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HEALTH & SAFETY LABORATORY

Testing of Reveal Pin Ties

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EXECUTIVE SUMMARY

Objectives

1. To carry out a test programme to determine the effectiveness of reveal pin tie installations, as recommended by BS 5973:1993.

2. To carry out testing using different installation methods and loads to give an indication of relative performance in possible worst-case scenarios for each type of reveal tie.

Main Findings

1. With a Factor of Safety of 1.6 applied to the peak pullout loads, the majority of reveal ties installed as directed by BS 5973 failed to achieve the safe working load of 3.5kN recommended by the standard. Those ties that achieved the SWL required upwards of 89.3Nm of torque during installation.

2. Reveal pin ties, installed with the tie tube in the centre of the reveal tube appeared to offer a pullout load performance advantage over pressure ties and over reveal pin ties with the tie tube within 150mm of the non-jacking end (as recommended by BS 5973).

3. The use of base plates and dry packing in the installation of reveal pin ties appeared to have little effect on the performance. Some minor benefits were found, but further tests, under a variety of conditions, would have to be carried out to give sufficient data to verify these findings.

4. Reveal material appeared to have little effect on reveal pin ties installed with the tie tube within 150mm of the end of the reveal tube. However, if the tie tube is installed in the centre of the reveal tube, a brick reveal pin tie installation appears to outperform a similar installation in a concrete reveal.

5. There is a relationship between the force required to pull a reveal pin tie from the reveal and the number of turns of the reveal pin. In the case of a reveal pin tie with the tie tube within 150mm of the end, there is a direct relationship where pullout load is around 76% of the load the tie applies to the reveal.

6. The testing highlighted a number of concerns about reveal pin tie installation. In particular it was not uncommon for around 20% of the initial reveal load applied by the tie to be shed within the first ten minutes of installation. In a single three day installation test, the reveal pin tie shed around 40% of the initial reveal load. This could easily result in some reveal pin ties failing to achieve the safe working load of 3.5kN recommended by BS 5973:1993.

7. The experimentation also highlighted concerns about variations in reveal pin manufacture and wear rates.

8. The variation of pullout loads that occurred between a small number tests carried out under identical installation conditions suggests that reveal pin tie performance is unpredictable. It may therefore be necessary to substantially increase the tie frequency to overcome unreliability.

Recommendations

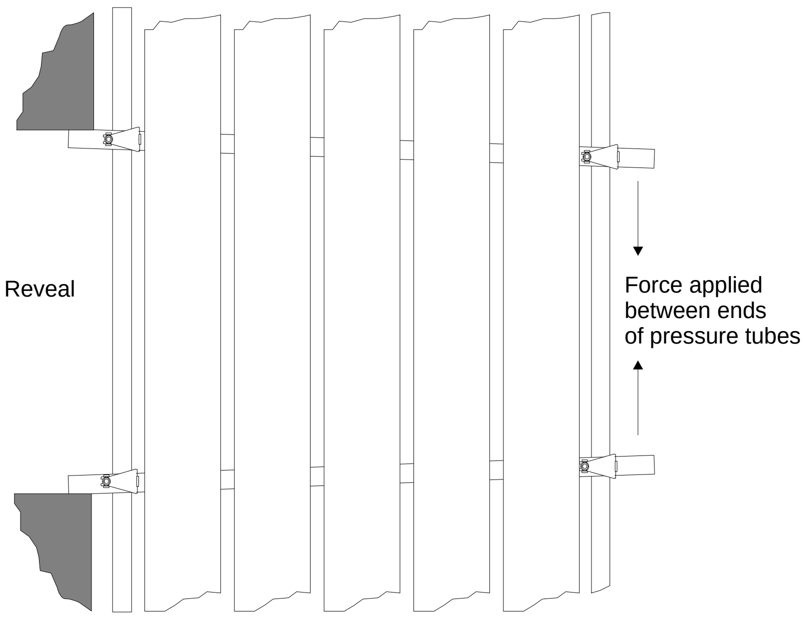
1. The findings suggest that reveal ties may frequently be unable to achieve the 3.5kN safe working load recommended by BS 5973:1993.

2. The results suggest that consideration should be given as to whether it should be recommended that reveal pin ties should be installed with the tie tube attached centrally to the reveal tube. Reveal ties attached at the centre of the reveal tube offered around 60% increase in pull out load and greater flexibility in the structure. However, when failure occurred it was generally very sudden. The structural flexibility, observed in the laboratory environment, may or may not prove to be of benefit in practice. On the one hand, the increased flexibility may prove beneficial in the absorption of wind buffeting effects. On the other hand, an increased reveal span also increases the deflection of the reveal tube. Over longer reveal spans, the resulting flexibility could be quite considerable. It is possible that this may allow greater loads to be transferred to other, more rigid, ties used in a scaffold structure.

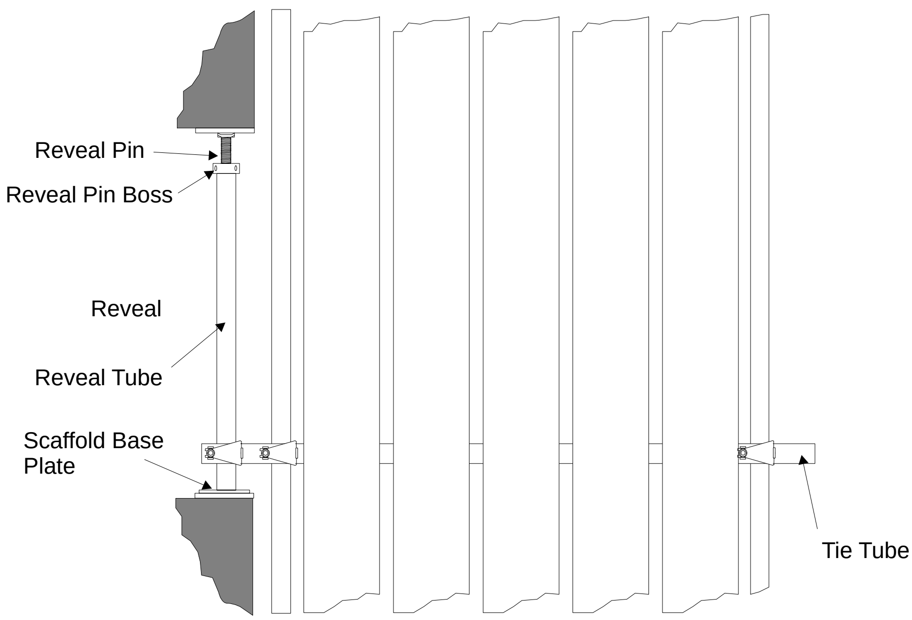
3. The testing also highlighted a number of concerns relating to the installation of reveal pin ties. There appears at present to be very little guidance as to how the ties should be installed, maintained and proof tested. The test results clearly show that there are significant changes in tie performance, dependent on installation variables and due to bedding in and wear effects.

1 INTRODUCTION

The Health and Safety Laboratory (HSL), Field Engineering Section (FES), Engineering Control Group were contracted by Martin Holden of Technology Division to perform a series of tests to determine the effectiveness of both pressure ties and reveal ties which utilise a reveal pin (referred to as reveal pin ties throughout this report), in a perpendicular, outward, pullout situation. Figure 1 gives a representation of the two different types of reveal tie. This report details the testing of reveal pin ties.



Plan view of scaffold level showing a Pressure Tie Arrangement



Plan view of scaffold level showing a Reveal Pin Tie Arrangement

Figure 1 – Types of Reveal Tie

2 SPECIFIED REQUIREMENTS FOR REVEAL TIES

BS 5973:1993, defines reveal ties and specifies requirements for their use, construction and loading. Some of these recommendations were considered relevant to the testing of reveal ties.

BS 5973:1993 Section 9.4.5 Reveal Ties, recommends that timber packing should be used with reveal ties, "Timber packs should be thin so as to reduce shrinkage (a thickness of 10mm is recommended). It is not expected that they should spread the load over the surface of the reveal but that they should grip it and protect it at the same time". All reveal pin tie tests were carried out using 10mm ply packing material to evaluate this recommendation.

BS 5973:1993 Section 9.4.5 also states: "The tie tube should be fixed to the reveal tube with a right angle coupler as near to the end opposite to the reveal pin and in all cases within 150mm of the face of the opening. All of the tests were carried out with the tie tube fixed to the reveal tube with a right angled coupler. For most tests this was centred at 150mm from the end opposite to the reveal pin, but ties were also tested with the tie tube at the centre and 150mm from the reveal pin end to evaluate this recommendation.

BS 5973:1993 Section 9.7.1(b) Capacity of tie systems and alternatives, details requirements for reveal tie loading. "Where these rely solely on friction there is no mechanical interlock and construction is in accordance with Figure 7: 3.5kN inwards and outwards". (The figure referred to details a standard reveal tie with reveal tube and reveal pin.) Table 1(a) Frequency of ties in square metres per tie, also specifies that 3.5kN is the "safe working capacity" for reveal ties. This gives a useful benchmark value to compare against the pullout load performance figures found from testing of reveal pin tie systems.

3 EXPERIMENTAL PROCEDURE

A test rig was designed and two pairs of samples were manufactured to represent typical reveal construction materials. Figure 2 shows a plan view of the test rig design, Figure 3 shows the actual reveal pin tie test rig that was used for the experimentation set up prior to commencing a test. One pair of samples consisted of three bricks with a textured surface. These were mortared together to form a block, shown uninstalled in Figures 4(a), 4(b), 5(a) & 5(b). The second pair of samples were textured concrete blocks made to a 40N mix using 10mm-dust aggregate. Shown installed in Figures 4(a), 4(b), 5(a) & 5(b). These samples were cast to give a block of the same surface area as the brick samples.

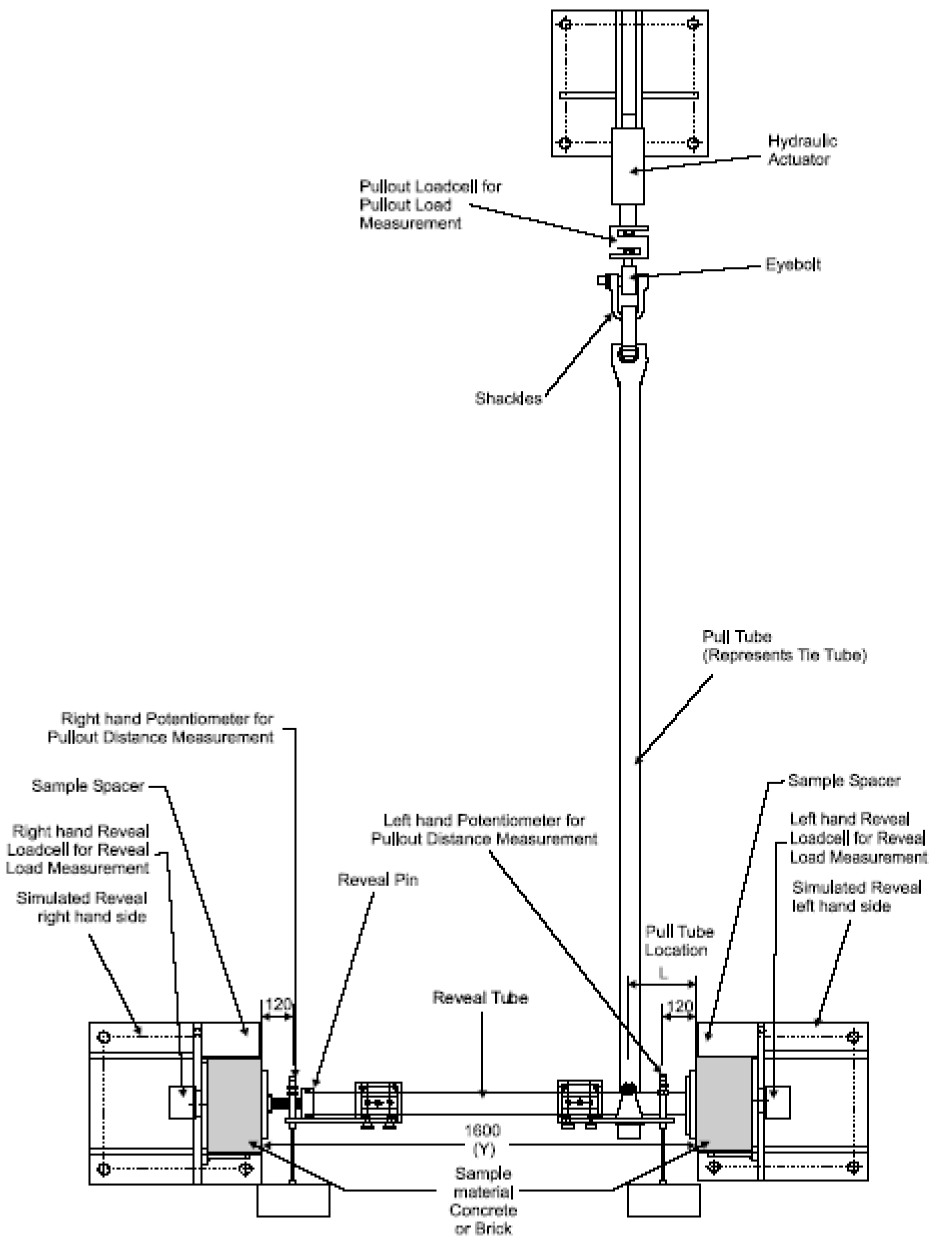


Figure 2 – Reveal Pin Tie Test Rig Construction

Figure 3 – Pressure Tie Test Rig

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Figure 4(a) - Reveal Pin Tie Installed with Concrete Reveal, Left Hand Side

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Figure 4(b) – Reveal Pin Tie Installed with Concrete Reveal, Right Hand Side

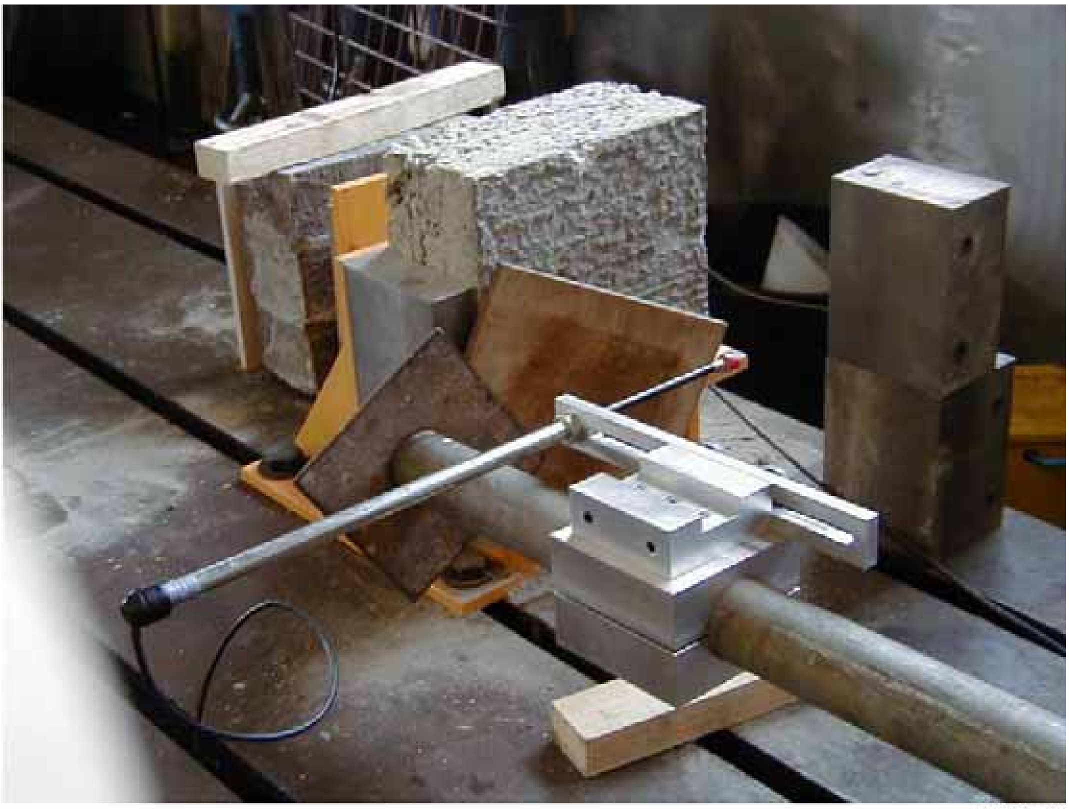

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Figure 5(a) - Reveal Pin Tie Failure, Concrete Reveal, Left Hand Side (Test rp18)

Figure 5(b) – Reveal Pin Tie Failure, Concrete Reveal, Right Hand Side (Test rp18)

3.1 REVEAL PIN TIE TESTING

The reveal pin tie test rig is shown in plan view in Figures 2 & 3. Much of the rig construction utilised the same components as for the pressure tie testing FE/02/03. The aperture “Y” (Figure 2) and construction of the reveal are consistent with the pressure tie testing. To form the reveal tube, standard scaffold tube was cut to a length of 1500mm. A typical reveal pin (Figure 6) was inserted into the right hand end of this tube and a scaffold base into the left hand end. This was installed into the reveal using 200 x 200 x 10mm ply packing material between the tie and the sample material at either end of the tie. The reveal tube was supported by timber spacers and positioned in the reveal such that the ends were directly aligned with the loadcell centres, giving 100mm pullout. A pull tube (representing the tie tube) was attached to this reveal tube using a standard right angle coupler (tightened to 40Nm). The opposite end of this pull tube had been drilled to accept a shackle, which allowed attachment to the hydraulic ram fitting. The right angle coupler and hydraulic ram were adjustable to allow the position of pull (labelled L on Figure 2) to be varied to any position along the complete length of the reveal tube.

Loadcells monitored the force transmitted to the sample materials within the reveal (reveal load) and also the force required to pull out the reveal tie. The output of the loadcells was monitored at all times to ensure that the test rig remained loaded to the correct reveal load prior to testing. A remote display was set up to allow the calibrated output of the logging computer to be seen while the adjuster boss of the reveal pin was being turned.

Potentiometers were fitted to either end of the reveal tube to monitor pullout characteristics during the testing. These were attached to the reveal tube using clamps and to stationary steel blocks by means of magnetic fixings. They were positioned as close to the reveal as possible so as to monitor movement at both sides during testing.

Figure 6 – Wear to surface of reveal pin boss

3.2 DEVELOPMENT TESTING

To assess the effectiveness of the test rig, several development tests were carried out. The original test programme required that the reveal pin ties should be tested at the equivalent reveal loads to those achieved by the pressure ties FE/02/03. It was the intention that this should give a direct comparison between the performance of both tie methods. However, from the initial tests, it became apparent that where it was difficult to achieve the higher reveal loads using the pressure tie, even with the benefits of a laboratory environment, high reveal loads could be more easily achieved using the reveal pin tie arrangement. It was thus felt that this test would not give a realistic representation of the relative performance of the reveal pin tie in normal use - effectively comparing a best case scenario for the pressure tie against a worst case scenario for the reveal pin tie. However, the load that can be applied by tightening the reveal pin is also dependant on a number of variables. These include the length and fit of the lever used to turn the adjuster, the condition of the reveal pin and the angle that the reveal tube is cut off.

