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Energy absorption capacity for fibre reinforced sprayed concrete. Effect of panel production technique, fibre content and friction in round panel tests with continuous steel support (Series 8 and 9)

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Title

Energy absorption capacity for FRSC. Effect of panel prod. technique, fibre content and friction in round panel tests with continuous steel support (Series 8 and 9)

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Summary

The test program is part of the on-going revision of The Norwegian Associations publication no. 7 (Sprayed concrete for rock support), which among others is to be harmonized with the new European regulations for determination of energy absorption capacity of fiber reinforced sprayed concrete.

After realising the very significant and varying effect of friction in panel tests with continuous support of wood it was decided to concentrate the further investigations on support of steel.

The present results show that the average coefficient of variation for the energy absorption capacity (EAC) at 25 mm displacement among all 6 individual sets in Series 8 was 7.1 % and among the six sets in Series 9 it was 8.7 %.

For the parallel sets in Series 8 performed with and without friction-reducing bedding material, the results show that friction between the panel and the supporting ring of steel constitutes 25.7% and 25.0% of what is taken to be energy absorbed by the panel at final displacement of 25 mm. This is in line with earlier results.

The cast panels had on average 90% energy absorption capacity compared to the sprayed panels. Possible influencing parameters are different air content, fibre orientation, compaction and w/c-ratio for cast and sprayed panels. The amounts of data are yet too scarce to draw general conclusions.

Series 9 was dominated by the panel fibre contents being strongly overdosed compared to the intended nominal dosages and, correspondingly, the energy absorption values became high, especially for the steel fibre mixes. The fiber measurements in fresh concrete differed strongly from the fibre measurements that was done on samples from the panels after testing.

Key words

Fibre reinforced sprayed concrete, energy absorption capacity, steel support, effect of friction, cast and sprayed round panels, effect of fibre type and fibre dosage

Preface

The present test program is carried out as a part of the ongoing revision of the Norwegian Concrete Association's publication no. 7 (NB 7): "Sprayed concrete for rock support"[1] (in Norwegian: "Sprøytebetong til bergsikring"). The publication will, among others, be harmonized with the new European standards dealing with energy absorption capacity for fibre reinforced sprayed concrete. The new European standards describes a test procedure using square panels (continuous support), while the Norwegian tradition has been to test round panels (also continuous support) as described in the previous version of NB 7. The test program that has been undertaken is a comparative study of these two methods, but the program has also included tests on ASTM round determinate panels.

The test panels should be produced with relevant concrete, personnel and spraying equipment (robot) for the given project. Some 10 years ago in Norway, it was decided to use round panels (600 mm diameter, 100 mm thick, net weight around 65 kg). These panels can be produced on-site where the actual spraying work is done.

The test procedure described in the new European regulations (EN 14488 part 1 and part 5, [2][3]) involves spraying large test panels (1000 mm x 1000 mm x 100 mm, with a net weight around 230 kg). The panels must not be moved for the first 18 hours. After that, all further handling must be machine-based. Later in the laboratory, the panels shall be saw-cut to a final size of 600 mm x 600 mm (net weight about 83 kg). By this rigorous procedure we fear that the connection between testing and practical application may be lost. It is also a big challenge to trim a 1000 x 1000 mm panel within the given tolerances for thickness.

The original scope of the project was to study the practical consequences of the new regulations and to carry out comparative tests on round and square panel tests. The results have revealed that panel tests are significantly influenced by the friction between the panel and the support, and lately the investigations have been focused on this issue.

The test program is a joint venture between Norwegian Public Roads (NPRA) and the members of the Norwegian Concrete Association's Sprayed Concrete Committee. The contractor Entrepenørservice AS has contributed with the building of moulds and production of test panels. The members of the Norwegian Concrete Association's Sprayed Concrete Committee have contributed in the planning of tests and production of panels. The tests are performed in the NPRA's Central Laboratory. The panels forming the basis of the present investigation, involving two test series, were produced by Veidekke Entreprenør AS and Entreprenørcervice AS, respectively.

Up till now (2007-2010) nine test series have been carried through. Results have been reported in [8]-[16]. The present report gives the results from "Series 8" and "Series 9".

Summary

After realising the very significant and varying effect of friction in panel tests with continuous support of wood, ref. [11]-[13] and [15], it was decided to concentrate the further investigations on support of steel. Friction occurs between the test panel and the support. This is measured as extra energy uptake from the panel during testing and, thus, the apparent energy absorption capacity of the concrete panel will be overestimated. The present report gives the results from two test series, Series 8 and Series 9, involving totally 39 round 600 mm panels. The main results are as follows:

One of the two series was supported by fibre measurements. It was shown that the actual fibre content in the tested panels differed strongly from the fibre measurement from fresh concrete. And, both measurements differed strongly from the nominal fibre dosages in the mixes. Probably several unfavourable factors occurred during the production of these panels. The consequences of improper mixing/homogenisation of fibres were clearly illustrated; unintentionally though. The panel tests results were however systematic with respect to the actual fibre content that was measured from the panels after testing.

Two parallel sets showed that the friction between the panel and the steel support constitutes 25.7% and 25.0%, respectively, of what is taken to be energy absorbed by the panel. This is in line with earlier results, giving today an overall average friction effect of 26.2%.

On average the cast panels had 90% of the energy absorption capacity measured in the sprayed panels. Possible influencing factors are different air content, compaction, fibre orientation and w/c-ratio for cast and sprayed panels. It is likely that these factors may vary from case to case.

Sammendrag

Etter å ha funnet den betydelige og varierende friksjonseffekten i platetester utført med kontinuerlig treopplegg, ref. [11]-[13] og [15], ble det besluttet å gjøre videre undersøkelser med opplegg av stål. Friksjon oppstår mellom plateprøven og opplegget. Friksjonseffekten måles som ekstra energiopptak i platen under forsøket, dvs. den målte energiabsorpsjonenen i forsøket overestimeres. Rapporten presenterer resultatene fra to forsøksserier, Serie 8 og 9, hvor totalt 39 sirkulære 600 mm plater er prøvd. Hovedresultatene ble:

I en av de to forsøksseriene ble det gjort fibermålinger. Det ble vist at det virkelige fiberinnholdet i forsøksplatene var svært avvikende i forhold til fibermålingene som ble gjort på den ferske betongen før sprøyting. Begge disse målingene var igjen svært avvikende fra nominelt fiberinnhold. Flere uheldige faktorer har antagelig vært til stede under blanding av betong/fiber og produksjonen av disse platene. Konsekvensene av for dårlig blanding/homogenisering av fibrer ble tydelig illustrert, dog utilsiktet. Resultatene fra plateforsøkene var imidlertid systematisk med hensyn til virkelig fiberinnhold som målt i platene etter forsøket.

To forsøkssett viste at friksjonen mellom plateprøve og stålopplegg utgjør henholdsvis 25.7% og 25.0% av hva som måles direkte i forsøket som energiopptak i plateprøvene. Dette er i tråd med tidligere resultater, noe som sett sammen betyr at overordnet gjennomsnittlig friksjonseffekt pr. i dag er målt til å være 26.2%.

