.98	0.254	-1.00	0.209	0.89	0.197	0.61	0.147	1.52	0.251
2.06	0.339	2.24	0.410	2.38	0.360	1.18	0.307	1.98	0.405	1.56	0.338	-1.00	0.314	1.58	0.287	1.57	0.308	2.77	0.439
3.13	0.459	3.51	0.522	3.51	0.476	1.90	0.395	2.72	0.484	2.15	0.400	-1.00	0.423	2.50	0.406	2.84	0.452	3.67	0.529
4.10	0.542	4.43	0.571	4.58	0.542	2.98	0.505	3.55	0.540	3.02	0.493	-1.00	0.496	3.61	0.538	3.98	0.545	4.72	0.580
5.46	0.607	5.50	0.615	5.47	0.583	3.71	0.550	4.34	0.575	3.93	0.553	-1.00	0.563	4.14	0.569	5.13	0.589	5.66	0.616
6.32	0.638	6.47	0.644	6.59	0.625	4.45	0.580	5.38	0.615	4.78	0.589	-1.00	0.601	5.36	0.629	6.65	0.640	7.03	0.655
7.68	0.677	7.51	0.676	7.82	0.665	5.38	0.617	6.34	0.639	5.79	0.630	-1.00	0.637	6.32	0.659	8.22	0.678	8.61	0.693
8.48	0.686	8.54	0.694	9.19	0.701	6.61	0.650	7.59	0.670	6.71	0.655	-1.00	0.666	7.44	0.688	9.30	0.695	10.07	0.729
9.38	0.699	9.37	0.711	10.51	0.732	7.71	0.677	8.24	0.685	7.90	0.687	-1.00	0.686	8.72	0.721	10.71	0.733	11.23	0.757
10.33	0.726	10.40	0.735	11.72	0.761	8.64	0.698	9.35	0.707	9.03	0.709	-1.00	0.726	9.81	0.748	12.69	0.787	12.54	0.799
11.50	0.749	11.87	0.773	12.99	0.798	9.90	0.724	10.17	0.723	10.39	0.743	-1.00	0.741	10.95	0.784	13.90	0.818	14.19	0.826
12.38	0.770	13.07	0.804	14.71	0.837	10.93	0.745	11.41	0.753	11.65	0.772	-1.00	0.775	12.28	0.816	15.79	0.851	15.41	0.854
13.53	0.805	14.22	0.828	17.41	0.883	11.90	0.768	12.44	0.766	12.67	0.801	-1.00	0.791	13.50	0.848	17.83	0.873	16.79	0.873
14.30	0.813	15.68	0.865	18.18	0.888	12.88	0.790	13.68	0.794	14.04	0.832	-1.00	0.814	14.87	0.873	19.17	0.857	17.76	0.885
15.39	0.839	17.20	0.890	19.54	0.880	13.81	0.813	15.26	0.821	15.31	0.850	-1.00	0.825	16.06	0.882	20.75	0.815	18.81	0.876
16.16	0.850	17.84	0.898	20.82	0.847	15.06	0.839	16.43	0.826	15.89	0.858	-1.00	0.839	17.98	0.861	22.33	0.743	20.22	0.850
17.08	0.850	18.96	0.896	22.41	0.805	16.47	0.868	17.41	0.828	16.43	0.852	-1.00	0.841	18.88	0.822	23.93	0.725	21.90	0.824
18.12	0.833	19.80	0.877	24.46	0.778	17.33	0.883	18.29	0.814	17.47	0.844	-1.00	0.836	20.23	0.801	25.41	0.691	23.01	0.804
18.94	0.823	20.74	0.839	25.48	0.773	18.42	0.899	20.10	0.709	18.67	0.813	-1.00	0.779	21.89	0.778			25.26	0.765
20.08	0.818	21.77	0.817			19.51	0.882	21.50	0.705	20.07	0.775	-1.00	0.740	23.49	0.766				
21.24	0.814	23.04	0.799			20.44	0.875	23.13	0.697	21.56	0.744	-1.00	0.733	25.30	0.747				
22.53	0.733	24.37	0.743			21.67	0.867	24.57	0.701	22.92	0.717	-1.00	0.664						
23.71	0.680	25.14	0.724			23.10	0.821	25.44	0.693	25.26	0.694	25,56	0.655						
25.01	0.653					25.15	0.787												

test 21		test 22		test 23		test 24		test 25		test 26		test 27		test 28		test 29		test 30	
mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
1.00	0.118	1.81	0.043	0.84	0.148	0.81	0.106	0.49	0.189	0.80	0.164	0.85	0.018	0.89	0.268	0.87	0.123	0.89	0.210