It was decided to use the number of rotations applied to the reveal pin boss as the load variable for experimentation. The intention was to count the number of rotations from a datum that represented handtight. The handtight datum proved to be very inconsistent, so tests were carried out to determine what reveal loads were applied at "handtight" and thus determine a suitable reveal load to use as a datum. A pre-load figure for handtightness of 0.3kN generated within the reveal was selected. At this level, the tie was self-supported within the reveal, but the force required was sufficiently low to be consistently achievable. It was also decided to measure the torque required to tighten the reveal pin to the specified number of rotations during each experiment. This would allow the data to be more usefully applied if future studies determine what torque would realistically be achieved in the practice.

During initial testing, it was also noticed that there was significant drop off in reveal load associated with the reveal pin arrangement. The majority of this load shedding occurred within the first few minutes after installation. For these tests the rig was allowed to settle until the desired reveal load became stable. For subsequent tests (all tests using the torque wrench) it was decided to allow the reveal pin tie 10 minutes to bed in before commencing each test, noting the initial reveal load achieved.

3.3 TEST PROCEDURE

The rig was set up with the puller tube secured to the reveal tube at the defined position (L), the hydraulic ram was moved parallel to the reveal such that the direction of pull would always be perpendicular to the reveal tube. For all tests, unless stated otherwise, packing material was soaked in water for at least one hour before use. With the tie in position within the reveal (Figures 3, 4(a) & 4(b)), the reveal pin adjuster was turned. For installation method tests this was accomplished using a 334mm long steel bar, for all other tests this was substituted for a digital torque wrench with a peak hold facility. With the logger displaying calibrated reveal load, the reveal pin adjuster boss was turned until the desired reveal load was achieved. The hydraulic pump was activated until the reveal tie had pulled completely from the reveal at one or both sides. Sample material, packing material, tubes and couplers were inspected for damage and replaced if necessary between tests. A typical failure is shown in Figures 5(a) & 5(b).

3.4 THREE DAY CREEP TESTING

A further test was carried out where a reveal pin tie was installed to three turns of the reveal pin boss in a concrete reveal with packing material soaked in water for one hour. The logger was set to log the right and left hand reveal load every ten seconds for 72 hours. Depth gauges were installed to measure any creep of the reveal brackets against the slotted bed plate.

3.5 INSTRUMENTATION

Data logging was carried out using a DAQCard-AI-16E-4 Data acquisition PCMCIA card installed in a Laptop computer running National Instruments Virtual Bench software. Logging rate was 200 samples per second and logging was triggered manually prior to each test. Data analysis was carried out using Sigmaplot software, graphs were cropped to show the area of interest. Amplification was carried out using FYLDE 379TA signal amplifiers. No filters were used.

Two 20kN EMS shearbeam loadcells were used to measure reveal load. A 20kN Tedea Huntleigh “S” type loadcell was used to measure Pullout Load.

Two 225mm Pioden linear displacement transducers were used to measure pullout distance. The right hand displacement transducer was replaced during the test programme. It was replaced by another calibrated transducer of the same type and specification.

3.6 CALIBRATION

Both Shearbeam loadcells and the 20kN “S” type Loadcell were calibrated in accordance with Field Engineering internal calibration procedure FE/CP/20 using a Denison Universal Testing Machine. This machine is calibrated externally against a NAMAS accredited known reference.

Potentiometers were calibrated against an externally UKAS calibrated digital height gauge in accordance with Field Engineering internal calibration procedure FE/CP/42.

Amplifiers were checked for voltage and frequency accuracy using a calibrated oscilloscope.

A digital torque wrench measuring from 10 to 100Nm was adapted to measure the torque used to tighten the reveal pin. With the adapter fitted it was calibrated against a UKAS Calibrated Norbar Static Torque Meter, across its full range.

4 RESULTS

This section gives a summary of the results obtained. Note, some graphs referred to in this section may show spikes in the “Distance pulled from Reveal” traces. This is due to a momentary loss of contact between the moving element and the winding within the displacement transducer. This phenomena, known as dropout, is purely a transducer irregularity and should not be interpreted as instantaneous movement of the structure.

Other than being cropped to focus on the area of interest, the graphical data referred to in this section is unfiltered and unedited.

4.1 DEFINITIONS & EXPLANATIONS OF RESULTS TABLE CONTENTS

Test - This column shows the original test number for each experiment. The test number shows the order in which the testing was carried out and is often different to the order in which the tests are referred. Testing was carried out in an order which required the minimum set up changes to the test rig between each experiment, as a result it is often not the the most logical order for representing the data. If a test column contains a number followed by an “r” followed by another number this indicates that it is a repeated experiment from the original planned test programme. As the reveal pin test programme was altered from the original intended programme, the new style tests are denoted by the prefix “rp” (reveal pin).

Pull Tube Location - The pull tube location (4.2) is the point at which the pull tube, which simulates the tie tube in a reveal tie system, is attached to the reveal tube. It is measured from the surface of the reveal material to the centre of the tie tube coupler. A visual depiction of this can be seen in Figure 2.

Reveal Material - This column indicates whether a textured brick or textured concrete sample was used in the test to replicate the construction material of the reveal.

Number of Turns - This column (in 4.3, 4.4 & 4.5) shows the number of rotations applied to the reveal pin adjuster boss for each test set up.

Torque Required - This column is shown adjacent to “number of turns” in 4.3, 4.4 & 4.5 and shows the torque applied to the reveal pin adjuster boss to achieve the desired number of turns. This value was measured using a calibrated digital torque wrench. This wrench had a working range of 11 - 108Nm. The display gave no reading below 11Nm, hence where torque was too low to give a reading it has been represented as <11Nm. Above 108Nm the display continues to indicate up to a maximum of 122Nm. Above 108Nm the calibrated range is exceeded and is therefore suspect. These values have been retained as an indication only.

Reveal Load - This column (in 4.2) shows the load generated (in kN) within the reveal by the action of the reveal pin. The load quoted is the value measured by the right hand side reveal loadcell (see figure 2 for visual depiction). Where the column header reads only “Reveal Load” the reveal pin was tightened until it achieved this particular reveal load.

Initial Reveal Load - This column (in 4.3, 4.4 & 4.5) shows the reveal load (in kN) that was achieved at the instant where the required number of turns of the reveal pin boss was reached. The load quoted is the greater of the values measured by the two reveal loadcells on either side of the reveal (see Figure 2 for visual depiction). The greater value was believed to be the most representative of the two loads, as the lower value may be due to some slight transfer of load to a non-instrumented part of the test rig.

Reveal Load after Ten Minutes – This column is shown adjacent to “Initial Reveal Load” in 4.3, 4.4 & 4.5 and shows a similar reading after the test rig had been allowed to bed in for ten minutes. It is the value of the reveal load (in kN) at the start of pull out. The load quoted is the greater of the values measured by the two reveal loadcells on either side of the reveal (see Figure 2 for visual depiction). The greater value was believed to be the most representative of the two loads, as the lower value may be due to some slight transfer of load to a non-instrumented part of the test rig.

Load Loss – This column (in 4.3, 4.4 & 4.5) gives the percentage difference between the “Initial Reveal Load” and the “Reveal Load after Ten Minutes” values.

Packing Material – This column indicates the material and thickness of any packing material that was placed between the ends of the pressure tubes and the reveal material.

Peak Pullout Force – This is the maximum value (in kN) recorded by the pullout loadcell before slippage occurred. Occasionally the tie subsequently gained another grip, in this case the highest of the peaks has been quoted. The peak pullout load may only be present for an instant and represents an upper limit for the tie.

Safe Working Load – BS 5973:1993 section 9.7.1 states that reveal tie systems should have a safe working load (SWL) of 3.5kN. In order to allow some comparison between the test results and this value, a factor of safety (FOS) of 1/1.6 has been applied to the peak pullout force value and entered into this column. The FOS used to calculate the SWL for a reveal tie is not stated in BS 5973:1993 and no reference is made to the origin of the 3.5kN SWL. To derive a SWL column, many assumptions have had to be made, so it is important that the values entered in this column be treated with caution;

Summarising, BS5973:1993 Section 9.7.1 gives a SWL for box, lip and through ties of 6.25kN for ties relying on one coupler and 12.5kN (6.25 x 2) for ties which share the load between two couplers. Since the weakest component in these ties is most likely to be the coupler, the SWL for the tie should therefore be based on the SWL of the coupler. This is supported by section 39.8.1, which states that the coupler SWL is 6.25kN. Section 39.8.2 recommends a design divisor of 1/1.6 for calculating the SWL of couplers when tested in accordance with BS 1139. This suggests that the SWL for box, lip and through ties has been calculated from a FOS of 1/1.6. However, in all of these cases, the weakest link has been the coupler. In the case of the reveal tie, the weakest link is most likely to be the tie slipping against the reveal material, so it is quite possible that a different FOS should be used for these tie systems.

Key to results table colour coding:

Pass BS 5973:1993		Fail BS 5973:1993	

Tie Frequency Ratio - BS 5973: 1993 Table 1(a) recommends the frequency of ties required in square metres per tie. The validity of this is based on reveal ties having a SWL of 3.5kN. The value given in this column can be multiplied by the applicable figure in Table 1(a) of BS 5973: 1993 to give the frequency of that particular tie which would be required to achieve the same loading capability as a 3.5kN tie. This ratio has been calculated by taking the 3.5kN from the standard and dividing by the calculated SWL from the preceding column. As the data in this column is calculated from the “Safe Working Load” column data, the values should be treated with similar caution (see 4.1.12).

Results Graph Figure Number - This column gives the figure number of the graph which shows the recorded data for each experiment.

4.2 REVEAL PIN TIE INSTALLATION METHODS

Testing of reveal pin ties gave the results shown in Table 1, graphs can be found in the figure sheets towards the back of the report. Figure sheets, with the exception of 6.0 and 8.5kN ties, have been arranged to allow a comparison of installation methods on each page. Ties installed to 6.0 and 8.5kN have the same installation method, but have been shown on the same page to allow a comparison of the performance.

Table 1 - Results for Reveal Pin Tie Installation Method Tests

Test	***Pull Tube Location (L) (from non-jacking end)***	***Reveal Material***	***Reveal Load (kN)***	***Packing Material***	***Peak Pullout Force (kN)***	***Safe Working Load (based on 1.6 FOS)***	***Tie Frequency Ratio***	***Results Graph Figure Number***
21	150mm	Concrete	1.8	10mm Ply, foot	1.3	0.81	4.32	7
21r1	150mm	Concrete	1.8	10mm Ply, no foot	1.2	0.75	4.67	8
21r2	150mm	Concrete	1.8	Moist 10mm Ply, no foot	1	0.63	5.56	9
22	150mm	Concrete	3.6	10mm Ply, foot	2.4	1.5	2.33	10
22r1	150mm	Concrete	3.6	10mm Ply, no foot	2.1	1.31	2.67	11
22r2	150mm	Concrete	3.6	Moist 10mm Ply, no foot	2	1.25	2.8	12
27	150mm	Concrete	6	10mm Ply, foot	4.2	2.63	1.33	13
28	150mm	Concrete	8.5	10mm Ply, foot	5.9	3.69	0.95	14

4.3 REVEAL PIN TIE, PULLED 150MM FROM NON JACKING END, INSTALLED WITH 10MM PLY PACKING, MOISTENED FOR 1 HR

Testing of reveal pin ties installed with pull tube location (L) = 150mm gave the results shown in Table 2, graphs can be found in the figure sheets towards the back of the report. Figure sheets have been arranged to allow a comparison of concrete and brick reveal material on each page.

The digital torque wrench used during experimentation had a working range of 11 - 108Nm. Above 108Nm the display continues to indicate up to a maximum of 122Nm. Nothing above 108Nm is within the calibrated range, so must not be relied upon. For the 3 & 3 $^{1}/_{3}$ turn brick reveal, the torque exceeded 122Nm. In the case of the 3 $^{1}/_{3}$ turn brick reveal, the reveal pin had to be tightened using a steel rod to avoid overload damage to the torque wrench.

Table 2 - Results for Reveal Pin Ties Pulled 150mm from Non Jacking End

Test	*Reveal Material*	*Number of Turns*	*Torque Required (Nm)*	*Initial Reveal Load (kN)*	*Reveal Load after Ten Minutes (kN)*	*Load Loss (%)*	*Peak Pullout Force (kN)*	*Safe Working Load (based on 1.6 FOS)*	*Tie Frequency Ratio*	*Results Graph Figure Number*
rp1	Concrete	1	<11	1	0.9	10	0.9	0.56	6.25	15
rp2	Concrete	2	20.5	3.1	2.7	13	2.2	1.38	2.54	17
rp3	Concrete	2	33.3	4.5	3.6	20	3.4	2.13	1.64	18
rp4	Concrete	2	26	3.8	3	21	2.9	1.81	1.93	19
rp5	Concrete	2	30.5	4.4	3.6	18	3.2	2	1.75	20
rp6	Concrete	2	42.4	4.9	3.9	20	3	1.88	1.86	21
rp7	Concrete	3	89.3	8.8	8.2	7	6.9	4.31	0.81	23
rp8	Concrete	$3\,^1/_3$	103.3	10.6	9.7	8	7.4	4.63	0.76	25
rp9	Brick	1	11.3	1.3	1.1	15	0.7	0.44	7.95	16
rp10	Brick	2	30.8	3.8	3.2	15	2.5	1.56	2.24	22
rp11	Brick	3	>122	8	7.1	11	5.8	3.63	0.96	24
rp12	Brick	$3\,^1/_3$	-	12.6	11.4	10	8.9	5.56	0.63	26

4.4 REVEAL PIN TIE, PULLED FROM CENTRE OF REVEAL TUBE, INSTALLED WITH 10MM PLY PACKING, MOISTENED FOR 1 HR

Testing of reveal pin ties installed with L = centre gave the results shown in Table 3, graphs can be found in the figure sheets. Figure sheets have been arranged to allow a comparison of concrete and brick reveal material on each page. The calibrated digital torque wrench used during experimentation had a working range of 11 - 108Nm. Above 108Nm the display continues to indicate up to a maximum of 122Nm. Nothing above 108Nm is within the calibrated range, so must not be relied upon.

Table 3 - Results for Reveal Pin Ties Pulled from Centre of Reveal Tube

Test	*Reveal Material*	*Number of Turns*	*Torque Required (Nm)*	*Initial Reveal Load (kN)*	*Reveal Load after Ten Minutes (kN)*	*Load Loss (%)*	*Peak Pullout Force (kN)*	*Safe Working Load (based on 1.6 FOS)*	*Tie Frequency Ratio*	*Results Graph Figure Number*
rp13	Brick	1	26	1.9	1.5	20	4.1	2.56	1.37	28
rp14	Brick	2	39.3	4.1	3.1	24	6.4	4	0.88	30
rp15	Brick	3	65.3	5	4.6	8	7.7	4.81	0.73	32
rp16	Brick	$3\,^1/_3$	>122	6.1	5.2	15	8.3	5.19	0.67	34
rp17	Concrete	1	13	0.7	0.6	14	1.9	1.19	2.94	27
rp18	Concrete	2	31.3	3.9	3.2	18	5.6	3.5	1	29
rp19	Concrete	3	60.8	7.9	6.5	18	6.7	4.19	0.84	31
rp20	Concrete	$3\,^1/_3$	59.6	10.2	8.5	17	7.1	4.44	0.79	33

Tests rp16, rp18, rp19 and rp20 caused permanent bending of the reveal tube, this was replaced each time prior to the next test.

4.5 REVEAL PIN TIE, PULLED FROM JACKING END, INSTALLED WITH 10MM PLY PACKING, MOISTENED FOR 1 HR

To indicate if there were any substantial performance changes, a reveal pin tie was tested installed with the reveal pin at the same end as the pull tube (L = 150mm from the jacking end). This was tested once to give an indication as to whether future testing should be carried out in this configuration. To allow comparison with the greatest range of results, the experiment was carried out in a concrete reveal, with two turns of the reveal pin boss. The experiment gave the results shown in Table 4, the graph can be found in Figure 35.

Table 4 - Results for Reveal Pin Tie Pulled 150mm from Jacking End

Test	*Reveal Material*	*Number of Turns*	*Torque Required (Nm)*	*Initial Reveal Load (kN)*	*Reveal Load after Ten Minutes (kN)*	*Load Loss (%)*	*Peak Pullout Force (kN)*	*Safe Working Load (based on 1.6 FOS)*	*Tie Frequency Ratio*	*Results Graph Figure Number*
rp21	Concrete	2	23.3	3.1	2.6	16	3.5	2.19	160	35

5 OBSERVATIONS

The testing identified several areas of concern involving reveal pin tie installation. These include a significant decay in reveal load after initial installation, effects of water saturation of packing material, wear rates and variations in manufacture of reveal pins. There was also a significant variation in the reveal load generated from one installation to the next and between different tightening methods. There was also an appreciable variation in the torque required to turn the reveal pin through a particular number of rotations.

There were substantial differences in the manufacture of the reveal pins purchased. Four reveal pins of exactly the same type, from the same manufacturer, were purchased. All were slightly different. The welds of the feet to the studding were not perpendicular and had different claw depths. The dimensions, material and surface finish of the jacking bosses were different. Jacking hole diameters and depths were accurately measured and also found to be inconsistent. The table below details the measurements which were taken of the reveal pin boss jacking holes.

Table 5 - Details of Reveal Pin Boss Jacking Hole Dimensions

Reveal Pin	*Hole Number*	*Diameter (mm)*	*Maximum Depth (at centre) (mm)*
rp1	1	14.47	15.43
	2	14.48	15.17
	3	14.48	15.41
rp2	1	14.65	15.85
	2	14.75	16.17
	3	14.62	15.67
rp3	1	14.41	14.31
	2	14.48	14.43
	3	14.05	14.01
rp4	1	13.71	17.01
	2	13.81	17.09
	3	13.8	17.34
	Maximum	14.75	17.34
	Minimum	13.71	14.01

During testing it was noted that these dimensional irregularities had a marked effect on the performance of the reveal tie. Due to the dimensional tolerance differences, it was decided to undertake the test programme using only one reveal pin (RP1).

The pins were not supplied with any guidance relating to their use.

During development testing it was noted that the reveal pins also tended to wear very rapidly. The edges of the jacking holes enlarged, so when jacked using a bar which was initially a good fit, the holes rapidly became such a loose fit that the bar readily pulled out. This resulted in the pin failing to apply the intended reveal load and the sudden loss of interlock could cause personal injury. New holes had to be drilled into the boss of the test reveal pin to allow testing to continue. It is possible that a “C” Spanner may be a more appropriate tightening device.

In addition to the jacking hole enlargement, abrasion of the boss against the end of the reveal tube was sufficient to wear the surface of the boss, causing increased friction and a build up of powder to form. This abrasion damage is shown in comparison in Figure 6. During use, the boss of the pin on the left had abraded and the boss of the pin on the right had become polished. The degree of abrasion to the pin on the left had occurred after only around ten installations. This abrasion had the effect of increasing the torque required to tighten the pin. If the pin was tightened to a similar torque for each installation, this abrasion effect would dramatically reduce the reveal load achieved compared to a new pin, or one with a harder surface. If, for instance a scaffolder were to install ties by tightening the bosses to the maximum they could achieve using a particular tool, this could create a great deal of variation in the reveal load achieved and hence a variation in the pullout load the tie could safely withstand.

Centre pulls on reveal ties appear to give greater pullout loads than end pulls. The usual mode of failure of a 150mm pulled tie was the base plate slipping on the packing material at the end where the pullout load was applied. As in this case the pullout load was applied at the centre of the reveal tube, the load was distributed evenly to both ends of the tie rather than being concentrated on a single end. Another possible explanation for this performance increase is described in Figure 36. However, a complete pullout results in permanent yield of the reveal tube for the higher installation force ties. The displacement of the hydraulic ram required to cause tie failure was also observed to be much greater and the system more elastic. Failure also generally occurred suddenly.