I gjennomsnitt hadde de støpte platene 90% av energiabsorpsjonskapasiteten til de sprøytede platene. Mulige faktorer som påvirker er ulikheter i luftinnhold, kompaktering, fiberorientering og v/c-tall for støpte og sprøytede plater. Det er sannsynlig at disse faktorene kan variere fra prosjekt til prosjekt.

Content

1 Introduction

After realising the very significant and varying effect of friction in round panel tests with continuous support of wood, ref. [11]-[13] and [15], it was decided to concentrate the further investigations on support of steel. Friction occurs between the concrete panel and the support. This is measured as energy uptake from the panel during testing, and, thus, the apparent energy absorption capacity will be overestimated.

Previous tests [14] have shown that support of steel reduces the friction influence in panel tests compared to support of wood. Steel also give more constant friction along with the displacement within a single test as well as it is more robust against wearing over time. Thus, steel support secures more constant friction from test to test. Friction influences directly the apparent energy absorption of the panel during testing as well as it may increase the number of cracks in the panel, which in its turn also influences the result.

The present report gives the results from two separate test series, Series 8 and Series 9. The following variables have been investigated:

1) When deciding to use steel as supporting material it was considered necessary to "calibrate" fibre reinforced sprayed concretes with regard to their energy absorption capacity in the modified set-up with steel support. <u>Effect of fibre type and fibre dosage in sprayed panels</u> was therefore investigated (Series 9).
2) Most panel tests have previously been on cast panels. Cast panels are very convenient for methodology studies, while sprayed panels shall be used when studying the energy absorption capacity of a given sprayed concrete mix. <u>Cast and sprayed panels produced from the same mix are investigated</u> (Series 8) in order to get an impression on possible differences/interrelations, which again can be used for predictions in previous and future tests.
3) The final investigated variable is <u>the effect of friction from steel support</u> on the apparent energy absorption from the test. The scope of this study is to verify earlier results in [14].

A special steel support with rounded inner edge has been tested previously [15] , but against our expectations it led to more friction than a sharp inner edge [14] . All present tests therefore make use of the latter; i.e. a steel support ring with sharp inner edge.

2 Concrete, fibres and production of panels

2.1 Series 8 – Sprayed and cast panels

This series consists of both sprayed and cast panels, a total of 21 panels. The production of panels was done on September 24, 2009, by Veidekke Entreprenør AS at the mixing plant of NorBetongs AS at Åsland near Oslo. The fibres were added to the concrete from the top of the automixer truck.

A standard concrete composition was used (M45, hence water-to-cement ratio maximum 0.45 after spraying, and around 0.41-0.42 before spraying), however no specific information about the concrete mixes was provided from the site. Two types of macro synthetic polypropylene (PP) fibres were used, see also fibre data sheets in APPENDIX 1:

- BarChip 54: PP fibre, 54 mm long **(denoted "BC54")**
- Barchip Kyodo: PP fibre, 48 mm long **(denoted "BK")**

From one concrete truck with 6 kg/m^3 of the BC54-fibre 6 panels were made where:

- 3 panels were cast (panels numbered 4-6)
- 3 panels were sprayed (numbered 1-3)

From one concrete truck with 7 kg/m^3 of the BK-fibre 15 panels were made where:

- 9 panels were cast (numbered 10, 11, 12, 16, 17, 18, 22, 23, 24)
- 6 panels were sprayed (numbered 13, 14, 15, 19, 20, 21)

Slump, air content and fibre content were not measured. For each of the two concretes, two 100x100 mm cubes were cast for 28 days compressive strength tests.

After one week the panels (and cubes) were demoulded and transported to the NPRA Central Laboratory. The cubes were then water cured, whereas the panels were stored outside the laboratory in open air. Two weeks before testing the panels were moved to indoor water baths where they were stored until testing at a concrete age of 159 days.

2.2 Series 9 – Sprayed panels

In this series a total of 18 panels were sprayed. The concrete was mixed February 1, 2010, at the mixing plant of Unicon AS in Sandvika near Oslo, and transported a short distance by an automixer truck to the mines of Franzefoss AS, also located in Sandvika, where the panels were sprayed by Entreprenørservice AS. Batches of 2 m^3 of each concrete were mixed. After loading the concrete batch to the automixer truck the fibres were added from the top of the truck. The truck was then run at high speed for 10-15 minutes. The air temperature during concrete mixing was around 3 ^oC, while the temperature at the spraying site was somewhat higher.

Two types of fibres were used (see also data sheet in APPENDIX 1):

- Dramix 65/35: Steel fibre, 35 mm long **(denoted "D")**
- Barchip Kyodo: PP-fibre, 48 mm long **(denoted "BK")**

From each concrete mix (6 in total) 3 panels were made, hence 18 panels were made in total. Concrete variables were fibre type and –content.

- Dramix: 20, 40 and 60 kg/m^3
- BarChip Kyodo: 5, 7 and 8 kg/m^3

The concrete ordered from the mixing plant was a standard mix of the quality B35 M45 (recipe 55330A). The different concrete batches had an initial water-to-cement ratio of 0.42 when mixed and obtain about 0.44 after spraying, due to the water-containing accelerator. The intended accelerator dosage was 4 % of the cement weight (20 litres/m^3). The concrete documentation notes from each of the trucks delivering the concrete batches are given in APPENDIX 2.

Air content and temperature of the fresh concrete was measured upon arrival at the spraying spot in the mine. For each of the six concretes, two 100x100 mm cubes were cast for 28-days compressive strength tests.

The fibre content of the fresh concrete was measured for each of the concrete deliverances. A 2 litre sample of fresh concrete was collected early in the deliverance and immediately transported to the NPRA Central Laboratory, where the fibre content was subsequently determined. (Later the fibre content was also determined from the hardened panels after testing, see following section). Slump was only measured for the mix with 40 kg Dramix fibre.

Upon spraying, the panels were screed and then covered with plastic sheets. After three days the panels (and cubes) were demoulded and transported to the NPRA Central Laboratory where they were stored indoors in water baths until testing at a concrete age of 30 days.

2.2.1 Mismatch between nominal and actual fibre content

As shown later in the report, the fibre content in the different batches was not as intended in Series 9, something that significantly influenced the panel test results. This was likely due to either wrong fibre addition, the fibre addition procedure or to insufficient homogenization/distribution of fibres in the truck, or a combination of these factors. The transportation time was short, and the time between the addition of fibres to the truck and the spraying was probably not sufficiently long to ensure good fibre distribution in the batch. The relatively small batches of 2 m^3 in a truck with a capacity of 8 m^3 require specific attention to the homogenization of fibres since the effectiveness of the mixing in the truck is not as effective as for one that is fully loaded (i.e. small batches needs prolonged mixing time). It is a fact that these issues were not sufficiently addressed during the planning and execution of the work. As described later in the report, the first batch of concrete with polypropylene (PP) fibres that followed the three batches of steel fibre reinforced concrete, contained both steel- and PP-fibres. This indicates that the shift was done without sufficient cleaning in between.