2.22	0.250	2.91	0.144	1.84	0.299	1.85	0.291	1.69	0.378	2.02	0.350	1.43	0.189	1.91	0.410	1.83	0.302	1.88	0.364
3.43	0.399	4.13	0.258	3.25	0.452	3.04	0.424	2.75	0.494	3.22	0.494	2.72	0.370	3.17	0.547	2.98	0.454	3.53	0.551
4.86	0.519	5.81	0.397	4.54	0.542	4.73	0.536	3.84	0.565	4.20	0.555	4.26	0.527	4.43	0.602	4.56	0.551	5.30	0.623
6.59	0.600	7.45	0.481	5.61	0.580	5.80	0.580	5.81	0.641	5.66	0.609	5.95	0.609	5.63	0.650	6.48	0.639	6.87	0.652
7.94	0.637	9.24	0.562	6.59	0.626	7.18	0.621	7.29	0.677	7.99	0.683	7.05	0.635	7.24	0.702	8.61	0.693	8.29	0.694
9.64	0.681	11.08	0.643	8.02	0.673	8.93	0.671	8.66	0.707	9.75	0.721	8.43	0.670	8.66	0.735	10.04	0.727	9.88	0.731
11.40	0.716	12.69	0.686	9.34	0.704	10.80	0.711	10.31	0.749	11.33	0.758	9.90	0.702	10.11	0.767	11.65	0.763	11.32	0.766
13.16	0.753	14.23	0.720	10.98	0.740	12.52	0.750	12.07	0.802	13.23	0.799	11.29	0.732	11.99	0.811	13.15	0.803	12.97	0.803
14.95	0.788	15.75	0.753	12.44	0.783	14.37	0.789	13.68	0.843	15.21	0.831	13.32	0.785	12.77	0.837	15.13	0.853	14.04	0.823
16.28	0.819	17.49	0.800	13.88	0.818	16.32	0.823	15.29	0.869	15.88	0.836	14.87	0.818	14.91	0.861	16.85	0.881	14.90	0.826
18.24	0.861	19.62	0.853	15.34	0.852	18.04	0.840	15.97	0.865	17.74	0.811	15.89	0.843	15.19	0.856	17.75	0.889	16.28	0.812
20.30	0.886	21.15	0.883	17.01	0.876	19.32	0.830	17.50	0.864	19.35	0.782	17.13	0.863	16.84	0.854	19.02	0.864	17.93	0.778
21.25	0.885	23.39	0.906	18.28	0.885	21.02	0.797	19.30	0.859	21.40	0.757	17.60	0.865	18.35	0.820	21.29	0.810	20.11	0.759
23.15	0.881	24.50	0.897	19.54	0.877	22.83	0.740	21.09	0.825	23.38	0.739	19.12	0.826	20.93	0.797	22.83	0.780	22.70	0.743
25.34	0.835	25.25	0.862	21.01	0.843	25.00	0.685	23.13	0.729	25.47	0.720	21.02	0.702	22.52	0.762	25.30	0.745	25.24	0.722
				22.76	0.798			25.30	0.698			22.76	0.656	25.39	0.759				
				25.18	0.778							25.02	0.637						

test 31		test 32		test 33		test 34		test 35		test 36		test 37		test 38		test 39		test 40	
mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
1.01	0.145	0.53	0.024	1.01	0.016	1.50	0.053	1.14	0.030	0.65	0.251	0.86	0.088	0.53	0.258	0.87	0.315	0.45	0.285
1.91	0.294	1.85	0.196	2.29	0.301	2.39	0.220	1.90	0.186	2.19	0.46	1.70	0.291	1.79	0.420	2.12	0.466	3.31	0.482
3.37	0.461	2.96	0.369	3.72	0.461	3.67	0.379	3.31	0.394	3.48	0.546	3.30	0.482	3.63	0.555	3.43	0.545	4.81	0.575
5.54	0.568	4.66	0.541	4.97	0.543	5.06	0.491	5.18	0.545	5.03	0.609	5.26	0.582	4.83	0.611	4.44	0.597	6.34	0.642
7.04	0.625	5.91	0.591	6.38	0.607	6.82	0.573	6.94	0.613	6.64	0.659	7.23	0.640	6.39	0.669	5.92	0.656	7.83	0.689
8.92	0.671	7.62	0.655	7.90	0.661	8.24	0.638	8.81	0.677	8.36	0.690	9.22	0.690	8.16	0.707	8.06	0.713	9.25	0.722
11.38	0.726	9.08	0.677	9.67	0.704	9.77	0.692	10.40	0.711	10.51	0.738	11.17	0.739	10.80	0.774	9.96	0.763	11.17	0.770
13.99	0.785	10.63	0.714	10.94	0.731	11.18	0.727	12.21	0.756	11.90	0.769	12.94	0.787	12.15	0.805	12.55	0.828	12.85	0.814