There is no guidance in the British Standards of what should be used at the opposite end of the reveal tube to the reveal pin. Figure 7 of BS 5973:1993 depicts a square object, but the accompanying text makes no mention of whether a foot should be used or not. The reveal pin supplier did not sell a fitting for this purpose, nor were they aware of the existence of one. Some preliminary tests were carried out to compare the differences in performance of using a standard base plate, and using no base plate. Although the tests showed there was little difference, it was decided to test using a base plate as this appears to be what is most commonly used in practice.

6 CONCLUSIONS & RECOMMENDATIONS

6.1 BASE PLATES AND PACKING

Figure 37 shows a graphical comparison of the pullout loads of reveal pin ties with or without base plates and with dry or moist packing. The graph does not show any particular performance advantage or disadvantage to be gained as a result of using a base plate. It is possible that base plates may offer a very slight advantage, but more experiments would have to be carried out to give an accurate opinion. For the purposes of these experiments, the results were sufficiently close to suggest that there was little difference, so it was decided to carry out testing using a base plate as this is apparently what is commonly used in practice. From the graph, the use of dry packing material does appear to consistently give a slight performance advantage. Again, due to the closeness of the results, more tests would need to be carried out to investigate whether this is a true finding. It was decided to use moist packing for the remaining tests as this would represent a frequently occurring scenario.

6.2 REVEAL MATERIAL

Figures 38 & 40, show a graphical comparison of reveal pin ties installed in reveals of both concrete and brick sample materials, to four different reveal pin boss rotations. In Figure 38, generally ties installed in a concrete reveal material seem to outperform those installed in a brick reveal, with the exception of 3 $^{1}/_{3}$ turn ties. However, in Figure 40 (centre pulled), it is brick reveals which consistently outperform concrete. Figure 39 shows a comparison of 5, 2 turn reveal pin tie tests with identical test criteria. The range of pullout loads required for tie failure in these tests varied by 1.2kN. With this in mind, more tests would be required to show which is genuinely the better reveal material for end pull reveal pin ties. Centrally pulled reveal pin ties (Figure 41) appear from the test results to consistently perform better in brick reveals than in concrete, but with so few tests, this may not be genuinely indicative.

6.3 NUMBER OF ROTATIONS OF REVEAL PIN BOSS

Figures 38 & 40, show a graphical comparison of reveal pin ties installed in two different reveal materials to four different reveal pin boss rotations. In Figure 38 the 1 turn reveal pin ties achieve 0.7kN and 0.9kN pullout load. The 2 turn ties achieve between 2.2kN and 3.4kN (including results shown in Figure 39). The 3 turn ties achieve 5.8kN and 6.8kN. The 3 1/3 turn ties achieve 7.4kN and 8.9kN. This clearly shows that there is a relationship between the number of turns of the reveal pin adjuster boss and the pullout load, although the degree of variation between results also increases dramatically as the pullout load increases.

In Figure 40 however the advantage of more turns of the reveal pin boss appears to tail off after around 2 turns. A single turn gives 1.9kN and 4.1kN. 2 turns gives between 5.6kN and 6.4kN. 3 turns gives 6.7kN and 7.7kN. 3 1/3 turns gives 7.1kN and 8.3kN. The overlap is possibly due to the differences of reveal material. During a centre pull test the reveal load increased during the first stages of the pullout. This can be seen from the graphs in Figures 27 to 34. A possible explanation for this, and the tail off of pullout load, is due to the bending of the reveal tube. This is depicted in Figure 36.

6.4 TIE TUBE LOCATION

Figure 41 shows a graphical comparison of the pullout loads for the three tie tube positions that were tested, with two turns of the reveal pin. The graph shows that there was very little difference between pullout load characteristics at 150mm from either end of the reveal pin tie. A test at 150mm from the non-jacking end (test rp5 was chosen as a typical representation) gave a peak pullout load of 3.2kN, 150mm from the jacking end (test rp21) gave a peak pullout load of 3.5kN. These are within the variations seen in Figure 39. However the pullout from the centre of the reveal tube (test rp18) gave a peak pullout load of 5.6kN, a performance increase of around 60%. The sudden failure characteristic of the centrally tied arrangement can also be compared from the graph. It was observed during testing that these ties offered greater flexibility before slippage occurred. This flexibility was due to deflection of the reveal tube at the centre and hence does not show up in the graphs as displacement was measured at the extremities of the reveal tube.

6.5 REVEAL PIN TIE LOAD SHEDDING

Readings of initial reveal load had been taken for all of the reveal pin tie tests which were based around the number of turns of the reveal pin boss. The experimentation had highlighted that shedding of around 20% of the initial reveal load applied by the tie within the first ten minutes of installation, was not uncommon. A further test was carried out where a reveal pin tie was installed to three turns of the reveal pin boss, with moist packing material, in a concrete reveal. Figure 43 shows the full 72 hour test, Figure 44 shows the first hour of logging. In the three day test, the reveal pin tie shed around 40% of the initial installation load. Much of this loss occurred within the first few minutes after installation. Depth gauges had been installed to monitor the reveal brackets to ensure that it was not relaxation of the test rig that was causing the creep. No movement of the brackets was detected. Packing material was allowed to dry naturally over the three days.

Figure 43 shows the reveal load drop off over 72 hours, it also shows a slight oscillation over this period. It is thought that this is due expansion and contraction of the reveal tube resulting from changes in temperature throughout the three day period. The tie was installed at 3:40pm, after the initial load drop off period, the load trace then shows a slight rise in reveal load up until about 5pm the following day. The reveal load then starts to gradually drop, beginning to rise again at about 8am the following morning. This pattern is repeated again on the third day. The test rig was housed in a laboratory which was heated on a timer.

If this load shedding also occurs in practice, it could easily result in poorly installed reveal ties failing to achieve the safe working load of 3.5kN recommended by BS 5973: 1993.

6.6 RELATIONSHIP OF REVEAL LOAD TO PULLOUT LOAD IN REVEAL TIES INSTALLED TO BS5973

Figure 45 shows a graphical representation of the peak pullout loads for reveal pin ties installed with ply packing, a base plate and with the tie tube installed 150mm from the non-jacking end. As there was found to be little difference, the data includes both brick and concrete reveal materials and is taken from the results tables in section 4. The graph indicates a clear relationship of Pullout Load equating to approximately 76% of Reveal Load. There is very little deviation from the regression line. This indicates that the reveal pin ties performed in a predictable manner.

6.7 REVEAL PIN TIE PERFORMANCE COMPARED WITH EQUIVALENT PRESSURE TIE PERFORMANCE

Figure 42 shows a comparison of the results of reveal tie tests and testing carried out on pressure ties FE/02/03 of equivalent reveal Loading. For the pressure tie test rig, there was a ratio of 6:1 between the length of the pressure tube in the reveal (after the swivel adjacent to the reveal) and the distance from the swivel to the length adjustable transom. For example a pressure tie installed with 0.6kN Installation load, applied by the length adjustable transom, generated approximately 3.6kN reveal load. Both sets of tests were carried out using a concrete reveal material. Pressure ties were installed to a depth of 50mm with no packing material. Reveal pin ties were installed according to BS 5973: 1993 using dry 10mm thick ply packing and base plates. They were pulled at 150mm from the non-jacking end.

At 1.8kN reveal load, the pressure tie took a peak pullout load of 1.2kN, the reveal pin tie took 1.3kN, a negligible difference. At 3.6kN reveal load, the pressure tie took a peak pullout of 3.3kN, the reveal pin tie took 2.4kN, significantly lower. At 8.5kN reveal load, the pressure tie took 6.4kN pullout load, the reveal pin tie took 5.9kN, again lower. A greater number of ‘equivalent tests’ with different couplers and rig dimensions would have to be carried out to give a full impression of whether pressure ties consistently outperform reveal ties. In reality, this is a test that favours the pressure tie. A new reveal pin tie can usually be manually installed to 8.5kN, all be it with some considerable difficulty, whereas the pressure ties would require mechanical assistance to achieve this load. A more realistic comparison may be gained by comparing them with a lower applied load pressure tie.

It is also possible that pressure ties may offer differing performance characteristics to reveal pin ties when subjected to lateral and/or inward loading. Further testing would have to be carried out to assess this hypothesis.

Figure 7 - Test 21, Reveal Pin Tie, Concrete Reveal, Dry Packing, Base Plate Foot

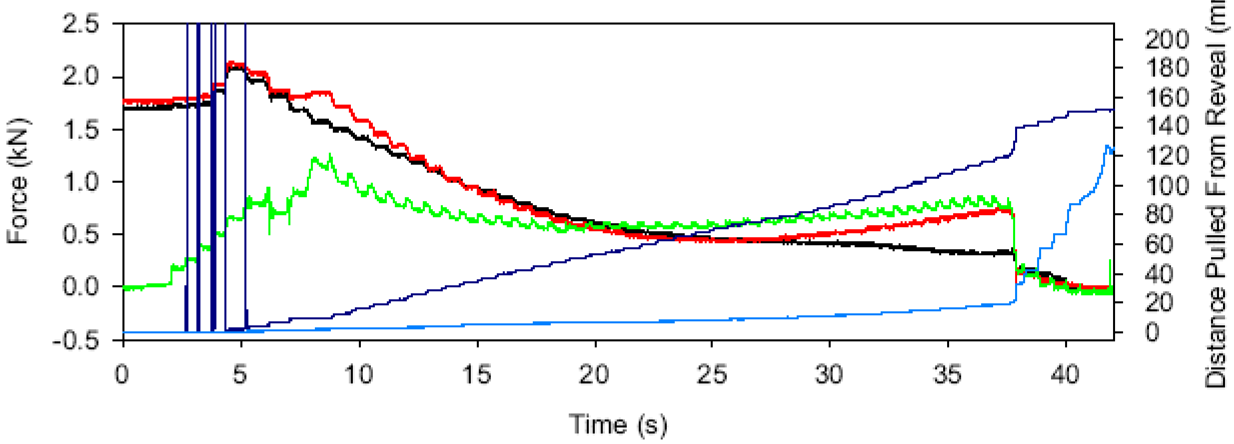


Figure 8 - Test 21r1, Reveal Pin Tie, Concrete Reveal, Dry Packing, No Foot

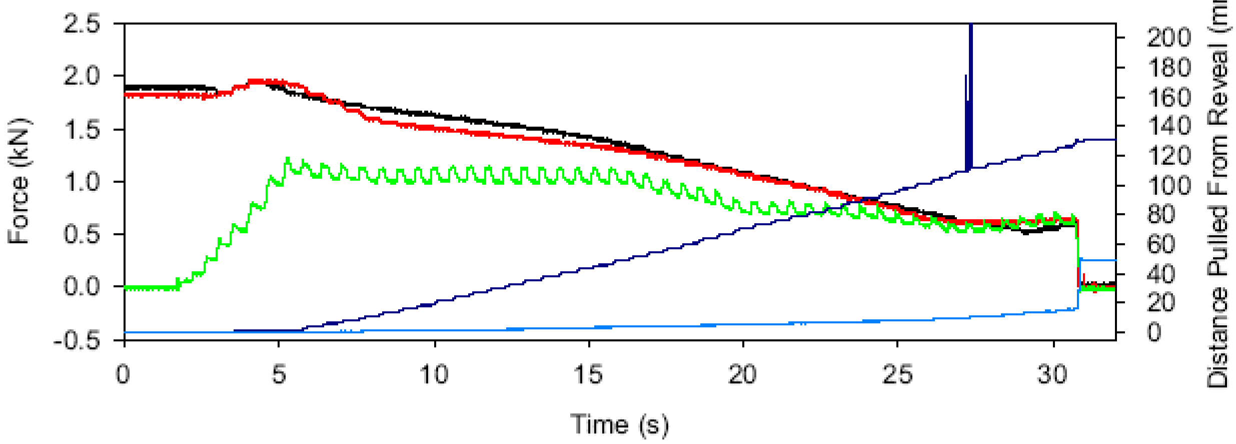
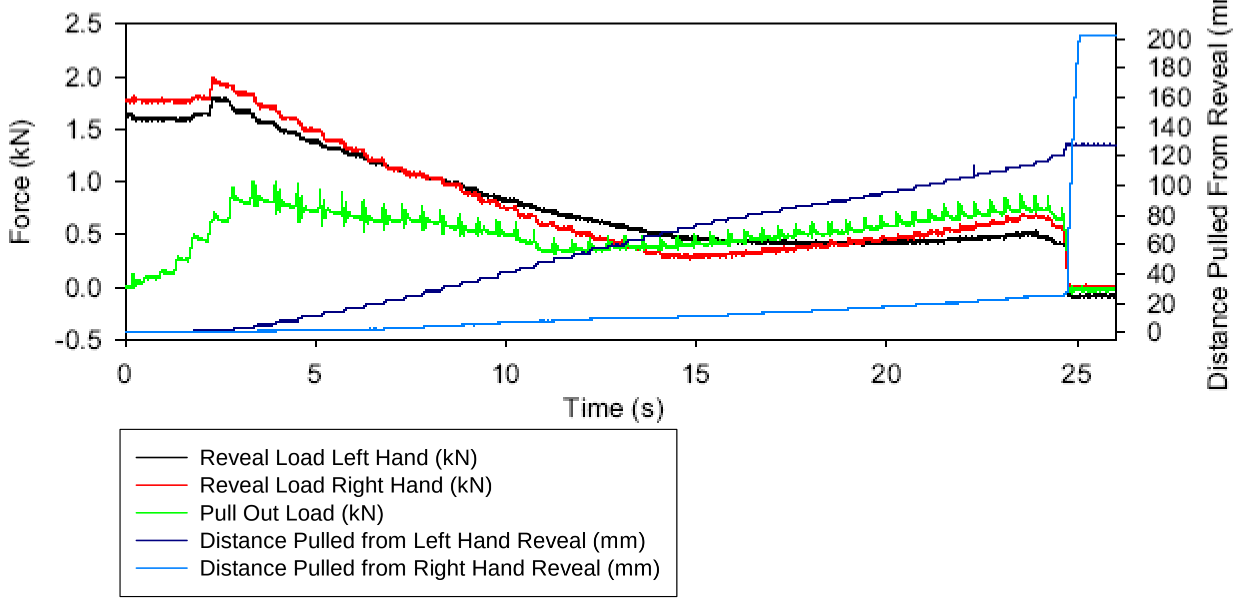
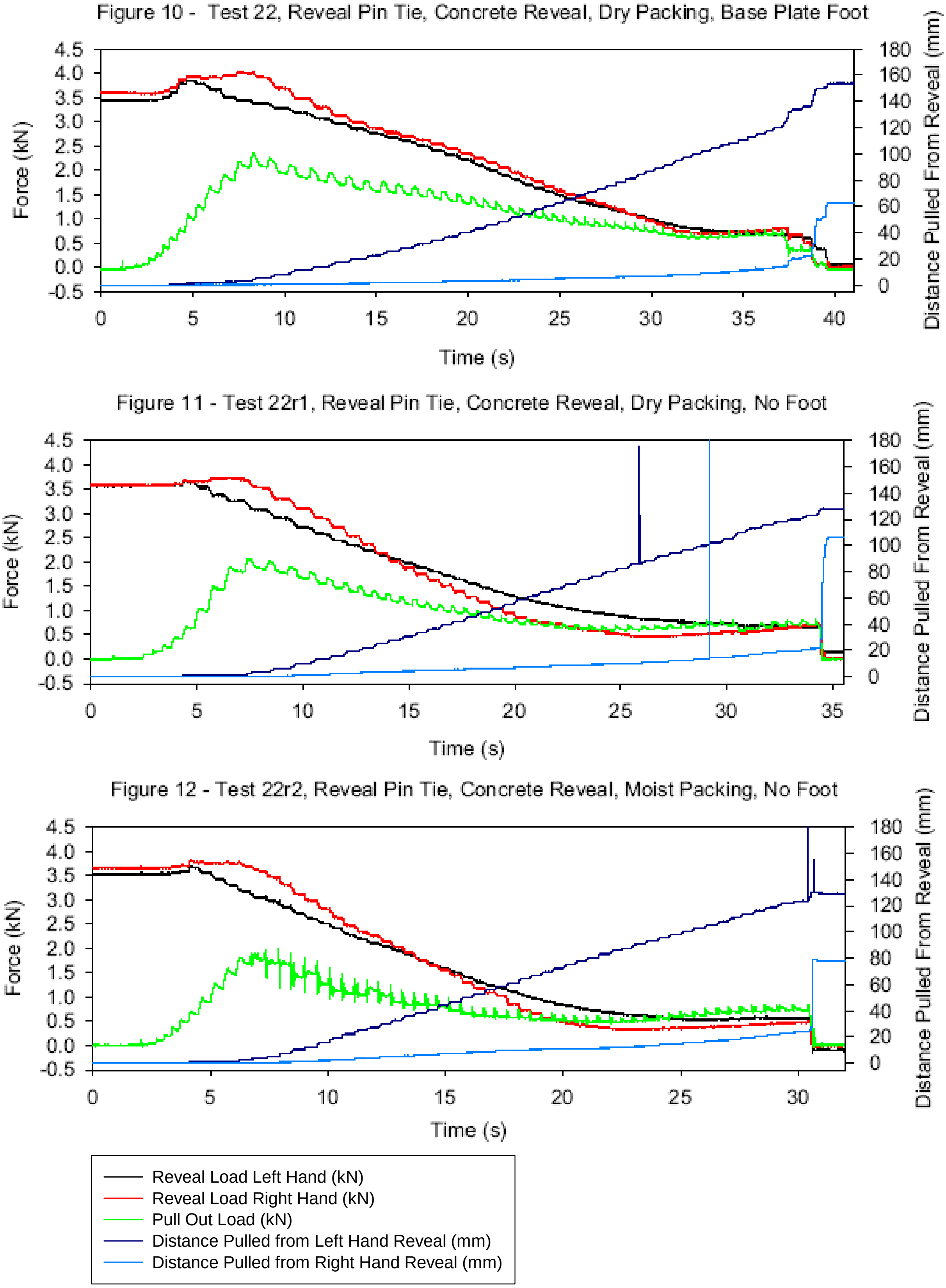


Figure 9 - Test 21r2, Reveal Pin Tie, Concrete Reveal, Moist Packing, No Foot



Figures 7, 8 & 9 – 1.8kN Reveal Load, Reveal Pin Tie Graphs, Pulled 150mm from Non-Jacking End



Figures 10, 11 & 12 – 3.6kN Reveal Load, Reveal Pin Tie Graphs, Pulled 150mm from Non-Jacking End

Figure 13 - Test 27, 6.0kN Reveal Load, Reveal Pin Tie, Concrete Reveal, Dry Packing, Base Plate Foot