Observations during the work on-site underline the discussion above. The steel fibres are delivered in glued bundles. The glue dissipates gradually when the bundles meet the fresh concrete and in the further mixing process. During the loading of the 40 kg steel fibre concrete mix, clusters of fibres were observed in the fresh concrete. This indicates that the mixing time after the steel fibre addition was too short for this mix. For the 60 kg steel fibre mix there was a failure in the compressor used by the spraying rig and the concrete stayed in the truck for about 3 hours. This definitely enhances fibre distribution, but it is uncertain to what extent it influenced the fresh concrete consistency and the quality of the spraying process; although the panels looked normal. The 7 kg PP fibres mix was observed to be very flowable (slump was not measured).

3 Test program, panel tests

3.1 Test program, Series 8

The panels were divided into 6 test sets (see Table 1) in order to investigate:

- **the energy absorption of cast panels versus sprayed panels**
- **the effect of friction caused by the steel support**

The friction between the panel and the support has been found to play a significant role in these tests as it increases the apparent capacity of the panel. The friction effect of the steel support is investigated in the same manner as in earlier tests ([11] and [14]) by comparing the results from tests were the steel support is covered/bedded with two layers of PVC with grease in between. The latter condition provides a situation with very little or no friction. This way the friction effect can be quantified directly from the tests.

In addition to the test panels, cubes were cast for compressive strength. The overall laboratory test program consists of:

- 28-days compressive strength. Two cubes for each of the two batches.
- Round panel tests at 159 days concrete age, see Table 1

The nominal fibre content in Series 8 was not verified by measurements on the concretes, hence we have to assume there is coherence between nominal and actual fibre contents.

Table 1 Test program for the round panel tests, Series 8

Set (se below for abbreviations)	Panel	Cast or sprayed	Support condition
S8-6-BC54-C	S8-6-BC54-C-1	Cast	Steel support
	S8-6-BC54-C-2		
	S8-6-BC54-C-3		
S8-6-BC54-S	S8-6-BC54-S-4	Sprayed	Steel support
	S8-6-BC54-S-5		
	S8-6-BC54-S-6		
S8-7-BK-C	S8-7-BK-C-10	Cast	Steel support
	S8-7-BK-C-11		
	S8-7-BK-C-18		
	S8-7-BK-C-22		
	S8-7-BK-C-23		
S8-7-BK-C-PVC	S8-7-BK-C-PVC-12	Cast	Bedding of two layers of PVC and grease
	S8-7-BK-C-PVC-16		
	S8-7-BK-C-PVC-17		
	S8-7-BK-C-PVC-24		
S8-7-BK-S	S8-7-BK-S-13	Sprayed	Steel support
	S8-7-BK-S-14		
	S8-7-BK-S-15		
S8-7-BK-S-PVC	S8-7-BK-S-PVC-19	Sprayed	Bedding of two layers of PVC and grease
	S8-7-BK-S-PVC-20		
	S8-7-BK-S-PVC-21		

Where:

S8 = Series 8
6-BC54 = 6 kg of Barchip 54 mm fibre
7-BK = 7 kg of Barchip Kyodo 48 mm fibre
S = Sprayed panels
C = Cast panels
PVC = Two layers of PVC with grease in between
Last number = The number of the panel as numbered during casting and spraying

3.2 Test program, Series 9

The intention with Series 9 was to investigate the effect of fibre content on the energy absorption capacity of sprayed panels. Two fibre types were used; one steel fibre type and one PP fibre type. With three dosage levels for each of the fibre types, a total of 6 concrete batches were produced. Sets of 3 panels were made from each batch, see Table 1. The nominal concrete mix was the same in all sets (B35 M45). The three pictures in Fig. 3.1 are taken under the production of the panels. The test program involved some supporting tests, and the overall laboratory test program was as follows:

Laboratory test program:

- Fibre content in fresh concrete: For each batch, a 2 litre sample was taken on-site and transported to the laboratory.
- 28-days compressive strength. Two cubes for each batch.
- **Round panel tests on continuous steel support at 30 days concrete age, effect of fibre type and –dosage. See Table 1.**
- Fibre content measured in each panel after performing the panel tests (1 - 2 litre pieces (around 2 - 5 kg) was cut from each panel after testing). Fibre content was determined from

the tested panels as an extra verification because the tests showed a peculiarly high energy uptake in relation to the nominal fibre dosages.

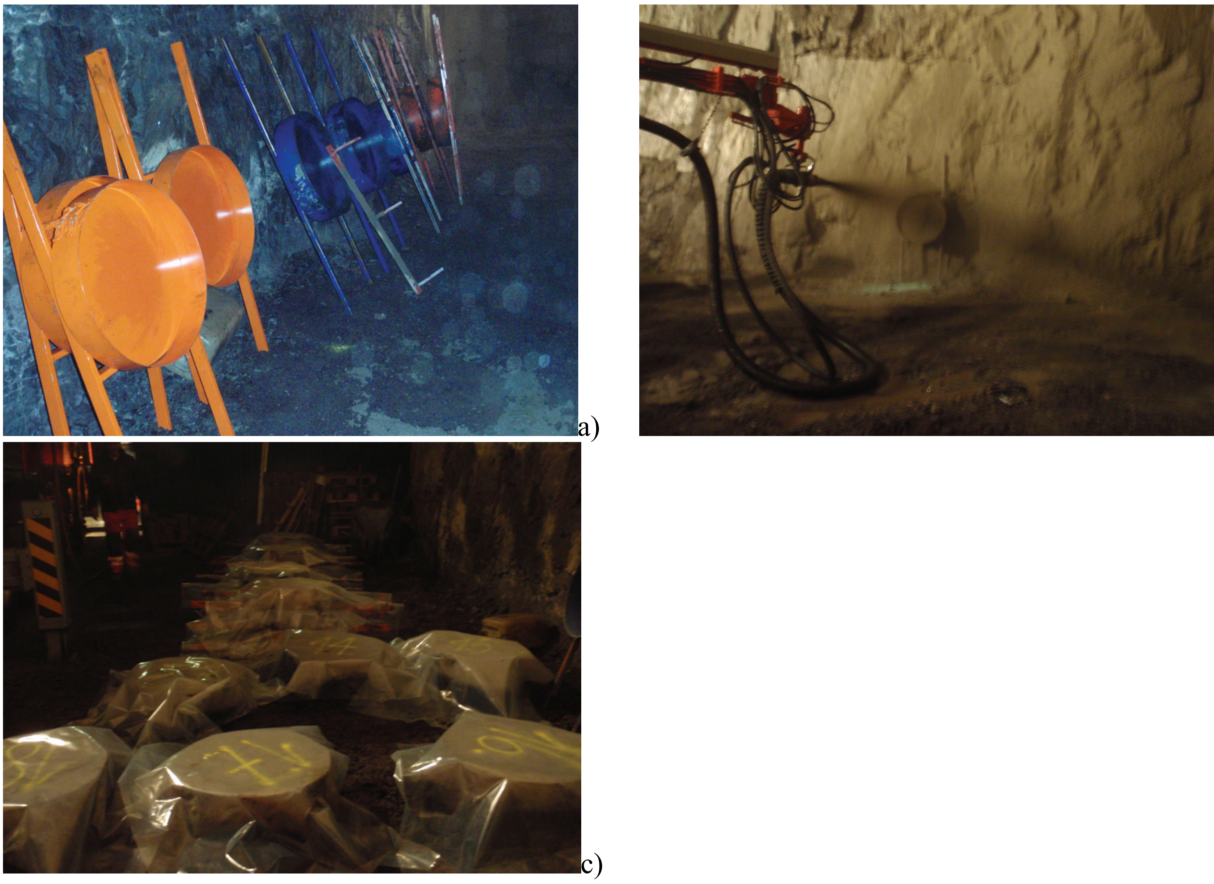
Table 2 Test program for the round panel tests, Series 9. All are sprayed panels and all were tested directly on steel support