16.17	0.820	12.12	0.749	12.69	0.780	13.01	0.773	14.05	0.796	13.11	0.801	14.90	0.833	13.97	0.840	14.56	0.869	15.34	0.862
18.04	0.840	14.32	0.794	14.06	0.810	15.14	0.836	15.19	0.823	14.89	0.840	16.71	0.873	16.32	0.874	15.54	0.874	17.05	0.867
18.52	0.838	16.01	0.824	15.87	0.849	17.18	0.871	16.58	0.852	16.30	0.856	17.97	0.897	18.39	0.864	16.91	0.850	18.97	0.790
19.94	0.821	16.72	0.831	21.02	0.852	19.02	0.853	17.62	0.860	18.01	0.853	18.88	0.904	20.24	0.812	18.88	0.730	21.30	0.712
22.70	0.744	17.69	0.806	21.99	0.832	20.97	0.798	19.04	0.790	19.84	0.711	19.22	0.910	22.33	0.735	21.29	0.705	22.94	0.695
25.12	0.682	19.03	0.718	23.50	0.745	23.41	0.761	21.09	0.744	22.50	0.674	20.86	0.882	25.32	0.689	23.77	0.702	25.13	0.685
		21.56	0.695	25.17	0.707	25.04	0.741	23.38	0.718	25.36	0.654	23.03	0.757			25.18	0.705		
		23.33	0.670					25.14	0.713			25.12	0.737						
		25.25	0.647																

test 42		test 43		test 44		test 45		test 46		test 47		test 48		test 49		test 50	
mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN	mm	kN
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
0.95	0.366	0.90	0.365	0.69	0.264	1.19	0.275	1.20	0.019	0.56	0.111	0.89	0.314	0.38	0.038	0.84	0.344
2.16	0.502	2.02	0.496	2.09	0.454	2.34	0.432	2.28	0.291	2.11	0.391	1.93	0.433	1.98	0.329	2.37	0.514
3.76	0.600	3.02	0.540	3.45	0.544	3.76	0.547	3.21	0.411	3.95	0.556	3.11	0.544	3.55	0.495	3.97	0.581
4.96	0.637	4.48	0.606	5.11	0.618	5.18	0.612	4.60	0.552	5.72	0.631	4.50	0.616	5.27	0.598	5.73	0.640
6.32	0.671	5.92	0.646	7.42	0.683	6.90	0.667	6.19	0.628	6.85	0.667	5.79	0.657	6.66	0.654	7.37	0.682
7.83	0.713	7.49	0.689	9.04	0.715	8.53	0.701	7.70	0.665	8.00	0.700	7.00	0.690	7.70	0.679	8.77	0.716
9.37	0.766	9.02	0.727	11.52	0.781	10.29	0.755	9.30	0.703	9.49	0.742	8.30	0.731	9.11	0.727	10.57	0.759
10.88	0.813	10.64	0.776	13.25	0.825	11.57	0.787	11.16	0.757	11.15	0.787	9.94	0.785	10.48	0.772	12.29	0.803
12.28	0.847	12.23	0.819	15.13	0.861	12.95	0.820	12.79	0.805	12.83	0.829	11.70	0.830	11.96	0.816	13.82	0.832
13.76	0.877	14.13	0.840	16.10	0.866	14.36	0.854	14.24	0.837	14.40	0.853	12.89	0.861	13.79	0.866	15.23	0.841
15.04	0.886	14.42	0.845	17.57	0.847	17.10	0.867	16.05	0.869	15.63	0.864	13.92	0.881	15.40	0.895	16.96	0.817
15.33	0.883	16.07	0.830	19.16	0.825	18.30	0.847	17.20	0.878	16.23	0.851	15.54	0.899	15.77	0.900	18.38	0.801
17.11	0.859	17.85	0.797	21.67	0.807	20.23	0.815	19.35	0.861	18.05	0.833	16.50	0.870	17.56	0.870	20.15	0.783
18.63	0.847	20.22	0.768	23.49	0.782	22.51	0.793	21.82	0.829	20.14	0.801	18.29	0.842	19.10	0.840	22.71	0.785
20.02	0.831	22.59	0.748	25.21	0.770	25.33	0.794	23.67	0.801	22.90	0.798	20.13	0.829	21.07	0.806	25.26	0.791
22.52	0.818	25.23	0.741					25.32	0.777	25.04	0.805	22.57	0.808	23.13	0.784		
25.09	0.795											25.13	0.789	25.20	0.756		