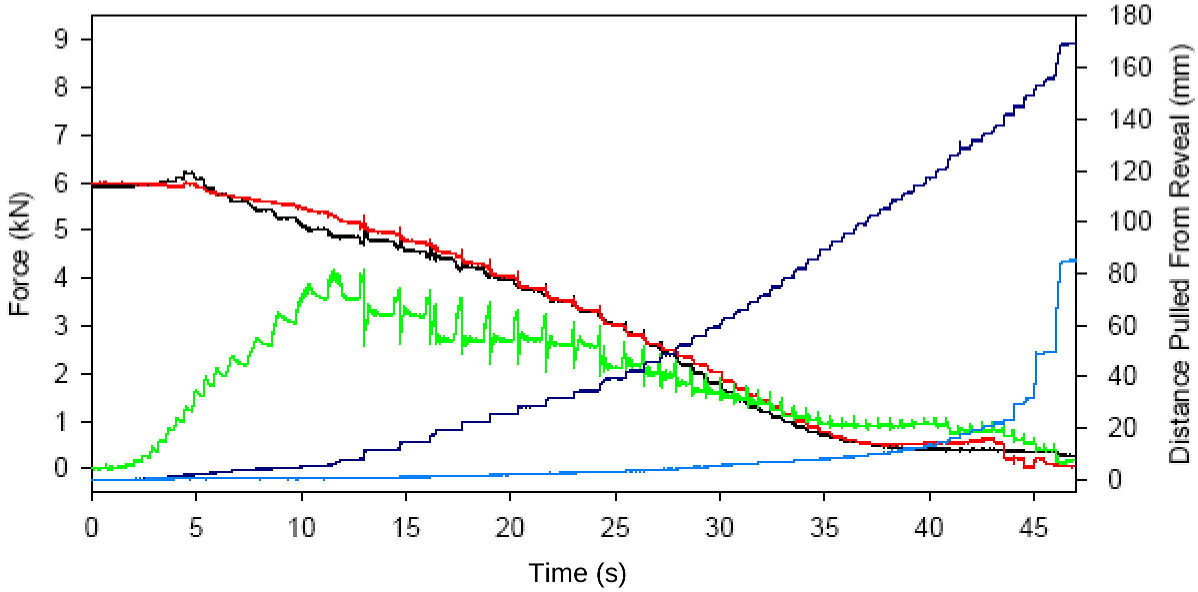
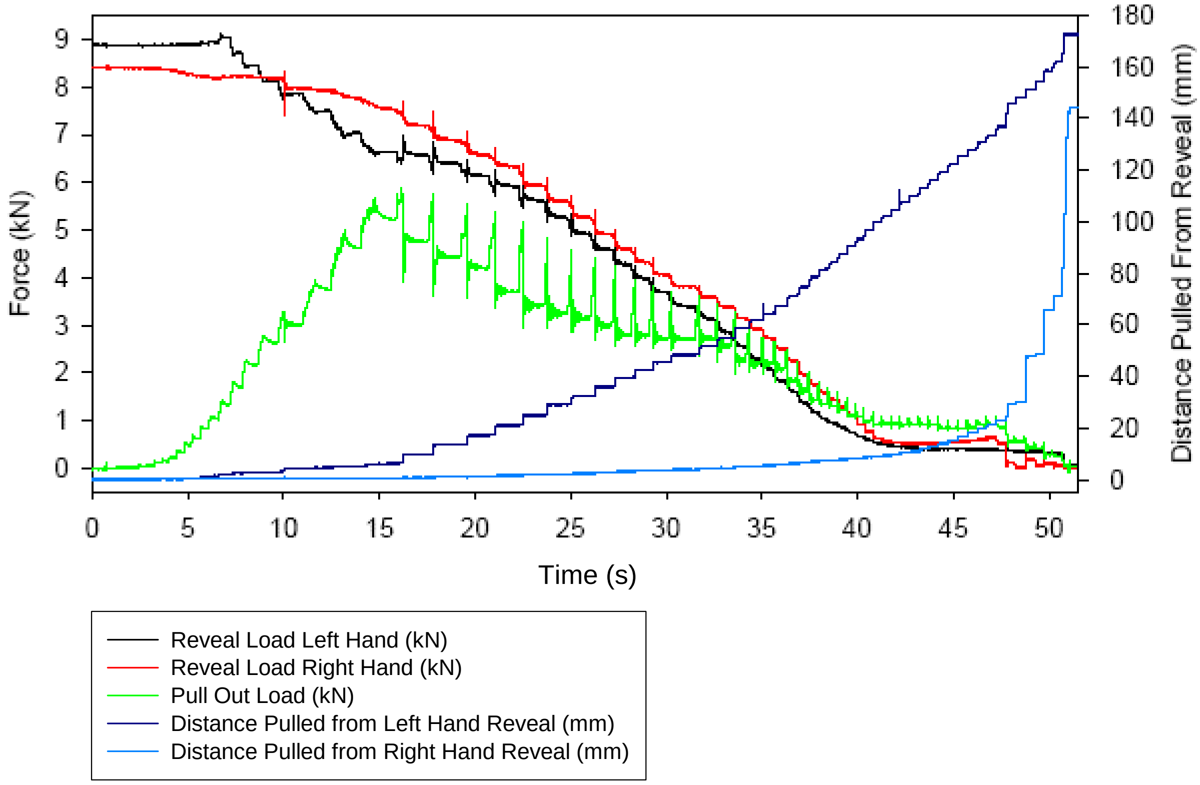


Figure 14 - Test 28, 8.5kN Reveal Load, Reveal Pin Tie, Concrete Reveal, Dry Packing, Base Plate Foot



Figures 13 & 14 – 6.0kN & 8.5kN Reveal Load, Reveal Pin Ties, Pulled 150mm from Non-Jacking End

Figure 15 - Test rp1, 1 Turn Reveal Pin Tie, Concrete Reveal

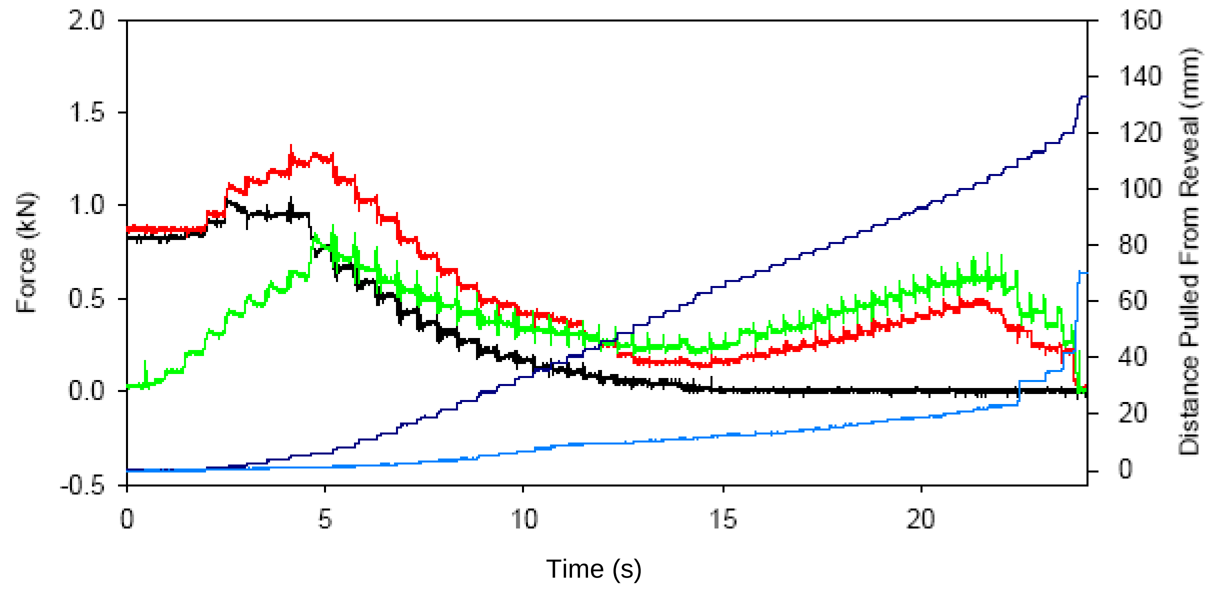
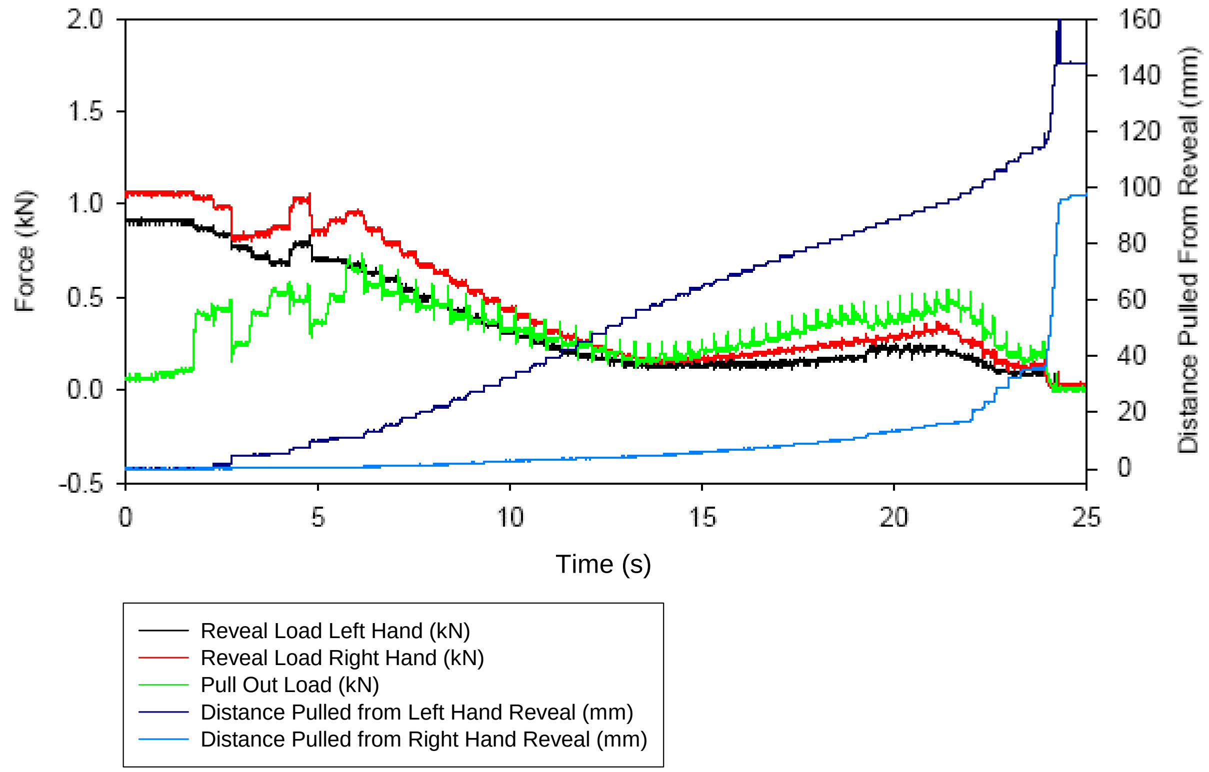


Figure 16 - Test rp9, 1 Turn Reveal Pin Tie, Brick Reveal



Figures 15 & 16 – 1 Turn Reveal Pin Ties, Pulled 150mm from Non-Jacking End, Moist Packing, 10 minutes bedding-in

Figure 17 - Test rp2, 2 Turn Reveal Pin Tie, Concrete Reveal

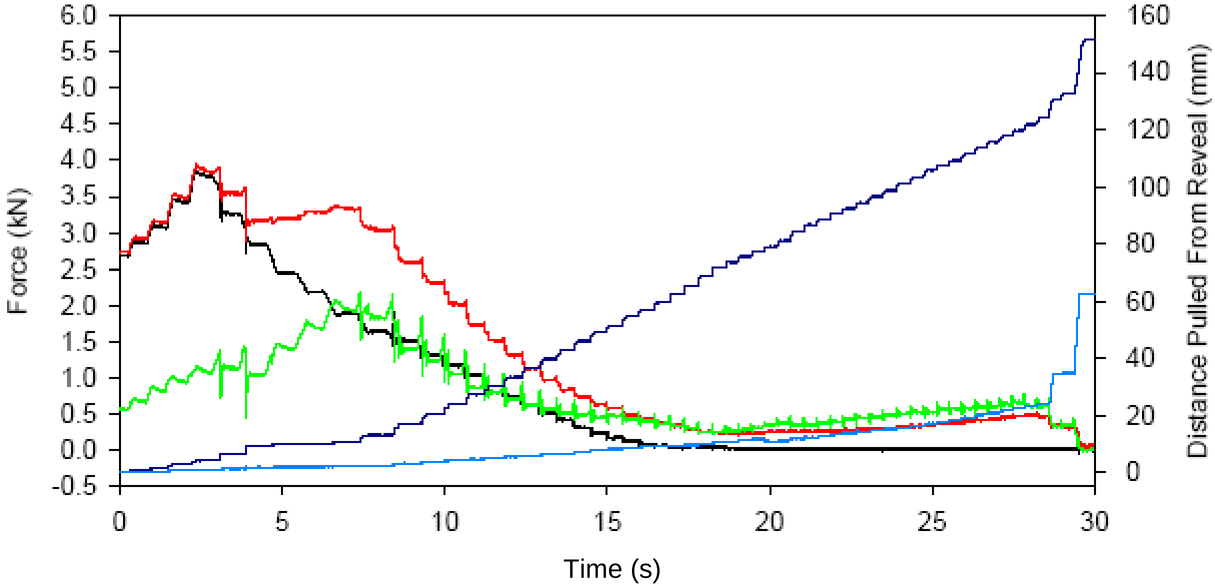
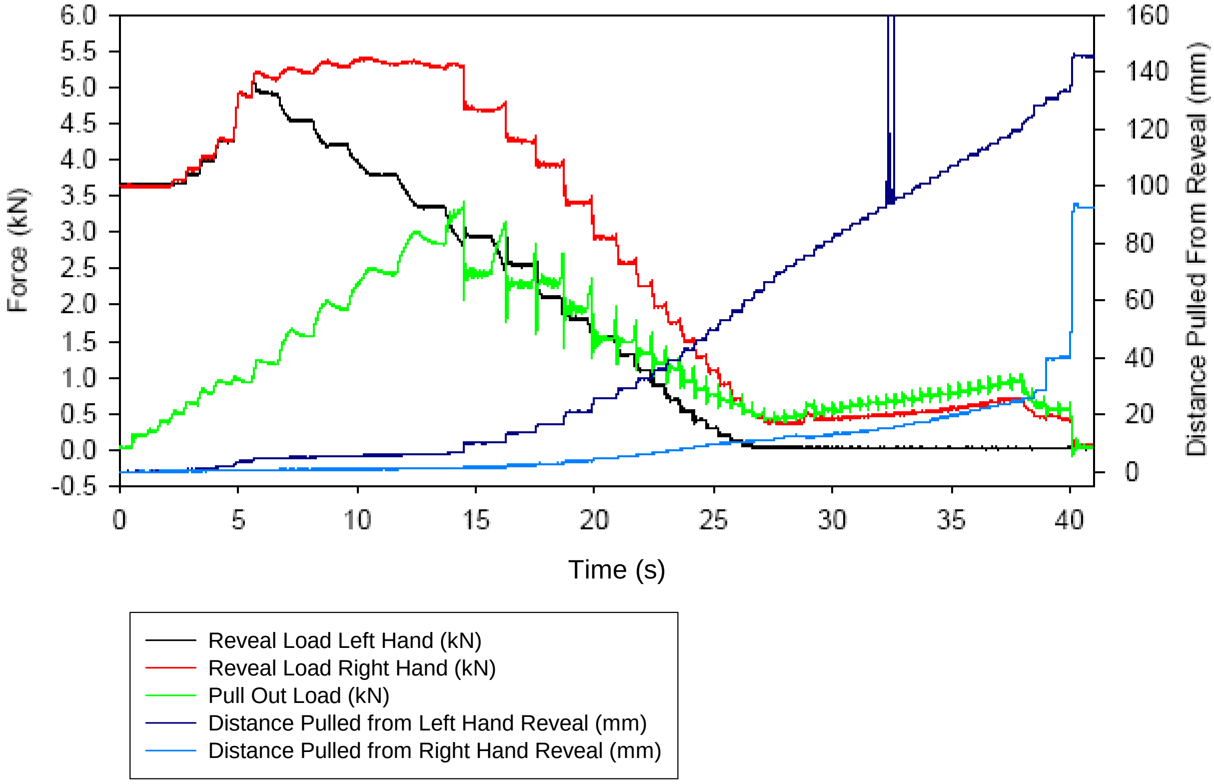


Figure 18 - Test rp3, 2 Turn Reveal Pin Tie, Concrete Reveal



Figures 17 & 18 – 2 Turn Reveal Pin Ties, Pulled 150mm from Non-Jacking End, Moist Packing, 10 minutes bedding-in

Figure 19 - Test rp4, 2 Turn Reveal Pin Tie, Concrete Reveal

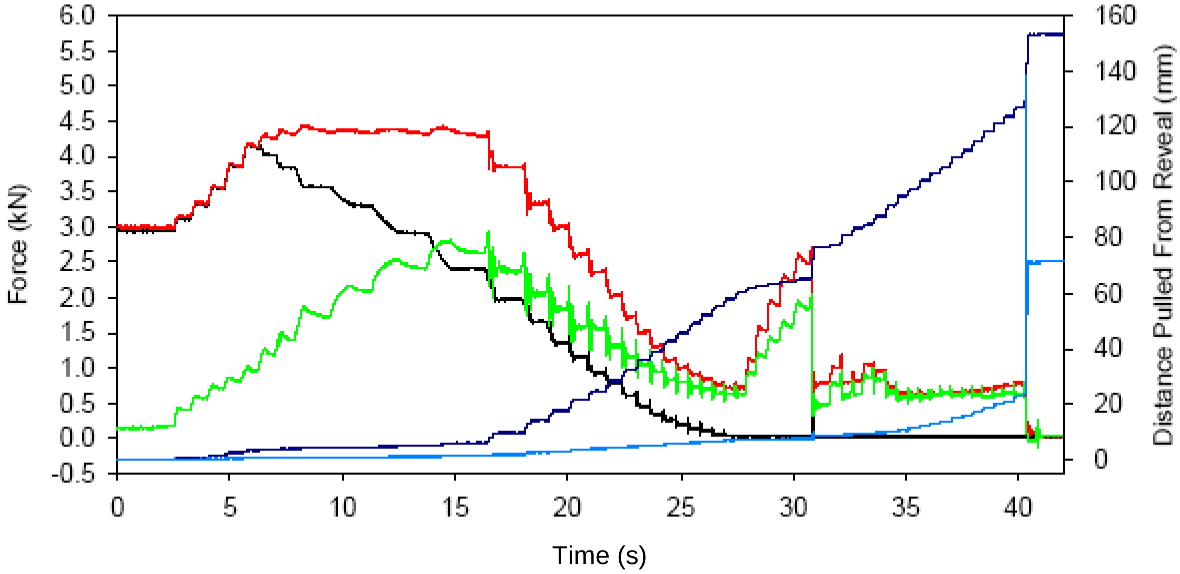
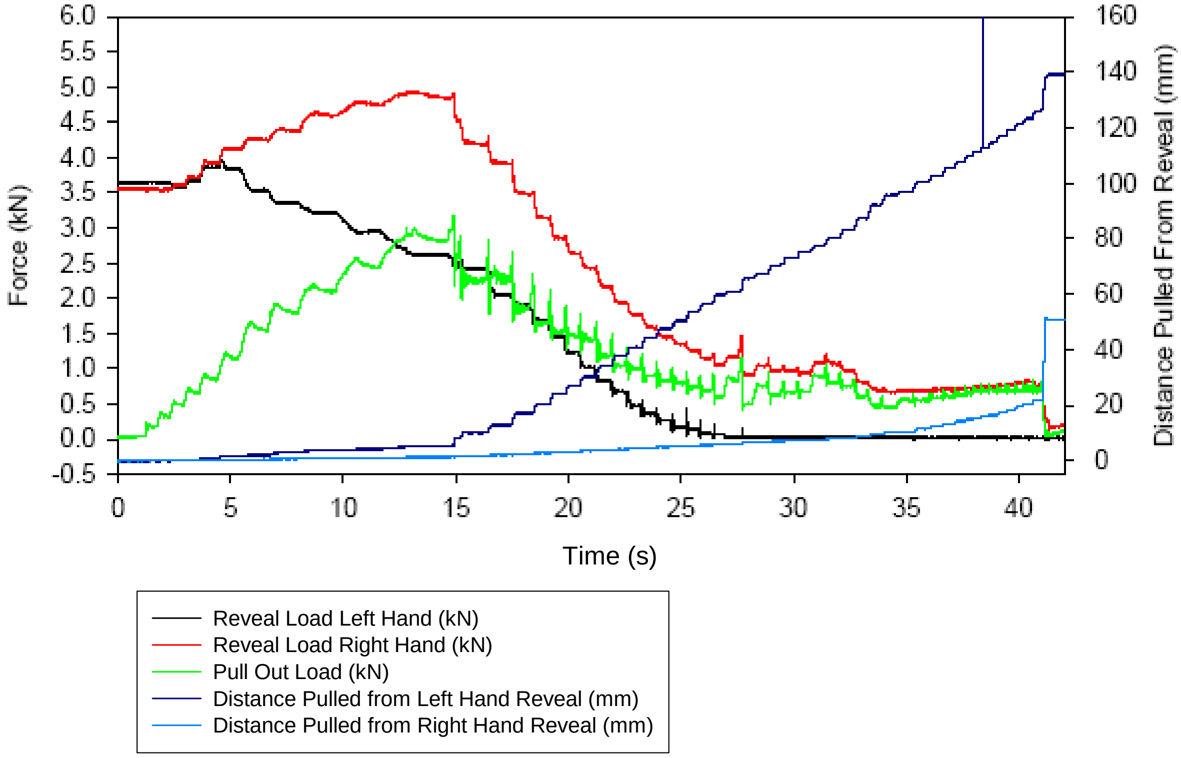