Set (se below for abbreviations)	**Panel**	**Nominal fibre content** (note: differs strongly from the actual fibre content)	**Fibre type**
S9-20-D-S	S9-20-D-S-1	20 kg	Dramix
	S9-20-D-S-2		
	S9-20-D-S-3		
S9-40-D-S	S9-40-D-S-4	40 kg	Dramix
	S9-40-D-S-5		
	S9-40-D-S-6		
S9-60-D-S	S9-60-D-S-7	60 kg	Dramix
	S9-60-D-S-8		
	S9-60-D-S-9		
S9-5-BK-S	S9-5-BK-S-10	5 kg	BarChip Kyodo
	S9-5-BK-S-11		
	S9-5-BK-S-12		
S9-7-BK-S	S9-7-BK-S-13*)	7 kg	BarChip Kyodo
	S9-7-BK-S-14		
	S9-7-BK-S-15		
S9-8-BK-S	S9-8-BK-S-16	8 kg	BarChip Kyodo
	S9-8-BK-S-17		
	S9-8-BK-S-18		

**) Panel test data lost due to logging error*

Where:

S9	*= Series 9*	*S*	*= Sprayed panels*
20-D	*= 20 kg of Dramix steel fibre*	*Last number*	*= The number of the panel as numbered during casting and spraying*
5-BK	*= 5 kg of Barchip Kyodo fibre*		



a) b) c)

Fig. 3.1 Pictures taken during production of panels. a) preparation of the moulds, b) spraying of panel, c) curing after spraying

4 Supporting test methods

4.1 Air content

Air content of fresh concrete, standard method [4].

4.2 Fibre content, fresh concrete

Each sample of fresh concrete is taken from the work site to the laboratory. The sample container has a known volume. The weight of each sample is measured. The sample is taken out of the container, in portions, and washed over a 2 mm sieve. Most fibres collect at the top of the sieve, but some go through. Most of the PP fibres going through the sieve will float, but some sink with the rest of the concrete; these are found by stirring and manual searching and repeating the sieving process. After collecting all the fibres, they are washed one extra time in clean water. The fibres are then spread out on paper in order to dry overnight.

The next day the fibres are investigated manually in order to spot possible particles attached to the fibres and, for ensuring total dryness, the fibres are treated with a hairdryer. The weight of the dry and clean fibres is determined and the ratio fibre content (gram) to concrete sample volume (litre) is calculated. The procedure is in accordance with EN 14488-7:2006 [5].

4.3 Fibre content, hardened concrete

The weight of the piece cut from the panel is measured in air and in water in order to find its volume. The piece is crushed in a compressive test machine and put into a LA test machine for about 15 minutes (500 rotations). Remaining small lumps are finally crushed by a hammer. A magnet is used to collect the steel fibres. Samples with PP fibres are placed into a bucket of water for the fibres to float (3 times in clean water). The weight of the fibres (dry condition) is measured.

4.4 Compressive strength

Compressive strength of cast cubes, standard method [6].

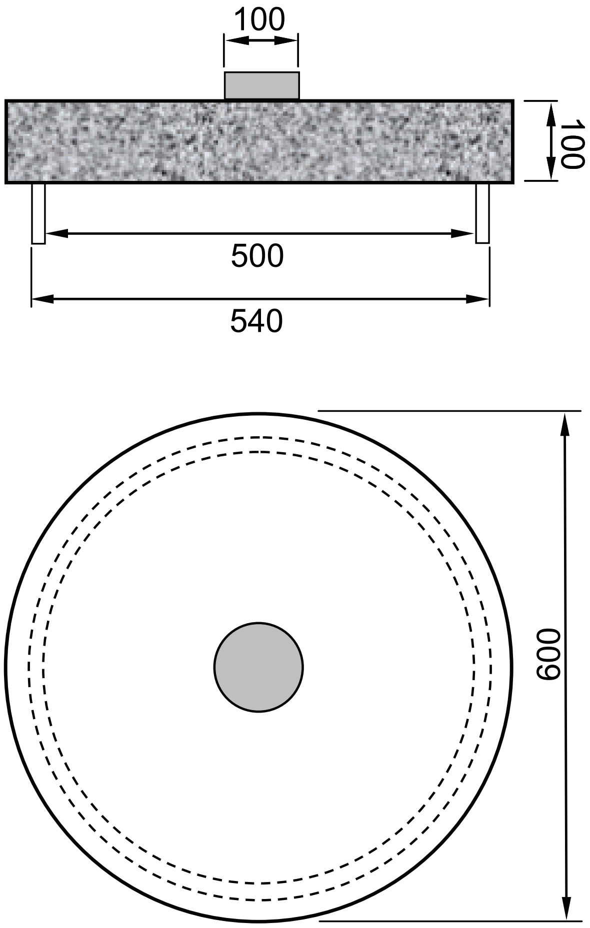
5 Test rig and test procedure, panel tests

5.1 Test rig

The test set-up is shown in Fig. 5.1 and Fig. 5.2. The central displacement of the panel is measured by a displacement transducer with measuring range 50 mm. The transducer is spring-loaded and of the type "ACT1000A LVDT Displacement Transducer" from the RDP Group. The test machine (FORM+TEST Delta 5-200 with control system Prüfsysteme Digimaxx C-20) has a maximum load of 200 kN and stiffness > 200 kN/mm.

The panel rests on a supporting steel ring with an inner diameter of 500 mm and outer diameter of 540 mm, hence the steel ring is 20 mm wide. The load is applied from the top through a load plate (Ø100 mm cylindrical steel plate).

The deformation rate during the test is controlled by the signal from the displacement transducer under the panel. Prior to the test, the load cell is stabilized at a load of 1 kN. With this initial load the test is started. The displacement rate during the test was 3 mm/min.