Figure 20 - Test rp5, 2 Turn Reveal Pin Tie, Concrete Reveal



Figures 19 & 20 – 2 Turn Reveal Pin Ties, Pulled 150mm from Non-Jacking End, Moist Packing, 10 minutes bedding-in

Figure 21 - Test rp6, 2 Turn Reveal Pin Tie, Concrete Reveal

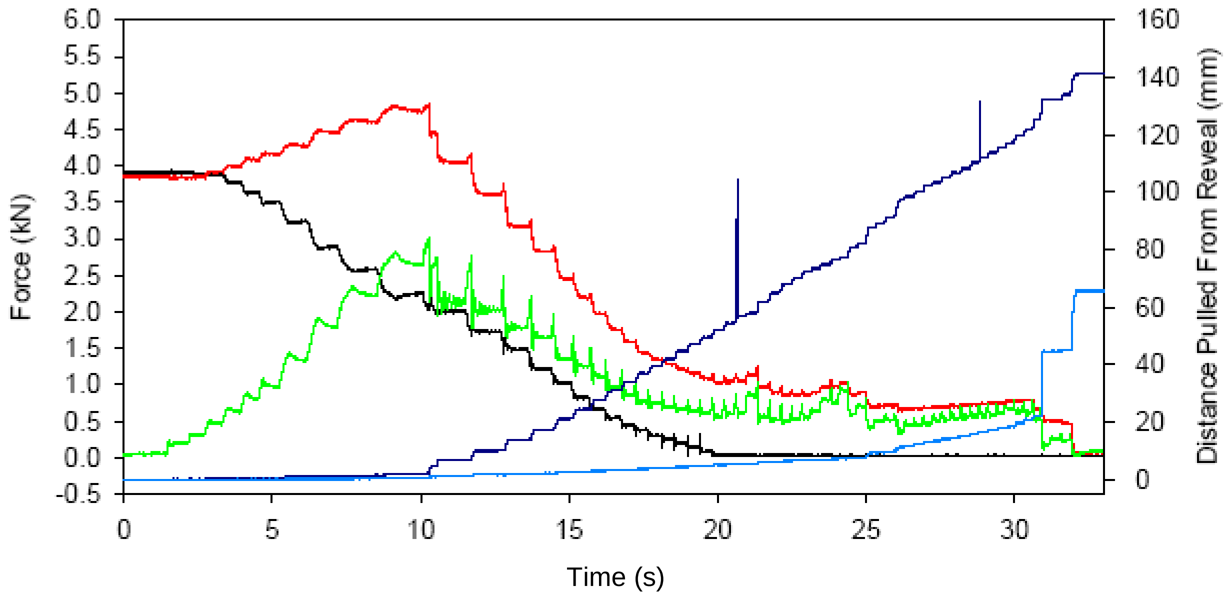
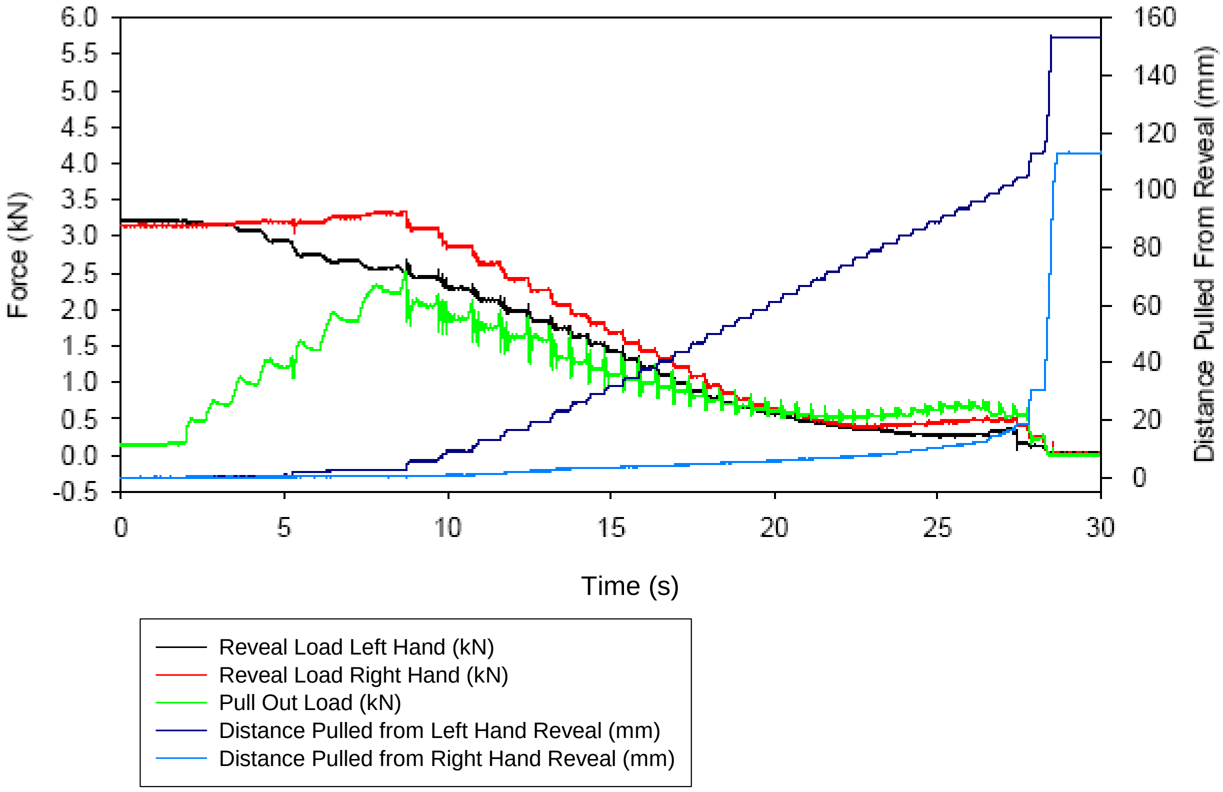


Figure 22 - Test rp10, 2 Turn Reveal Pin Tie, Brick Reveal



Figures 21 & 22 – 2 Turn Reveal Pin Ties, Pulled 150mm from Non-Jacking End, Moist Packing, 10 minutes bedding-in

Figure 23 - Test rp7, 3 Turn Reveal Pin Tie, Concrete Reveal

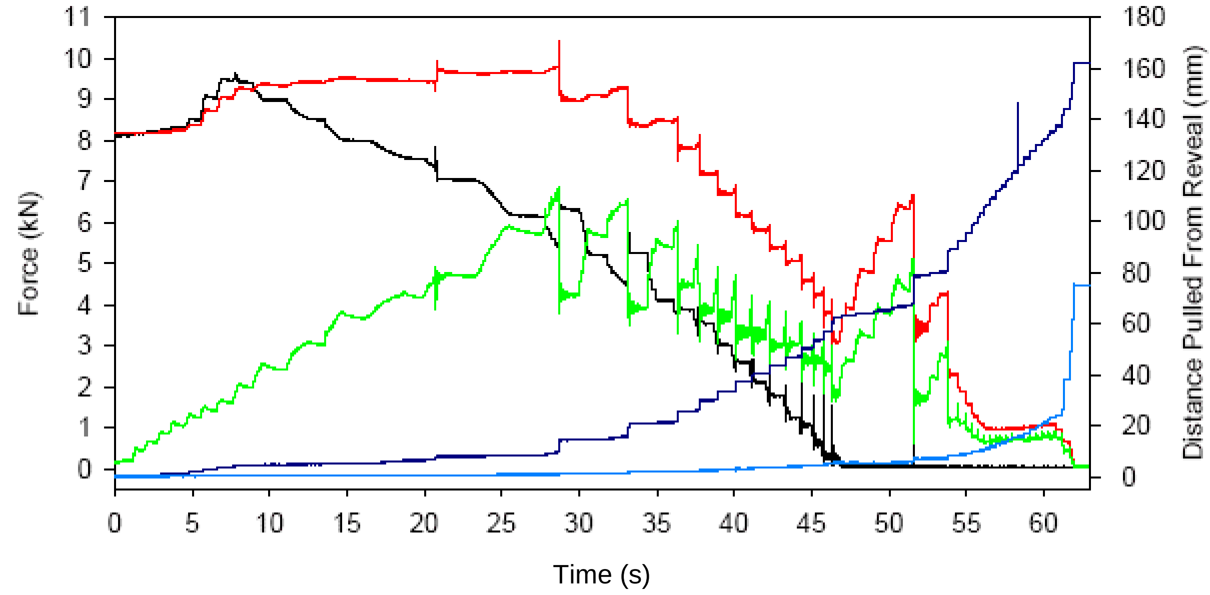
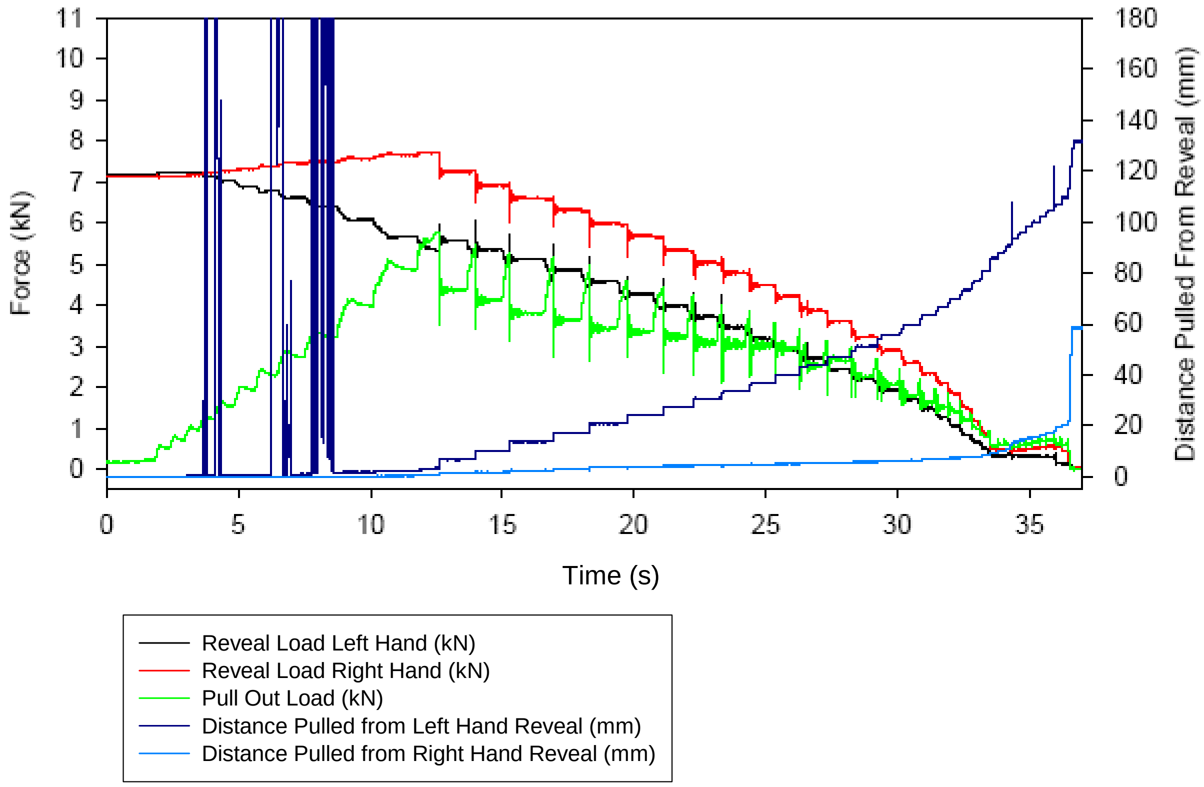


Figure 24 - Test rp11, 3 Turn Reveal Pin Tie, Brick Reveal



Figures 23 & 24 – 3 Turn Reveal Pin Ties, Pulled 150mm from Non-Jacking End, Moist Packing, 10 minutes bedding-in

Figure 25 - Test rp8, $3\ {}^{1}/_{3}$ Turn Reveal Pin Tie, Concrete Reveal

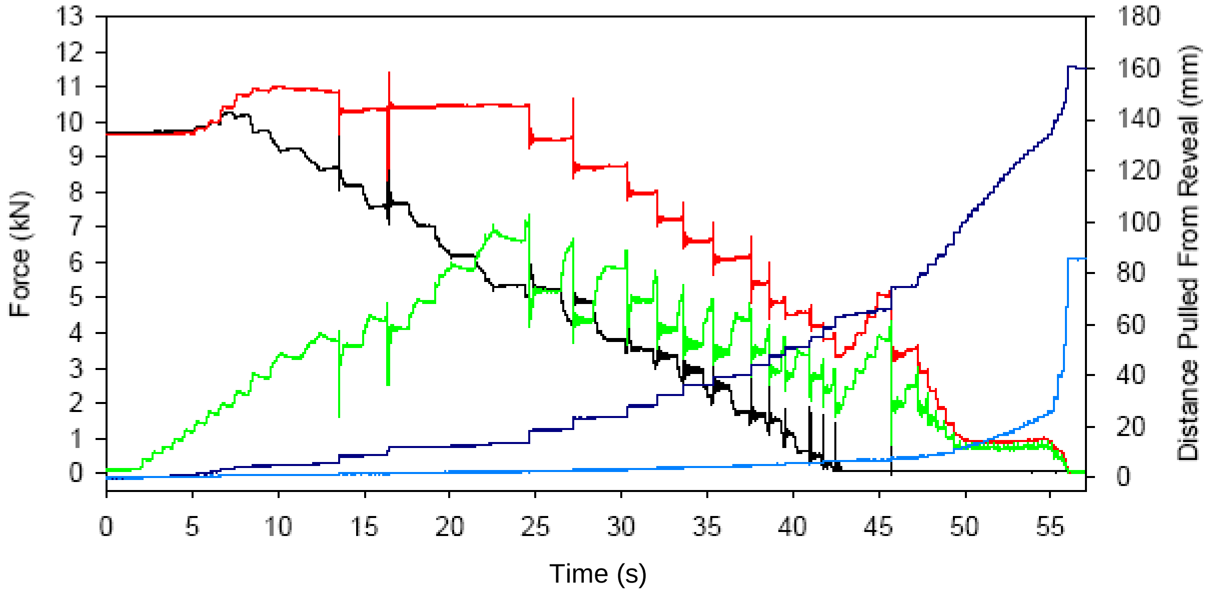
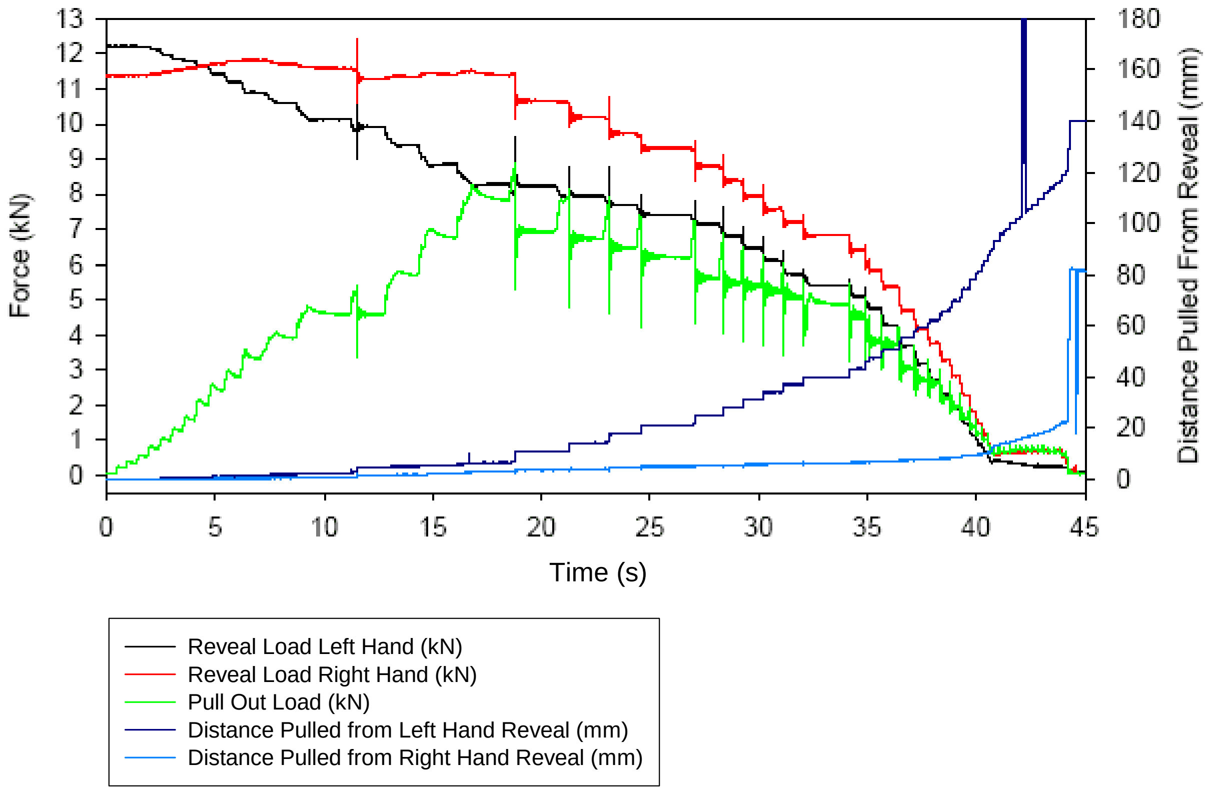


Figure 26 - Test rp12, $3\ {}^{1}/_{3}$ Turn Reveal Pin Tie, Brick Reveal



Figures 25 & 26 – $3\ {}^{1}/_{3}$ Turn Reveal Pin Ties, Pulled 150mm from Non-Jacking End, Moist Packing, 10 minutes bedding-in

Figure 27 - Test rp17, 1 Turn Reveal Pin Tie, Concrete Reveal

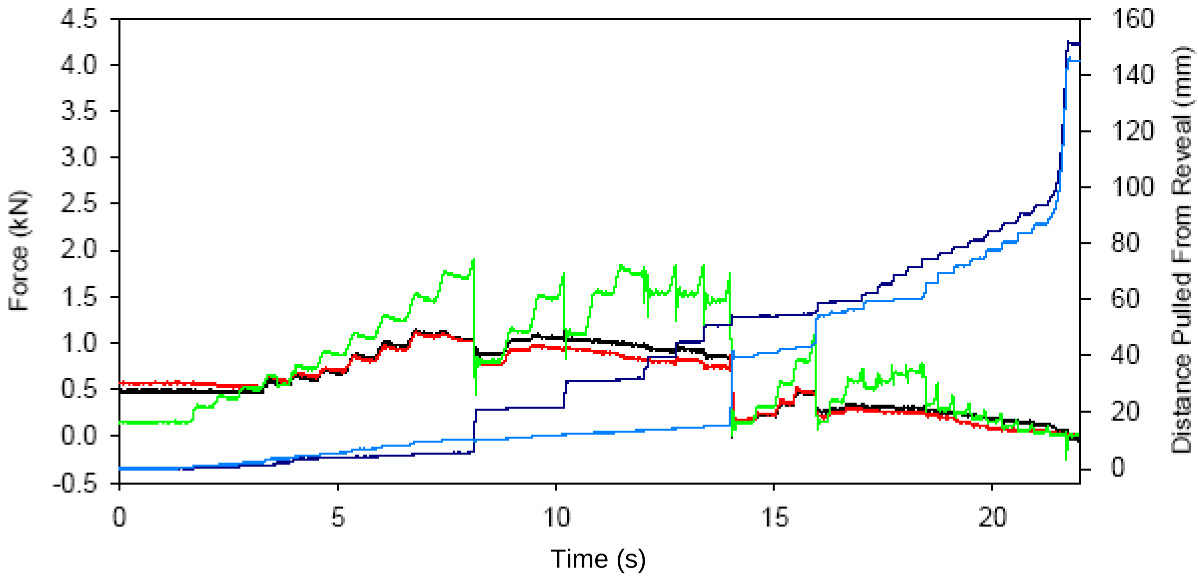
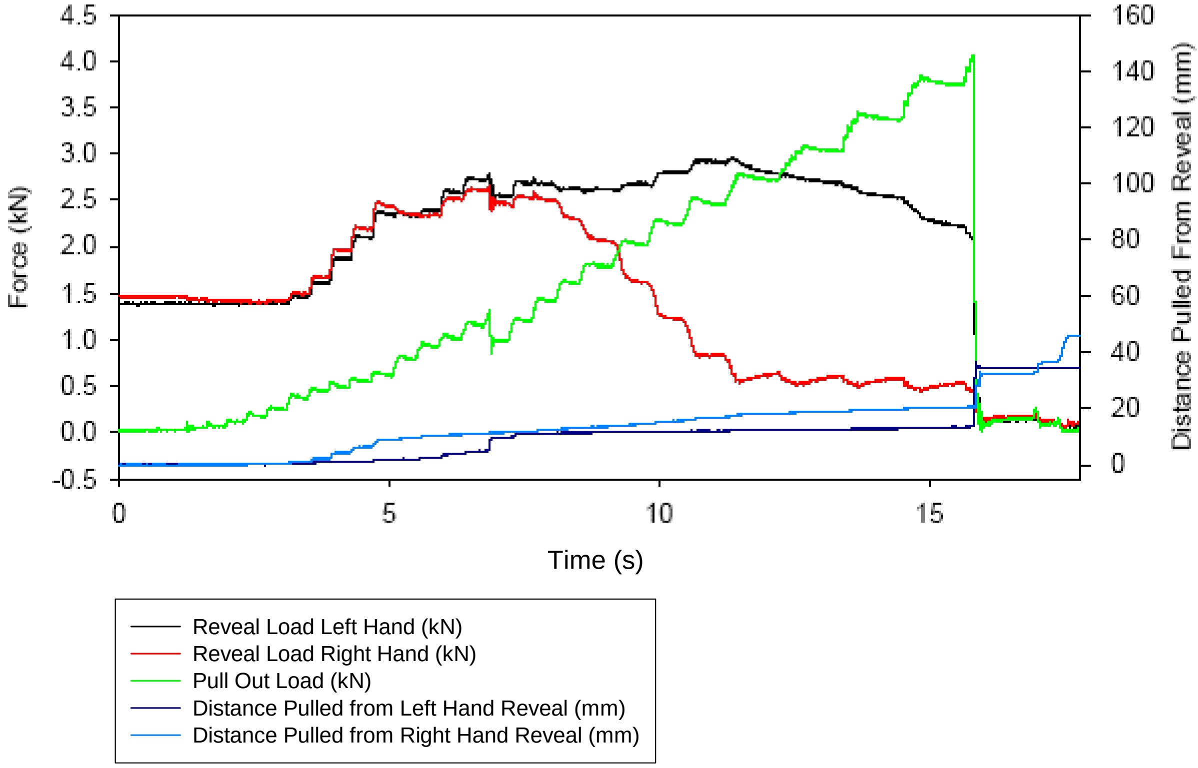


Figure 28 - Test rp13, 1 Turn Reveal Pin Tie, Brick Reveal



Figures 27 & 28 – 1 Turn Reveal Pin Ties, Pulled from Centre of Reveal Tube, Moist Packing, 10 minutes bedding-in

Figure 29 - Test rp18, 2 Turn Reveal Pin Tie, Concrete Reveal

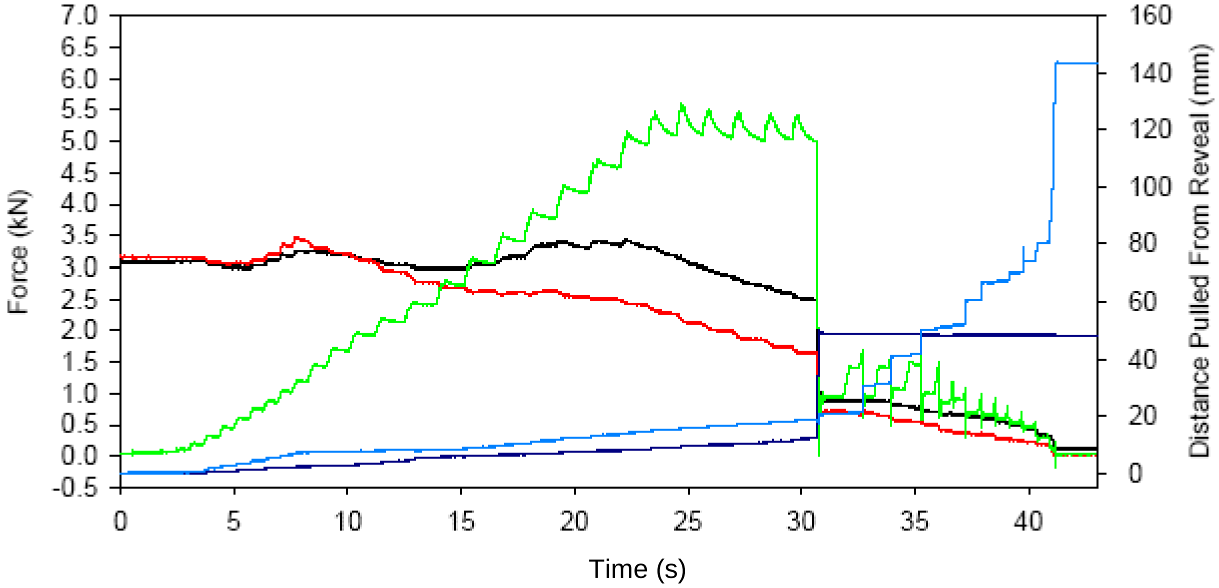
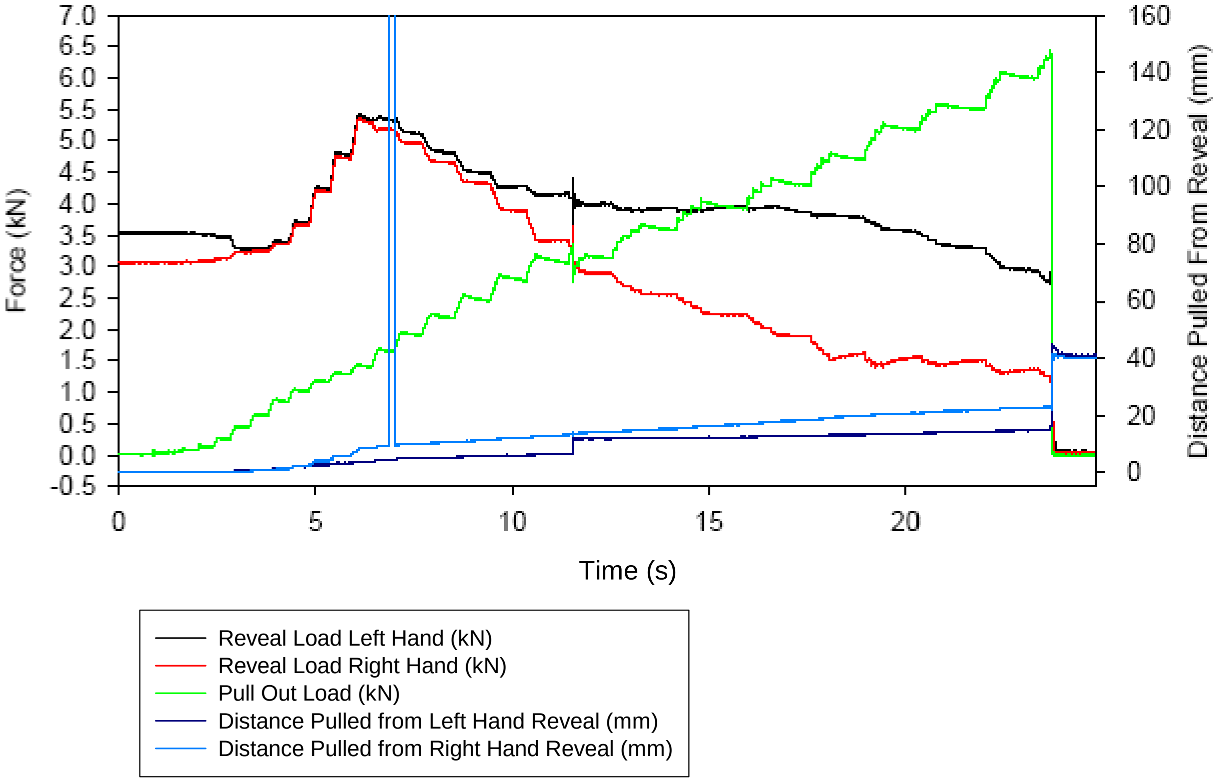


Figure 30 - Test rp14, 2 Turn Reveal Pin Tie, Brick Reveal



Figures 29 & 30 – 2 Turn Reveal Pin Ties, Pulled from Centre of Reveal Tube, Moist Packing, 10 minutes bedding-in

Figure 31 - Test rp19, 3 Turn Reveal Pin Tie, Concrete Reveal

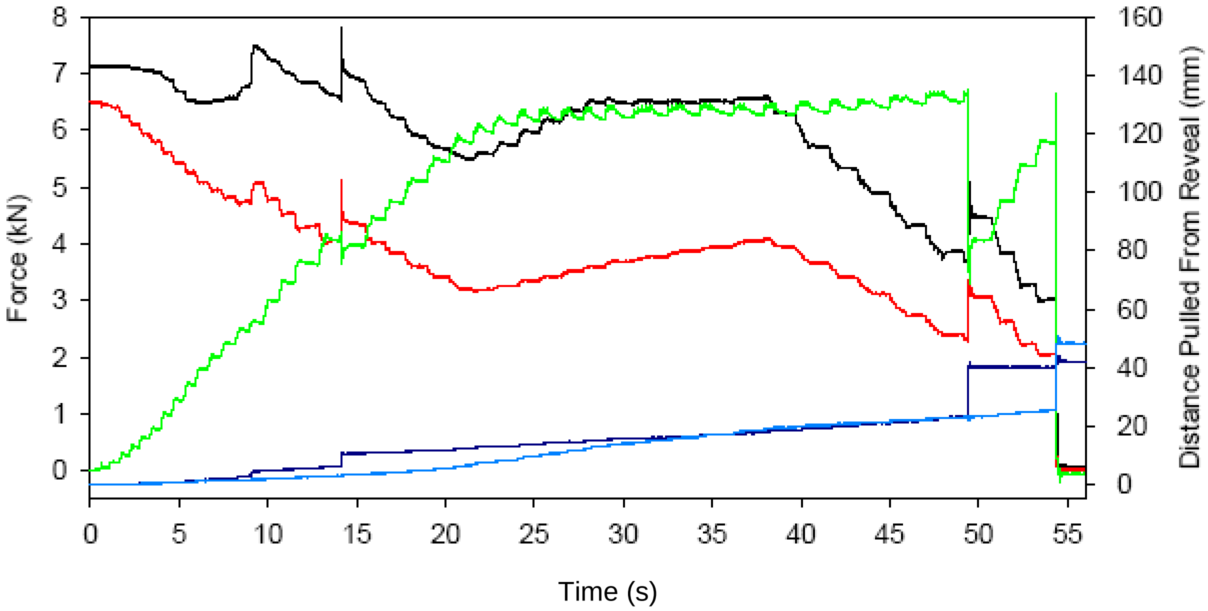
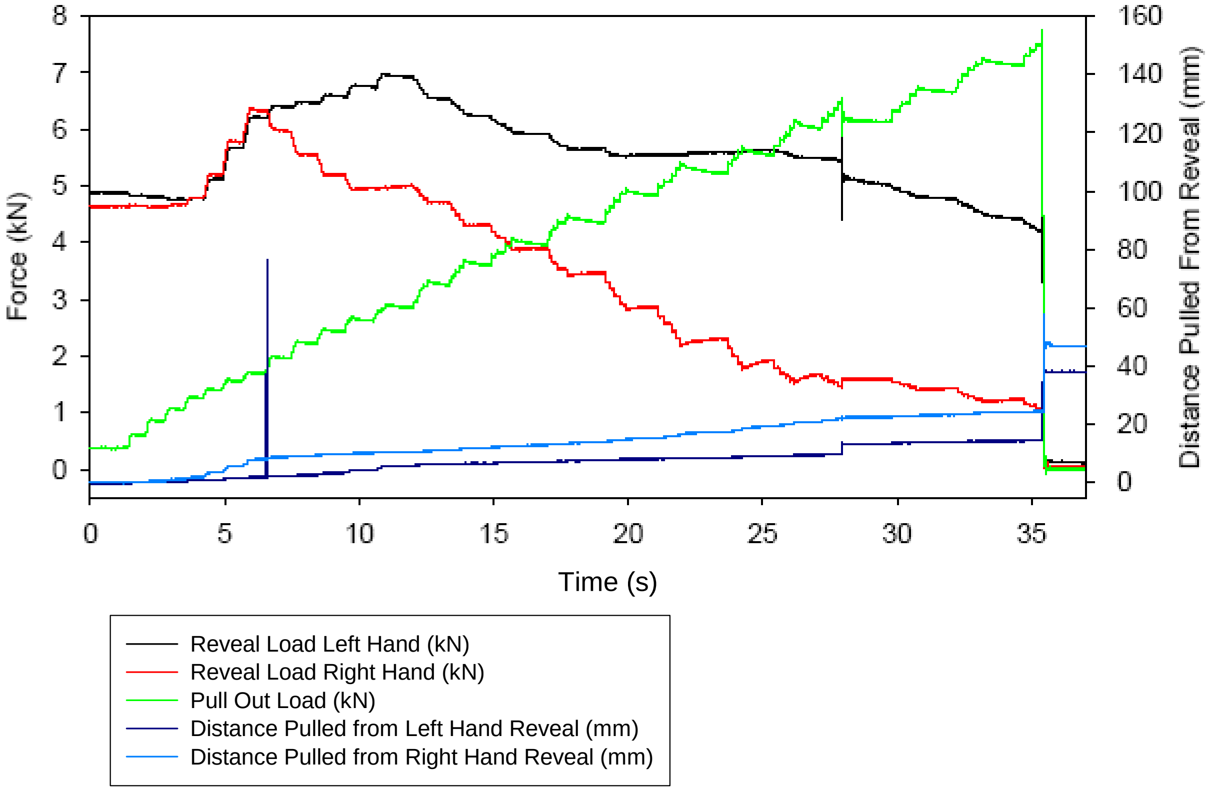


Figure 32 - Test rp15, 3 Turn Reveal Pin Tie, Brick Reveal



Figures 31 & 32 – 3 Turn Reveal Pin Ties, Pulled from Centre of Reveal Tube, Moist Packing, 10 minutes bedding-in