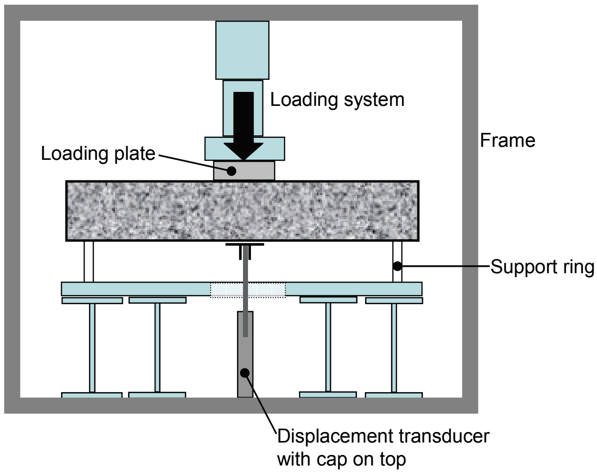


Fig. 5.1 Round panel test: Dimensions

Fig. 5.2 Round panel test: Set-up

5.2 Support conditions

The present tests use two support conditions, steel support (no bedding) and steel support with bedding of PVC and grease.

5.2.1 Steel support, no bedding

For this test condition the panel is simply placed directly on the supporting ring of steel, see Fig. 5.3. The support ring has a rectangular cross section, i.e. it has a (rather) sharp inner edge.

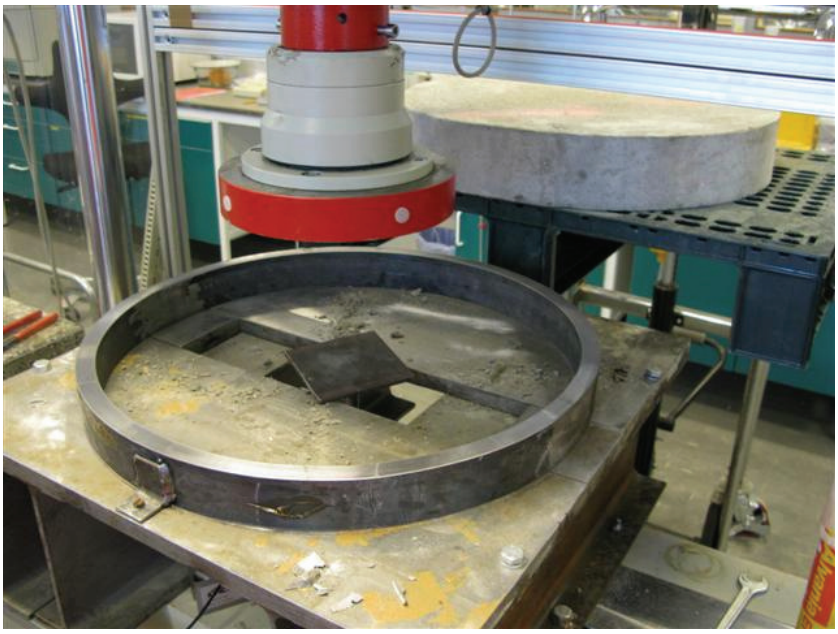


Fig. 5.3 Steel support, no bedding

5.2.2 Steel support with bedding of two layers of PVC membrane and grease

The bedding is similar to that used in previous tests [11][12], see Fig. 5.4. The bedding concept has proven to be very effective in removing friction between the panel and the support during testing.

The bottom ring-shaped PVC membrane is well covered with grease. Strips are cut in the upper membrane (in contact with the concrete panel) leaving about ¼ of the width uncut. The cut membrane is placed on the bottom membrane into a "sandwich". The strips will enhance the ability of the cracks to open (tangential direction), while the grease is favourable in reducing friction in both tangential- and radial direction.

Fig. 5.4 Steel support with bedding of two layers of PVC with grease in between

5.2.3 Test procedure

Prior to testing, each panel was taken out of the water bath and transported to the test rig. The test started within 45 minutes.

The procedure was as follows:

1) Prior to testing the diameter of the panel was measured three times with angles of 60^o.
2) The panel was placed in the test rig with the smooth moulded face against the support fixture.
3) The panel was centred on the support.
4) The displacement transducer was placed under the centre of the panel.
5) On the upper side of the panel (the cast side) the load plate was placed in the centre.
6) The load cell was prepared for testing by lowering it to the load plate until a load of 1 kN is applied to the panel.
7) The test was started and load- and deflection signals were logged continuously by a computer. The displacement rate was controlled by the computer at 3 mm/min.
8) The test is stopped automatically when the central deflection is 30 mm.
9) The panel was lifted out of the test rig, and the bottom side of the panel was photographed in order to document the crack pattern. If the panel suffered shear failure, the top side of the panel was also photographed.
10) After the tests all panels were completely broken into pieces along the cracks, and over each cracked surface 3 thickness measurements were made. The thickness was measured with a digital sliding calliper.
11) The energy absorption capacity was calculated as the area under the load-deflection curve from 0 to 25 mm deflection. The calculated area (i.e. the energy) is corrected for thickness when deviating from 100 mm, see Section 5.2.4.

5.2.4 Evaluation of results / correcting for deviating thickness

The energy absorption capacity (EAC) of the panel shall according to the standards be calculated as the energy uptake between 0 and 25 mm central deflection during a fixed deflection rate. The panel thickness influences the ability to take up energy, where increased panel thickness will increase the energy uptake, and vice versa. Consequently, the calculation of EAC should be corrected for thickness when deviating from the reference thickness. A theoretical evaluation of the effect of panel thickness was done in [16] Bjøntegaard Ø. (2008) Testing of energy absorption for fibre reinforced sprayed concrete. Proc. of the 5th Int. Symp. on Sprayed Concrete – Modern use of wet sprayed concrete for underground support. Lillehammer, Norway, 21-24 April 2008, pp. 60-71, ISBN 978-82-8208-005-7. Tekna, Norwegian Concrete Association.
[17]. Target panel thickness is in our case h_0 = 100 mm. The following analysing procedure was proposed for panels with thickness h deviating from h_0:

1. The area under the load-displacement curve is calculated between 0 and a modified displacement $\Delta_m = 25\text{ mm} \cdot k_t$, and $k_t = 100/h$
2. The area is then multiplied with the factor k_t.
3. The corrected area is the EAC from the test.

The following formula is used to calculate the energy absorption capacity (EAC) from a panel test, involving the correction for panel thickness:

Equation 1

$$EAC = k_t \sum_{i=0}^{\Delta_m} \left[\left(\Delta_{i+1} - \Delta_i \right) \frac{P_i + P_{i+1}}{2} \right]$$

where k_t and Δ_m are explained above. Δ is the measured central displacement, P is the measured central load, and the parameter i is the increment number.

Maximum load during the test and residual load at 25 mm displacement are also discussed later in this report. Both of these load values have been multiplied with the factor k_t^2 in order to correct for the influence of panel thickness.

6 Test results and discussion, Series 8

6.1 Compressive strength

The results below gives the average result for the two cast cubes for each of the two concretes in Series 8.