Figure 33 - Test rp20, 3 $^{1}/_{3}$ Turn Reveal Pin Tie, Concrete Reveal

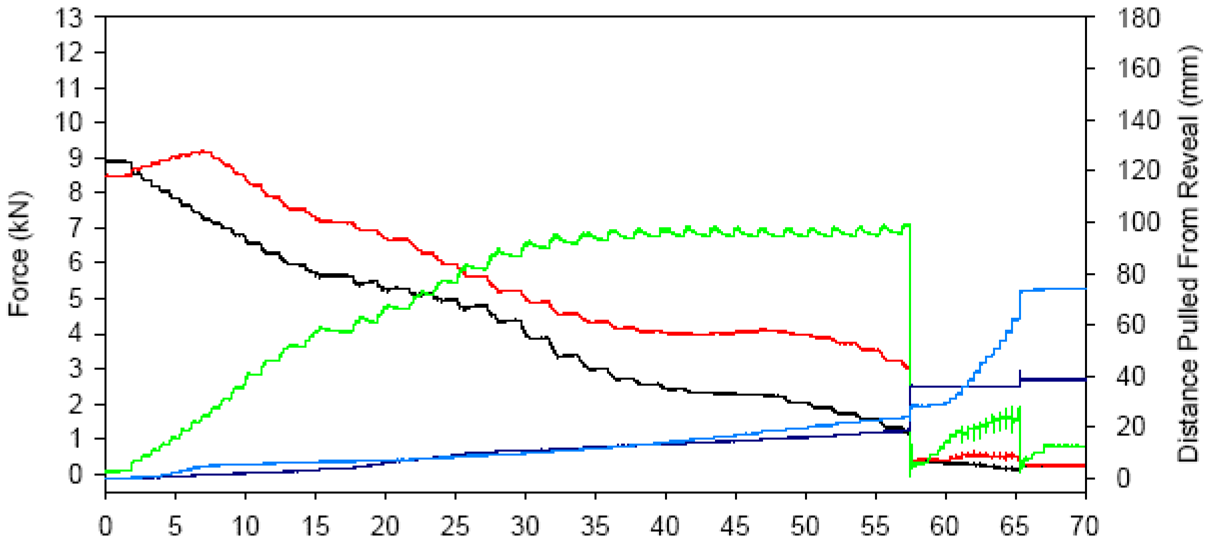
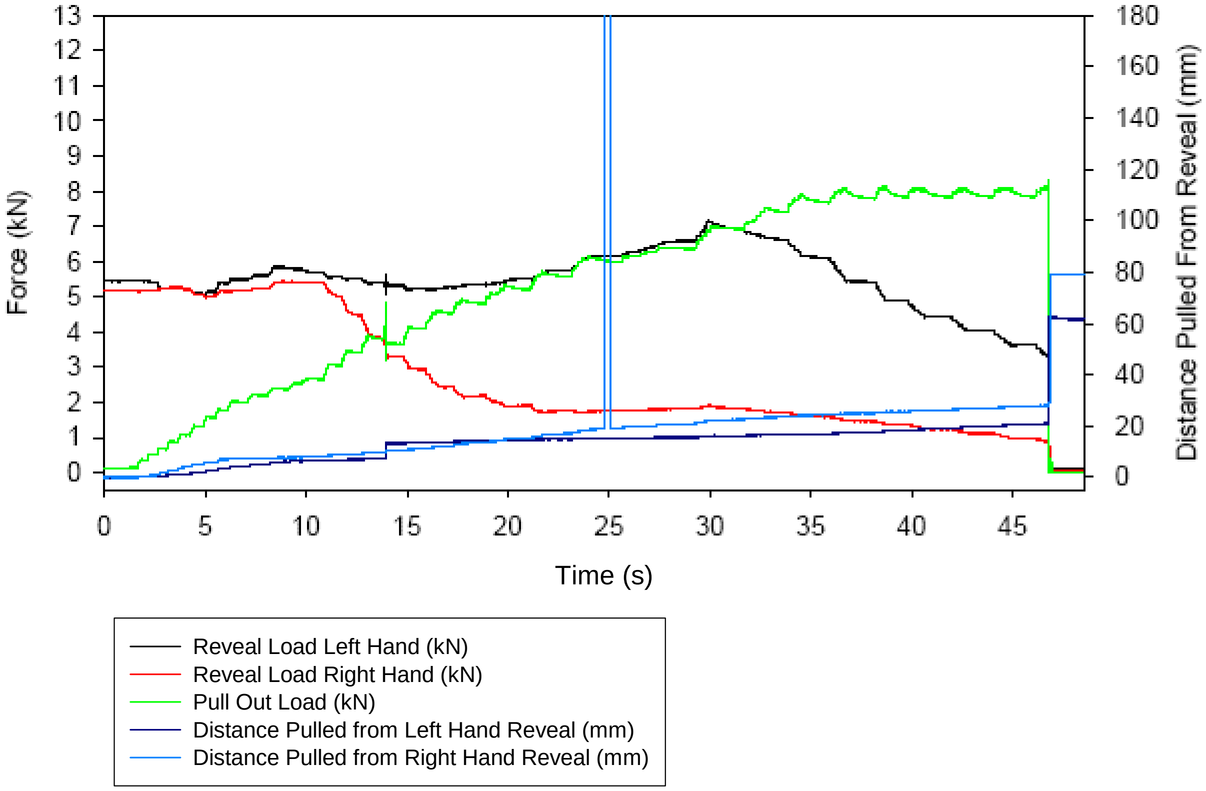


Figure 34 - Test rp16, 3 $^{1}/_{3}$ Turn Reveal Pin Tie, Brick Reveal



Figures 33 & 34 – 3 $^{1}/_{3}$ Turn Reveal Pin Ties, Pulled from Centre of Reveal Tube, Moist Packing, 10 minutes bedding-in

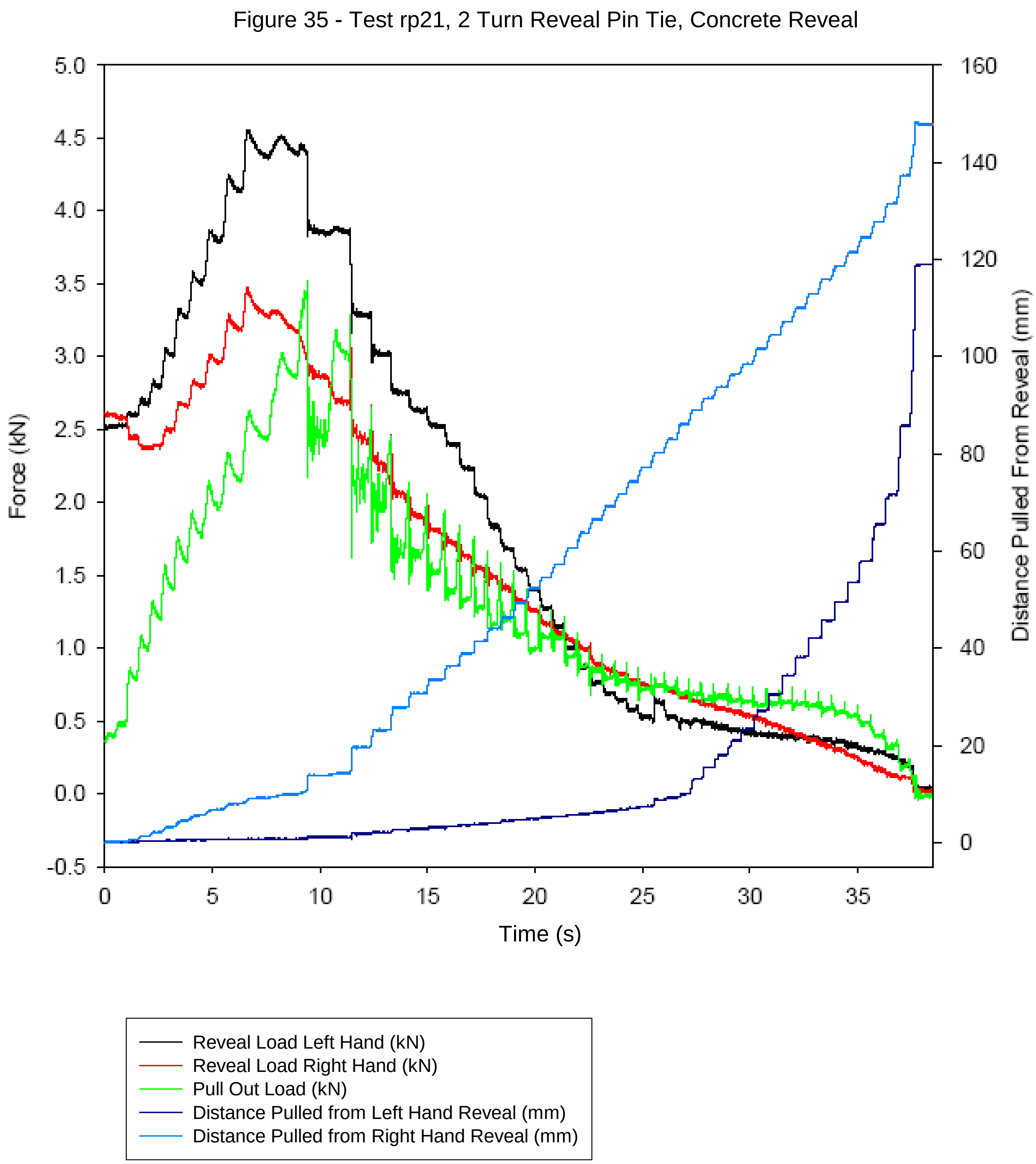
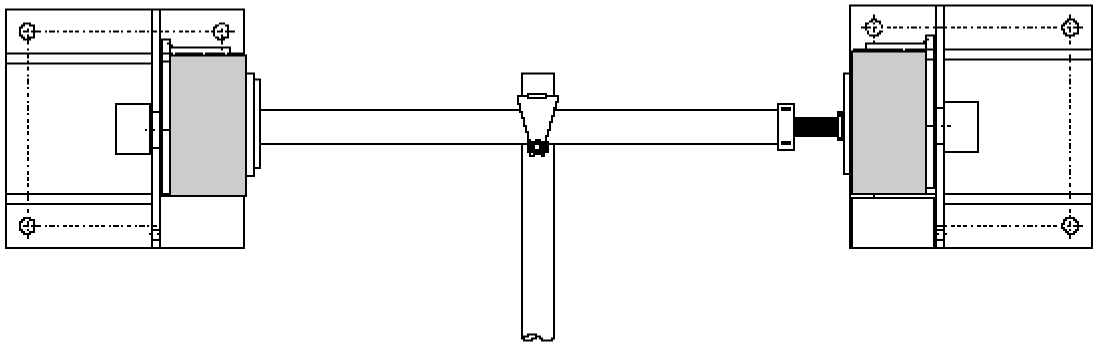
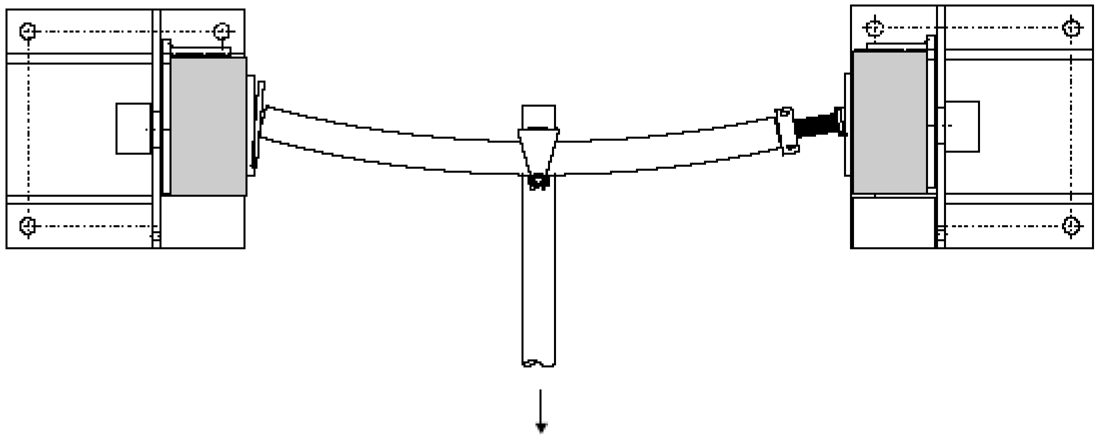


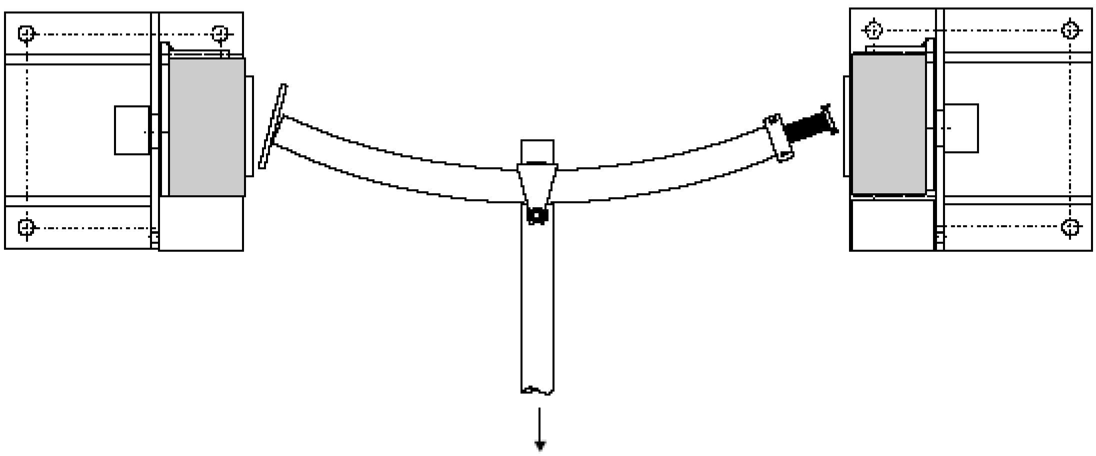
Figure 35 – 2 Turn Reveal Pin Tie, Pulled 150mm from Jacking End, Moist Packing, 10 minutes bedding-in



Stage 1 - The tie is tightened into the reveal



Stage 2 - As the pullout load is applied, the reveal tube bends, increasing the overall length which increases the reveal load



Stage 3 - As the tube continues to bend, it exceeds the critical point where the length starts to decrease and reveal load drops off. As permanent bending occurs, pullout load levels off.

Figure 36 – Loading of Centrally Pulled Reveal Pin Ties

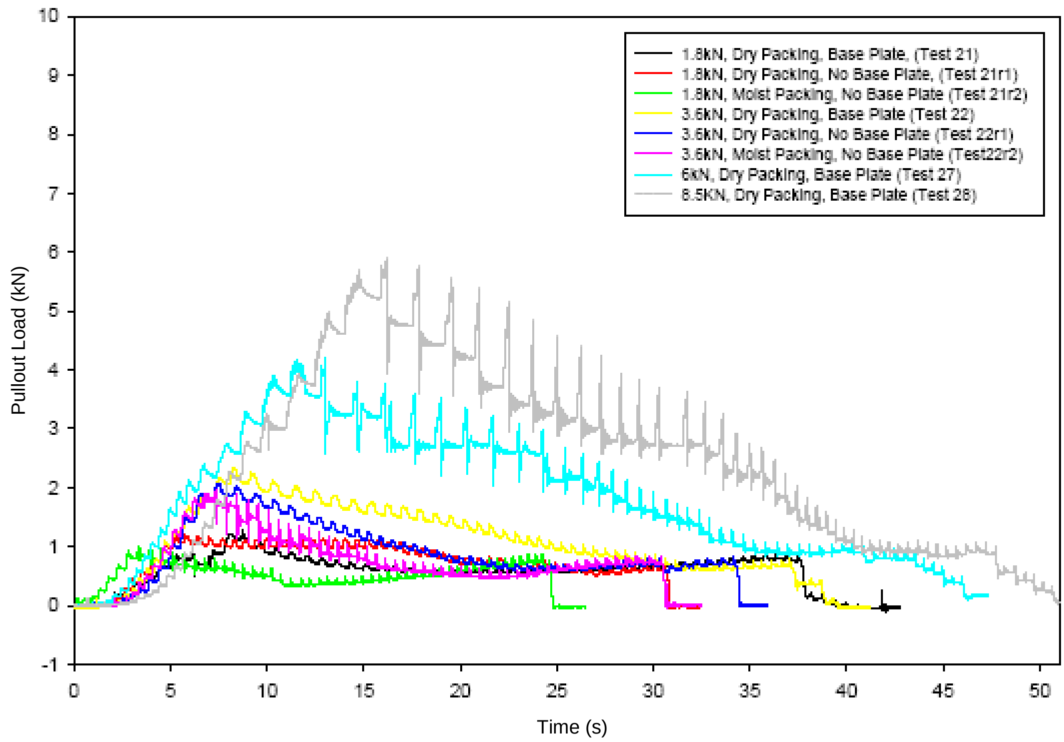


Figure 37 – Comparison of Reveal Pin Tie installation methods, Pulled 150mm from Non-Jacking End, Concrete Reveal

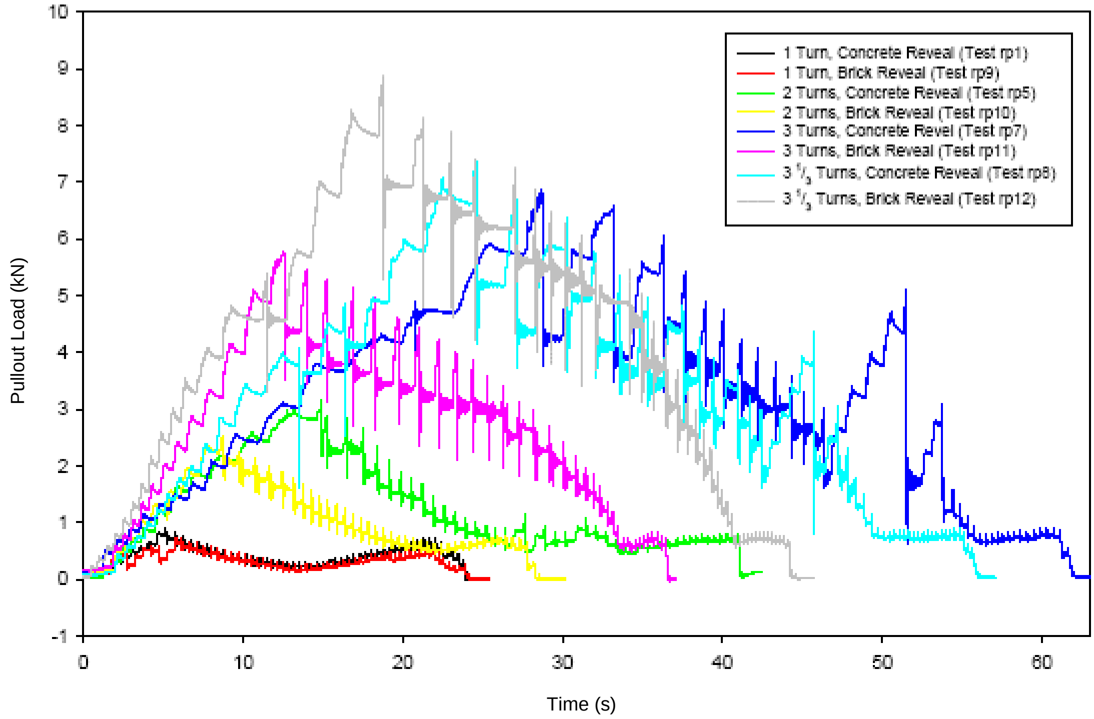


Figure 38 – Comparison of Reveal Pin Ties Pulled 150mm from Non-Jacking End

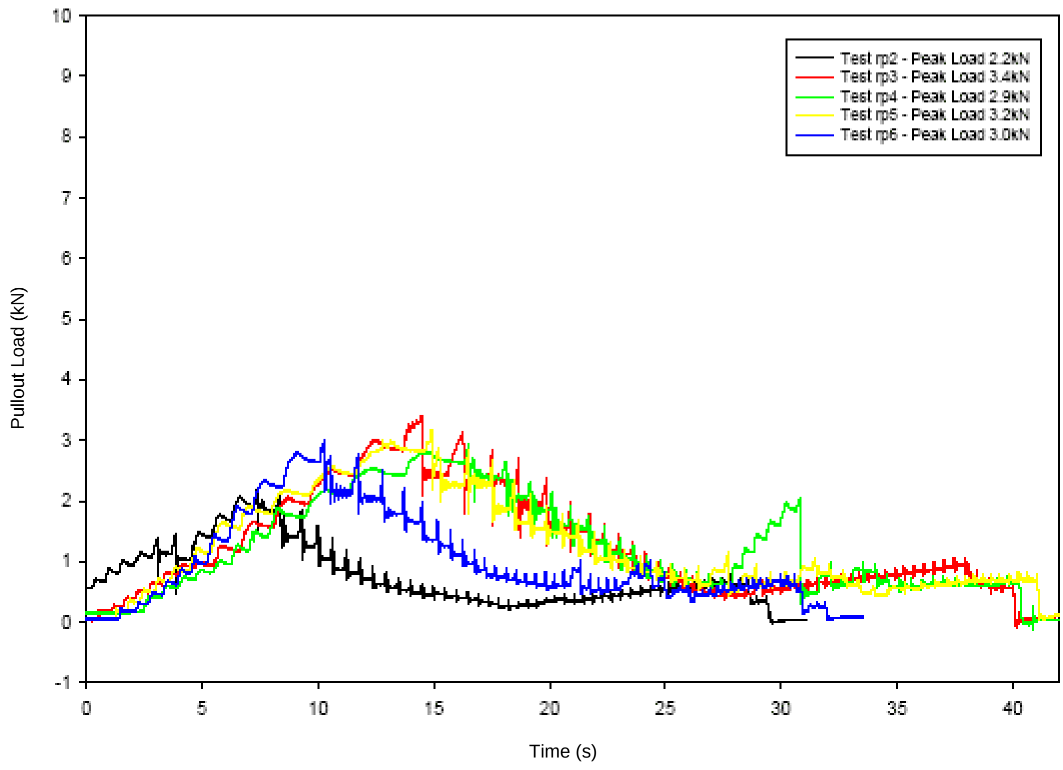


Figure 39 – Comparison of 2 Turn Reveal Pin Ties Installed in a Concrete Reveal, Pulled 150mm from Non-Jacking End