Table 3 Compressive strength, Series 8

Concrete	28-days cube strength
S8-6-BC54	56.3 MPa
S8-7-BK	49.0 MPa

6.2 Panel tests

6.2.1 Panel thickness and diameter

All measurements of panel geometries are given in APPENDIX 3, while an extract for Series 8 is given in the following. The average thickness for all panels was 102.3 mm. The thickest panel was 108 mm and the thinnest panel was 99.2 mm. The average standard deviation (STD) for all the panels was 1.8 mm. The highest STD for one single panel was 6 mm, the lowest 0.6 mm.

Similar numbers for the panel diameters are: 600.6 mm average (average STD = 2.9 mm), largest panel diameter 603.3 mm and lowest diameter 598.3 mm. Highest STD for one single panel was 5.5 mm and lowest 1.0 mm.

6.2.2 Crack pattern

The panels were taken out of the test frame after end of testing, and the underside of the panels were photographed, see Fig. 6.3 through Fig. 6.7, including some examples of shear failure taken from the upper side of the panel.

When studying the average number of cracks for each set of panels, the panel tests performed directly on steel support developed, on average, 1 more crack (a total of about 6 cracks) than those with bedding of PVC and grease (a total of about 5 cracks). This trend has also been seen in previous tests.

It is also notable that 6 of the totally 14 panels that was placed directly on steel support developed shear failure or tendency of shear failure. None of the panels with bedding of PVC and grease (totally 7 panels) developed shear failure.

As previously seen [15], there is often a local crack zone around the contact point between panel and steel support rather than a distinct crack. The crack zone occurs due to the restraining friction forces from the steel support. For the panels tested with no friction (with PVC and grease), however, a more distinct crack forms.

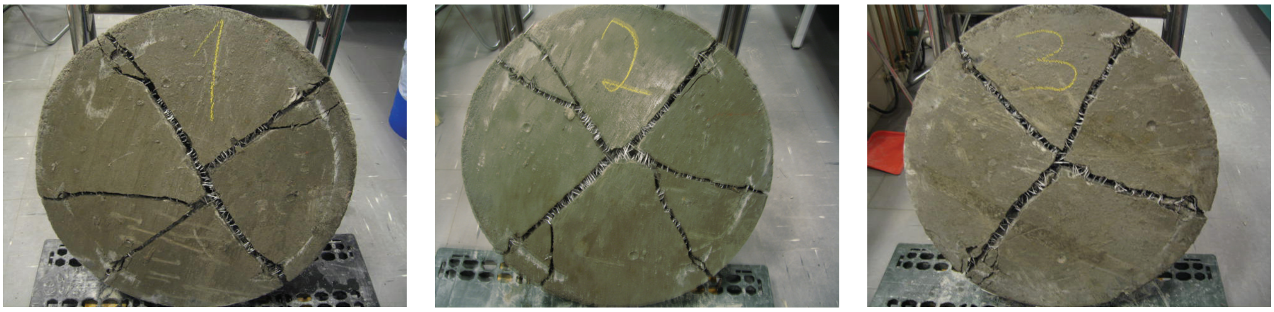


Fig. 6.1 Crack pattern, set S8-6-BC54-C (6 kg BC54, cast, no bedding)

Fig. 6.2 Crack pattern, set S8-6-BC54-S (6 kg BC54, sprayed, no bedding)

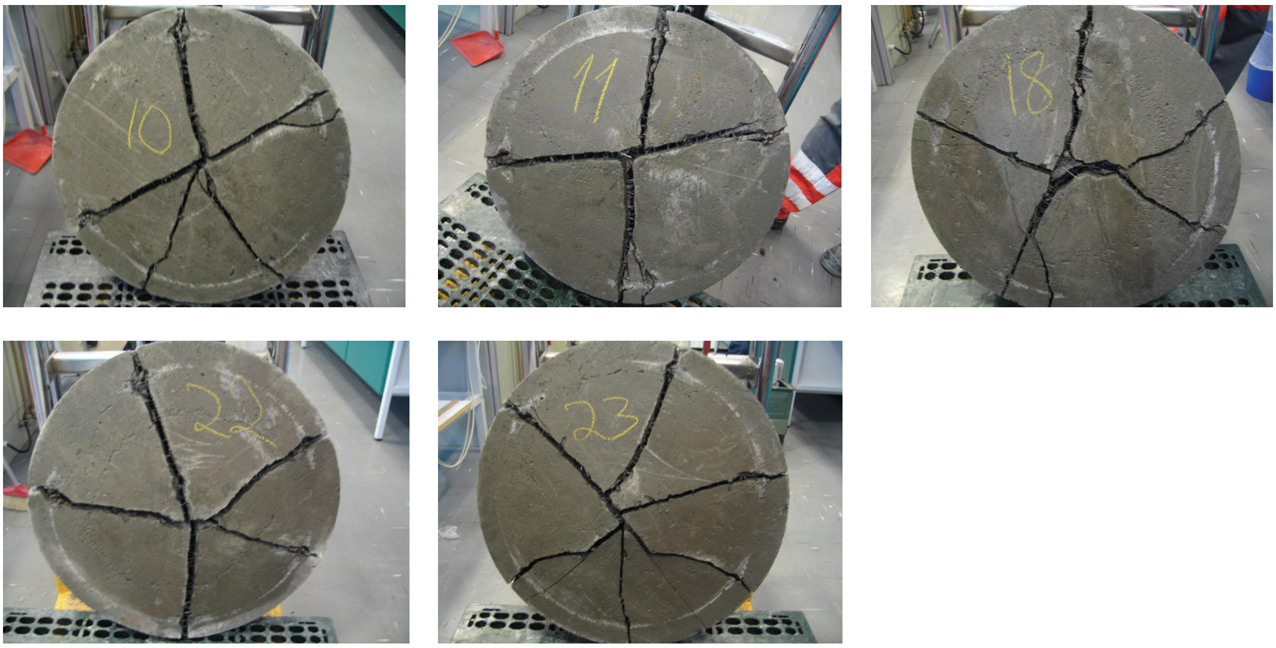


Fig. 6.3 Crack pattern, set S8-7-BK-C (7 kg BK, cast, no bedding)

Fig. 6.4 Examples of shear failure, set S8-7-BK-C (7 kg BK, cast, no bedding)