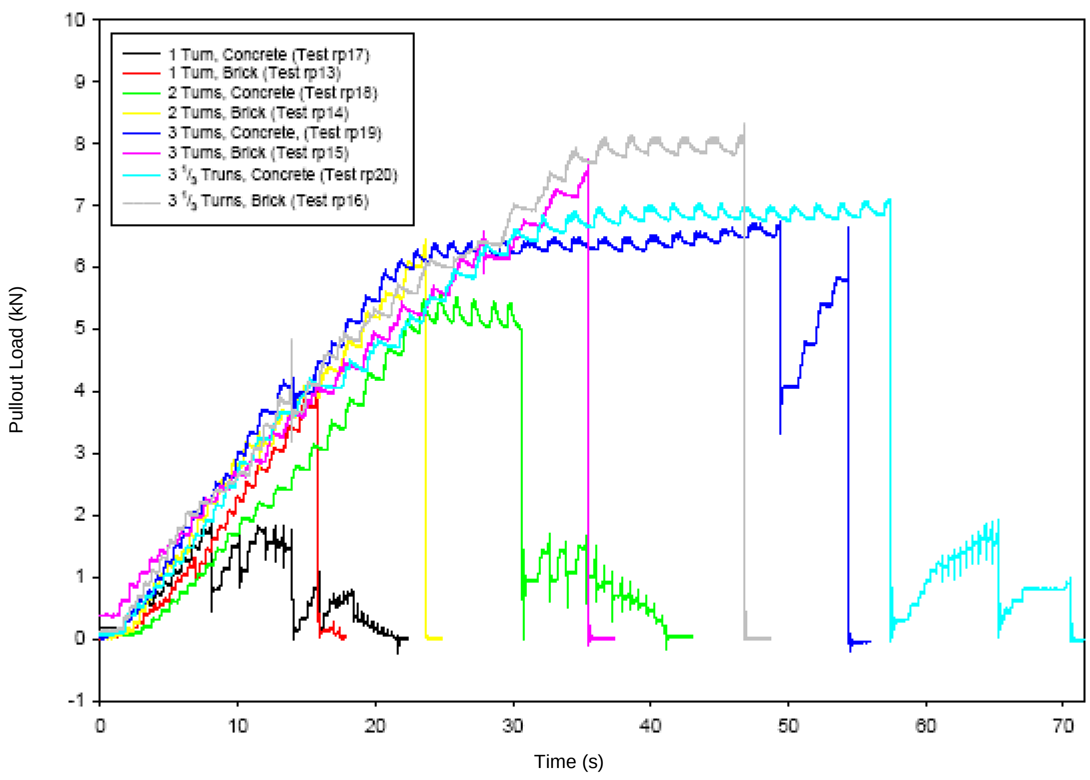


Figure 40 – Comparison of Centrally Pulled Reveal Pin Tie Tests

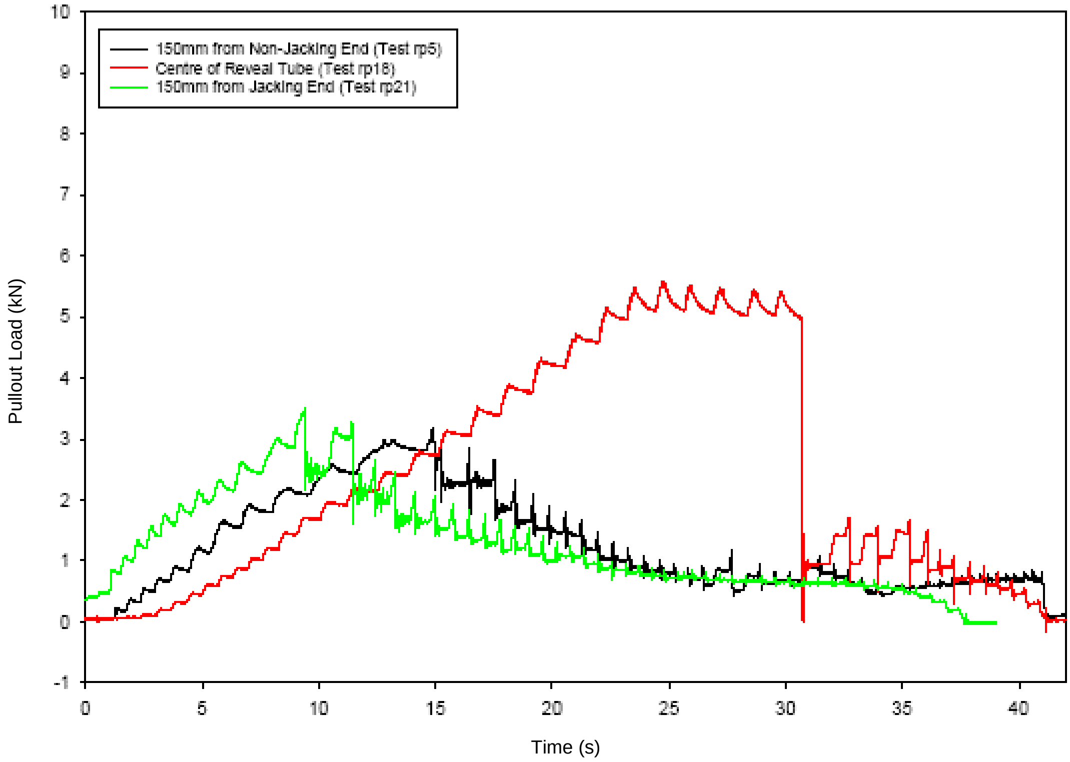


Figure 41 – Comparison of Effects of Pull tube Location on 2 Turn Reveal Pin Ties Installed in a Concrete Reveal

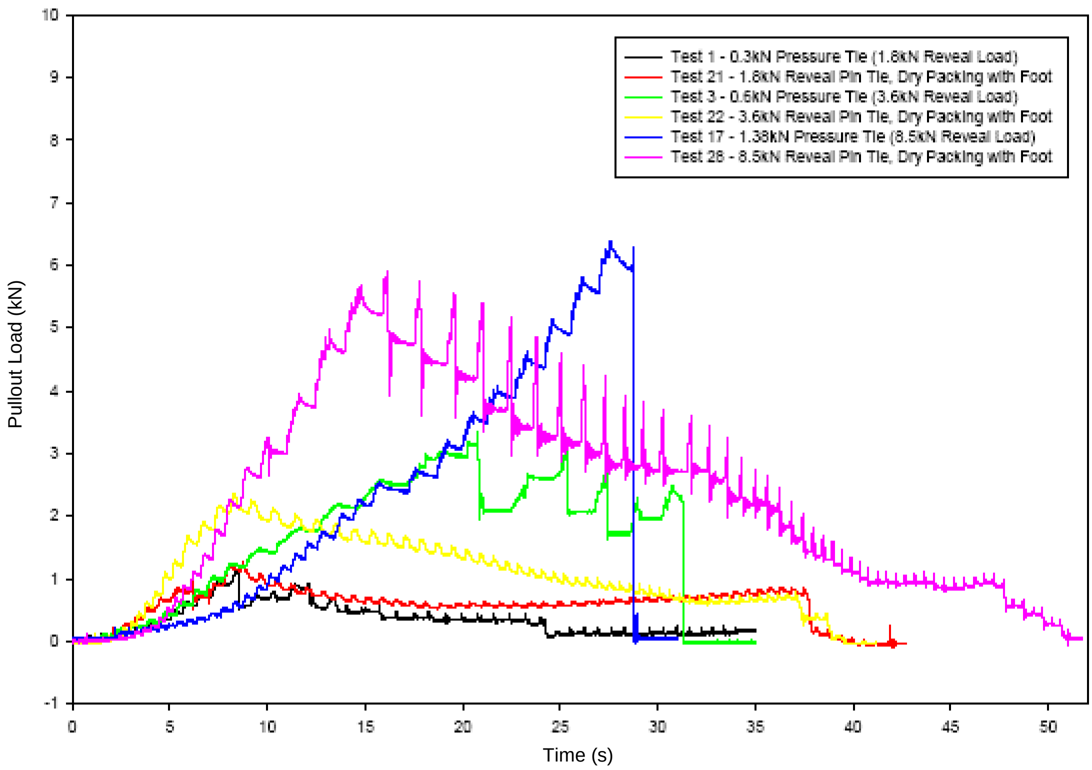


Figure 42 – Comparison of Pressure Ties with Reveal Pin Ties of Equivalent Reveal Load

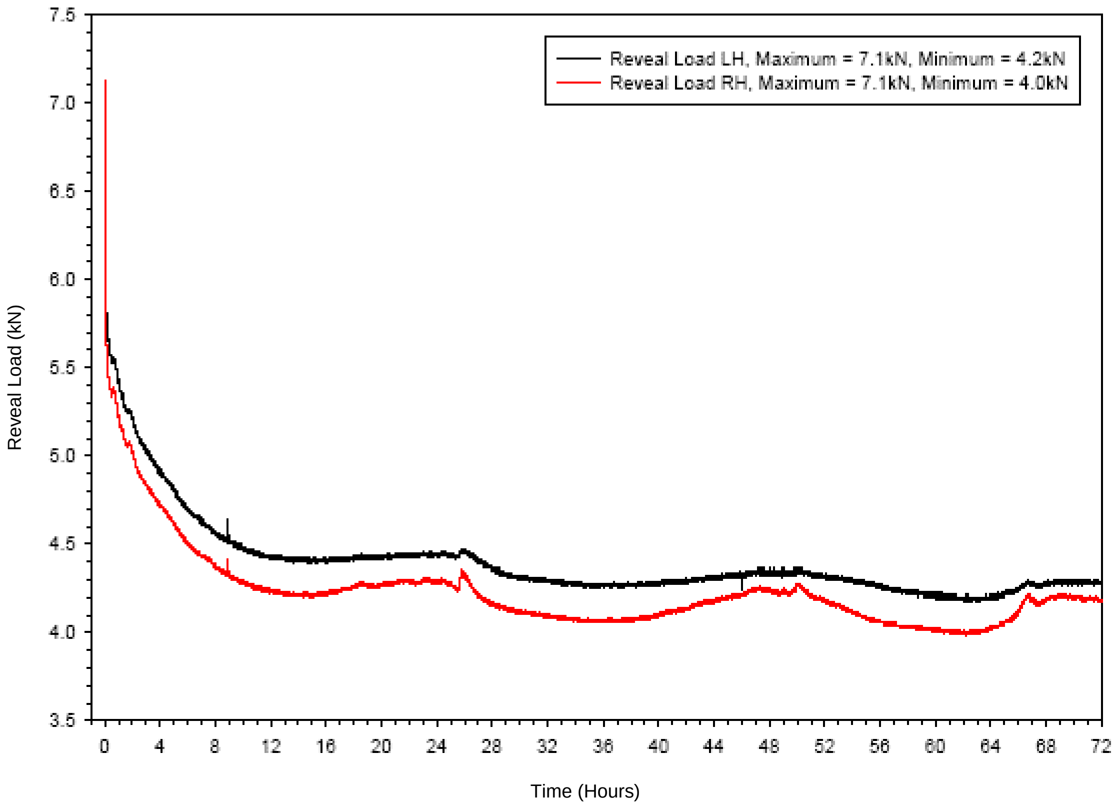


Figure 43 – Graph Showing Relaxation of 3 Turn Reveal Pin Tie over 3 Day Period

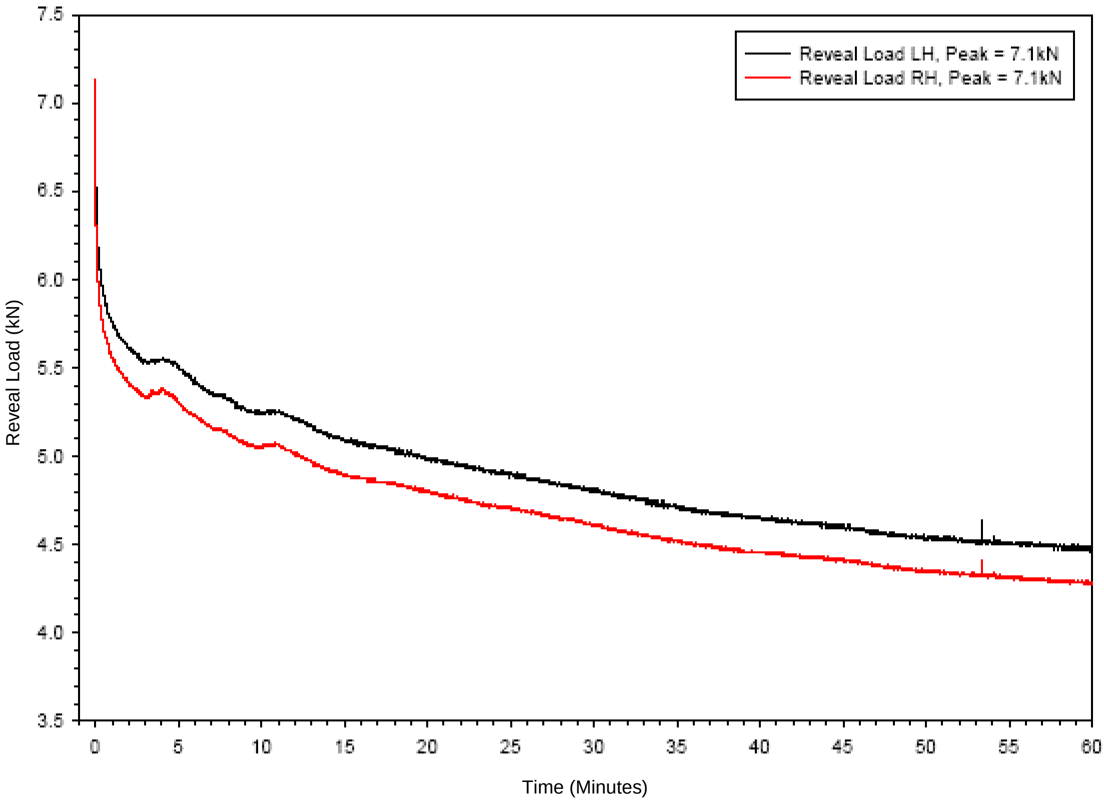
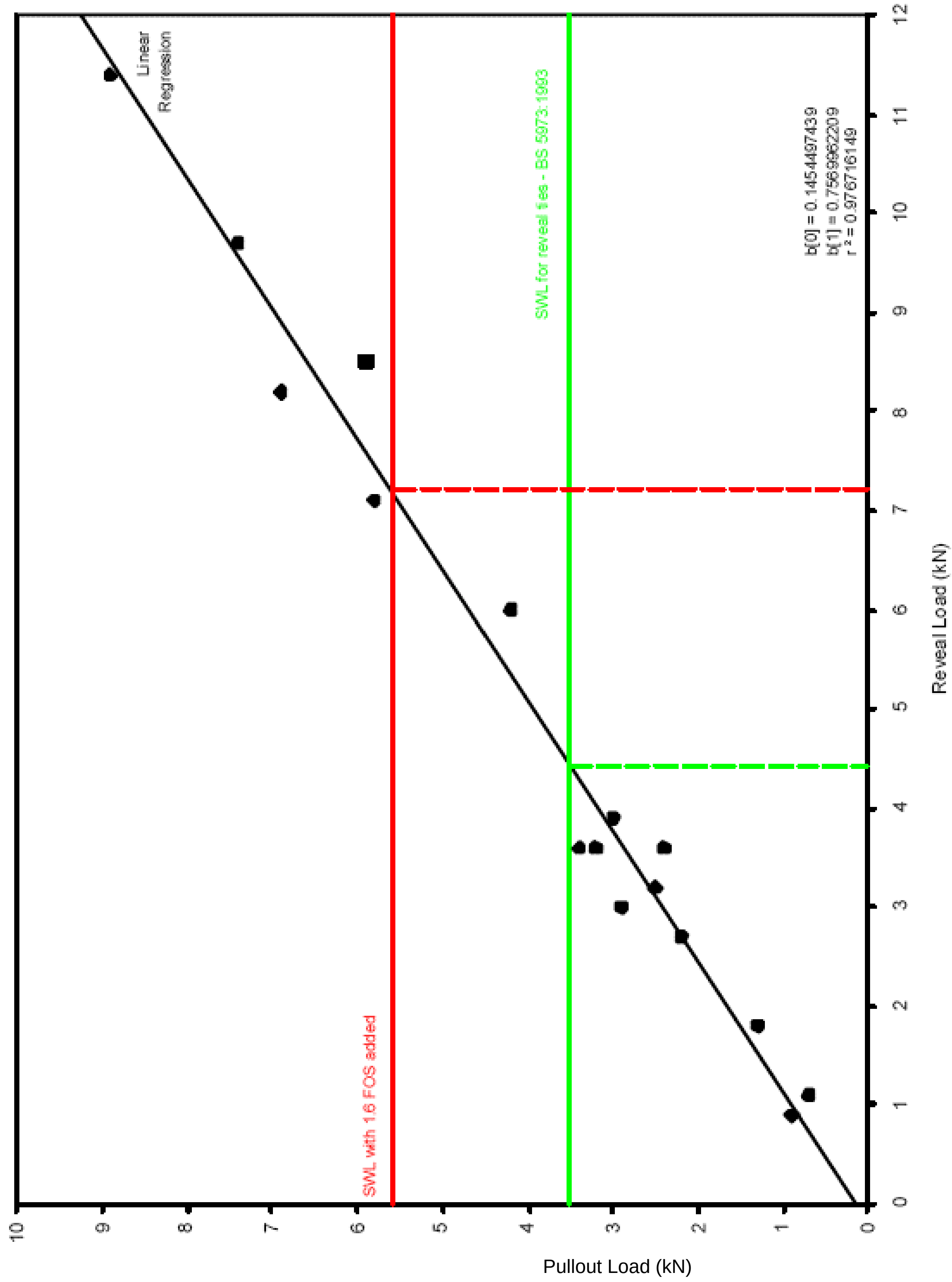


Figure 44 – Graph Showing Relaxation of 3 Turn Reveal Pin Tie – First Hour



Linear Regression
SWL for reveal ties - BS 5973:1993
SWL with 1.6 FOS added
b[0] = 0.1454497439
b[1] = 0.7569962209
r² = 0.976716149
Reveal Load (kN)
Pullout Load (kN)

7 REFERENCES

Reference 1

BS 5973 : 1993 - Code of practice for Access and working scaffolds and special scaffold structures in steel. Section 9 - Tying scaffolding to Building facades. Specifically:

9.4.5 - *Reveal Ties*.

9.7.1 - *Inwards/outwards capacity*.

Figure 7 - Reveal tie

Table 1(a) - Frequency of ties in square metres per tie.

39.8.1 - *The Load on the Couplers*

39.8.2 - *Safe Working Loads*

Reference 2

Testing of Pressure Ties FE/02/03, R. Richardson,

Health and Safety Laboratory, 2002