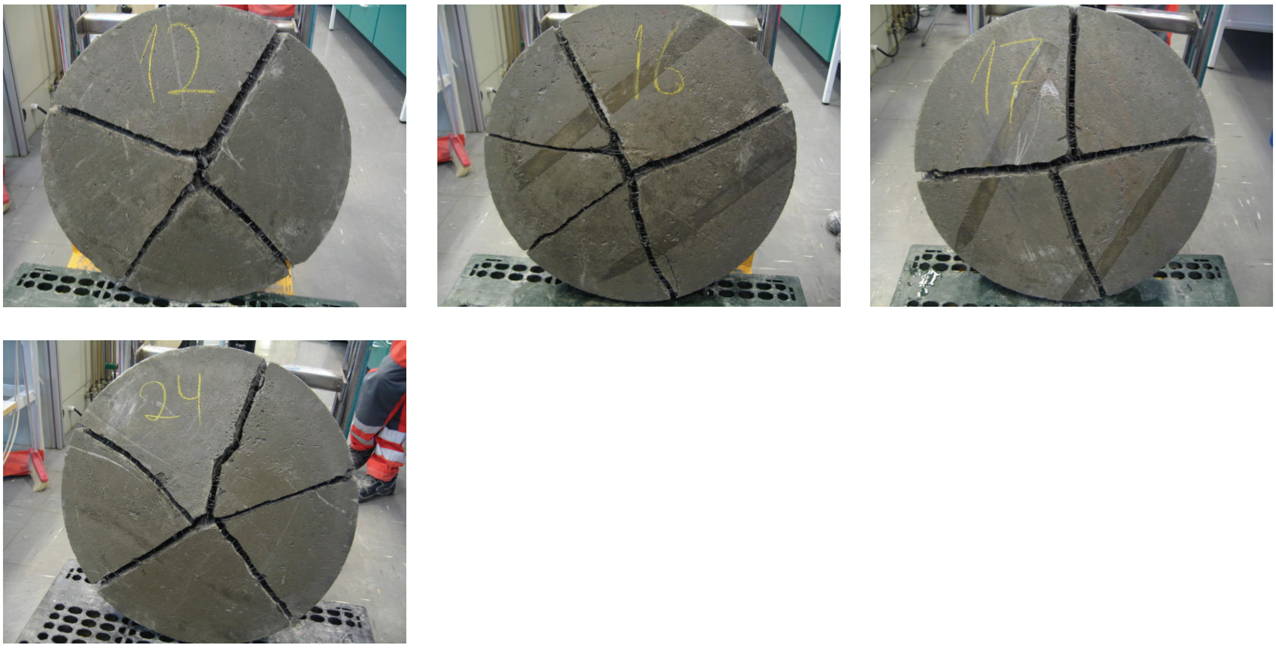


Fig. 6.5 Crack pattern, set S8-7-BK-C-PVC (7 kg BK, cast, PVC-bedding)

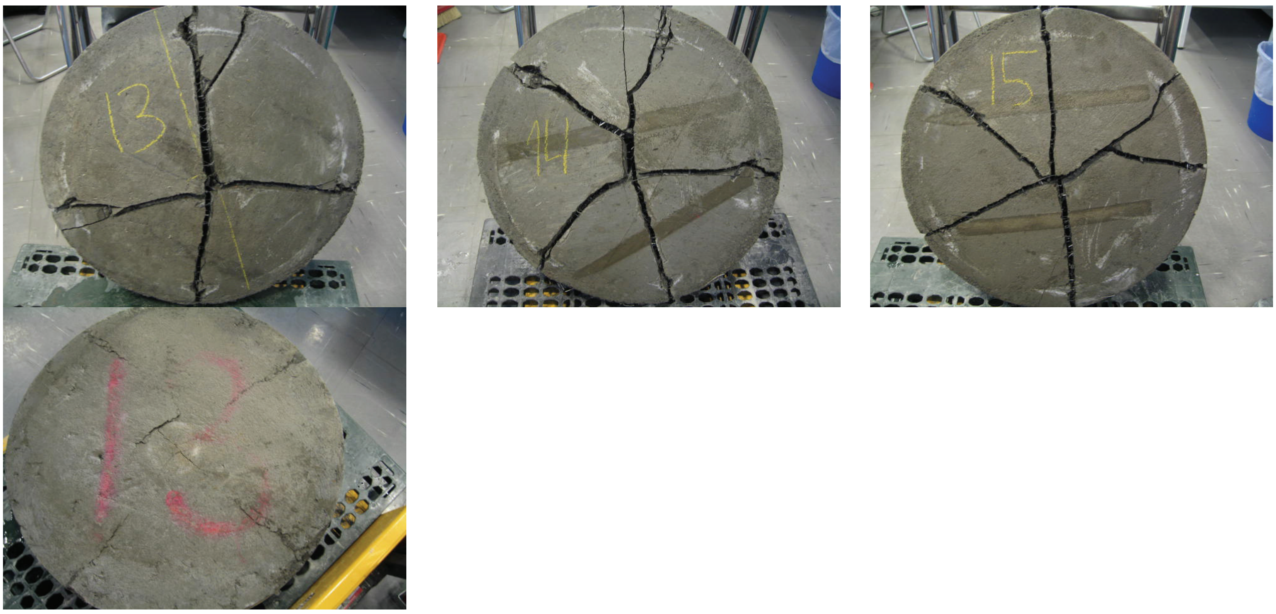


Fig. 6.6 Crack pattern, set S8-7-BK-S (7 kg BK, sprayed, no bedding) and shear failure tendency for panel 13 (lower picture)

Fig. 6.7 Crack pattern, set S8-7-BK-S-PVC (7 kg BK, sprayed, PVC-bedding)

6.2.3 Energy absorption capacity (EAC)

The coefficient of variation (COV) for EAC vs. displacement for each set, consisting of three to five panels is shown in the table below. At small displacements the variation is high. This is mainly due to the small energy values early in the tests. At 25 mm displacement COV varies from 2.2 % to 9.8 % among the different sets, and the average COV for all six individual sets is 7.1 %.

Table 4 Coefficient of variation (COV) of EAC for each set vs. displacement (Series 8)

(corrected) Displacement (mm)	COV S8-6-BC54-S	COV S8-6-BC54-C	COV S8-7-BK-C	COV S8-7-BK-C-PVC	COV S8-7-BK-S	COV S8-7-BK-S-PVC
1	13,5 %	3,5 %	26,7 %	31,2 %	31,4 %	27,2 %
3	1,6 %	13,3 %	16,2 %	18,1 %	28,1 %	15,6 %
5	4,6 %	9,7 %	13,9 %	13,8 %	22,4 %	7,2 %
10	4,0 %	8,6 %	8,9 %	10,5 %	13,1 %	3,4 %
15	5,6 %	7,3 %	7,5 %	9,5 %	11,1 %	3,4 %
20	7,4 %	6,4 %	7,0 %	9,9 %	10,1 %	2,9 %
25	**8,8 %**	**5,5 %**	**6,6 %**	**9,6 %**	**9,8 %**	**2,2 %**

The average accumulated energy uptake at 25 mm final displacement is shown in Table 5, whereas the energy uptake over the whole displacement range is shown in Fig. 6.8. The energy uptake relative to the energy at 25 mm is shown in Fig. 6.9. Measured results for single panels are given in APPENDIX 5.

Table 5: Results at 25 mm displacement (corrected for panel thickness), average results (Series 8)

Set	**Average accumulated energy uptake at 25 mm**	**Average residual load at 25 mm**
S8-6-BC54-C	1016	32,9
S8-6-BC54-S	1258	38,3
S8-7-BK-C	1172	34,3
S8-7-BK-C-PVC	870	23,7
S8-7-BK-S	1247	36,9
S8-7-BK-S-PVC	936	27,2

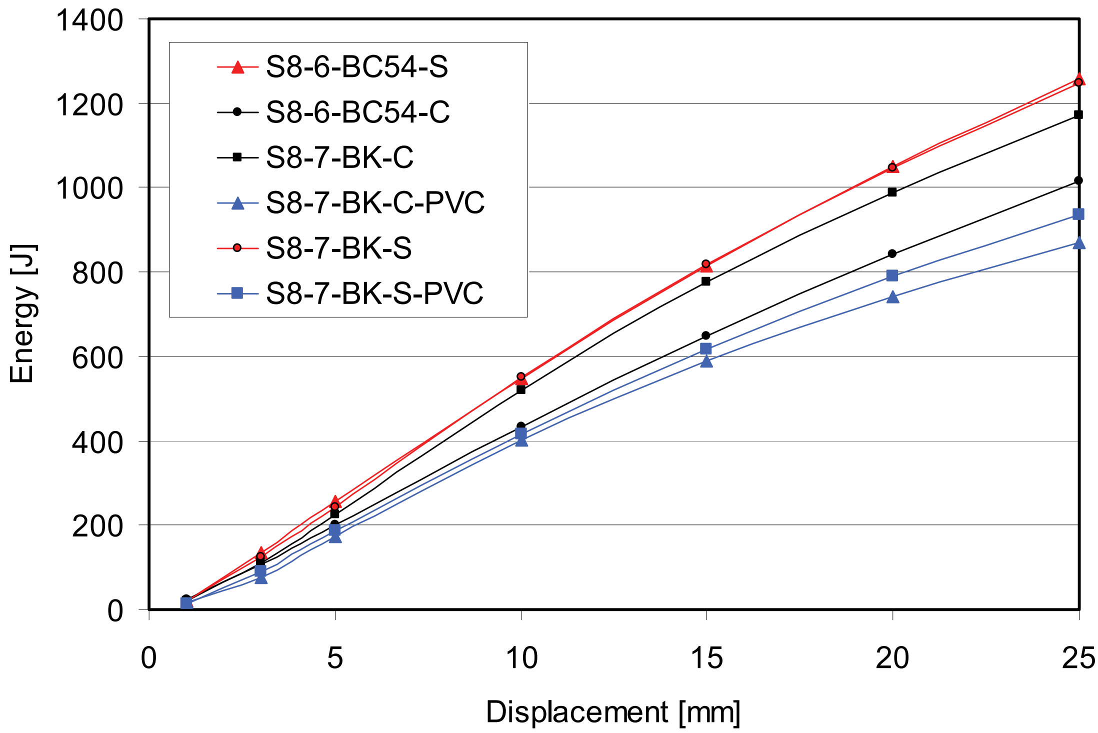


Fig. 6.8 Measured energy uptake for all sets (Series 8), average results.

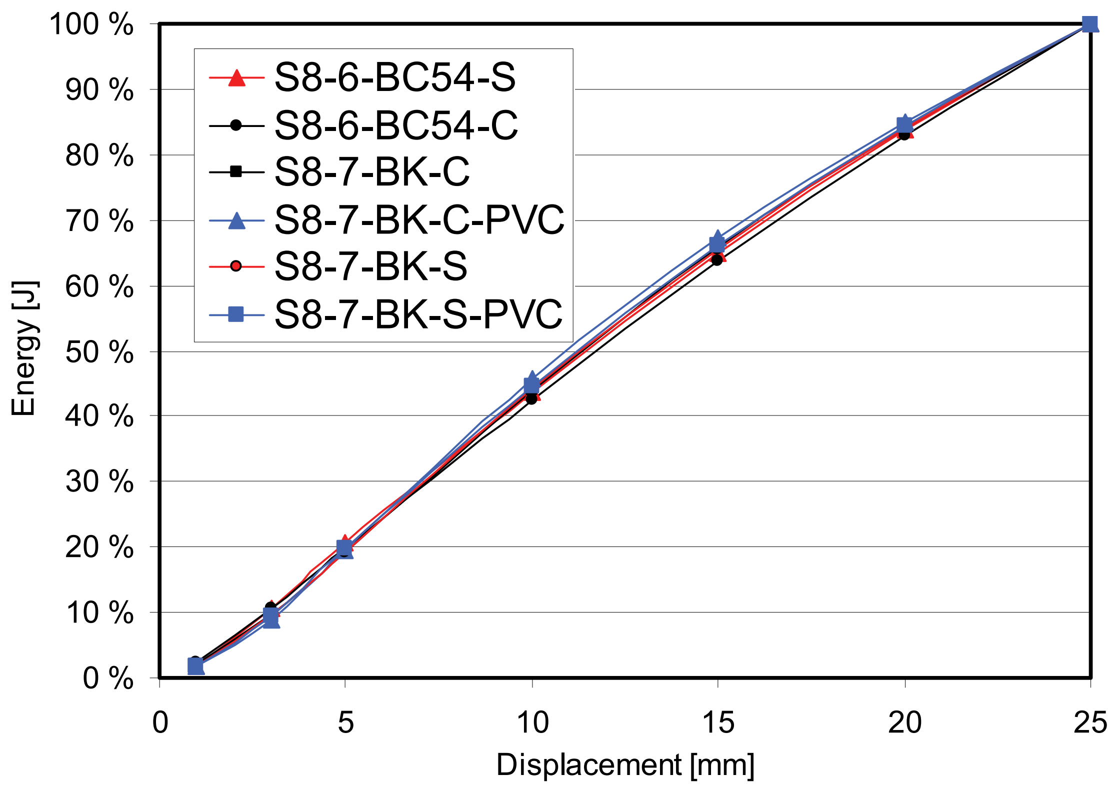


Fig. 6.9 Relative energy uptake for all sets (Series 8), average results.

6.2.3.1 Effect of friction

Fig. 6.10 shows the effect of friction on the apparent energy uptake in the two sets performed on steel support (no bedding), as compared to their parallel sets performed with bedding of PVC+grease (parallel sets S8-7-BK-C and parallel sets S8-7-BK-S). The effect of friction is calculated according to *Equation 2*. As can be seen, the two independent curves are very similar and there is little variation in the friction effect over the 25 mm displacement span. At 25 mm displacement the effect of friction was 25,7 % and 25,0 % for the two sets of parallel sets, respectively.

The same comparison for the residual load shows that the average friction effect was 30.9% and 26.4%, respectively, and for the maximum load during the test the friction effect was 14.9% and 15.3%, respectively.

To calculate the effect of friction on the energy uptake when using steel support ($EAC(\Delta)_{steel}$) the sets using bedding of two layers of PVC membranes+grease are used as reference ($EAC(\Delta)_{PVC}$), as we assume that there is no or very little friction influence for these cases. Thus, the friction effect is calculated according to:

Equation 2

$$\text{Friction effect (\%)} = \left(1 - \frac{\text{EAC}(\Delta)_{\text{PVC}}}{\text{EAC}(\Delta)_{\text{steel}}}\right) \text{x}100\%$$

where Δ is the displacement.

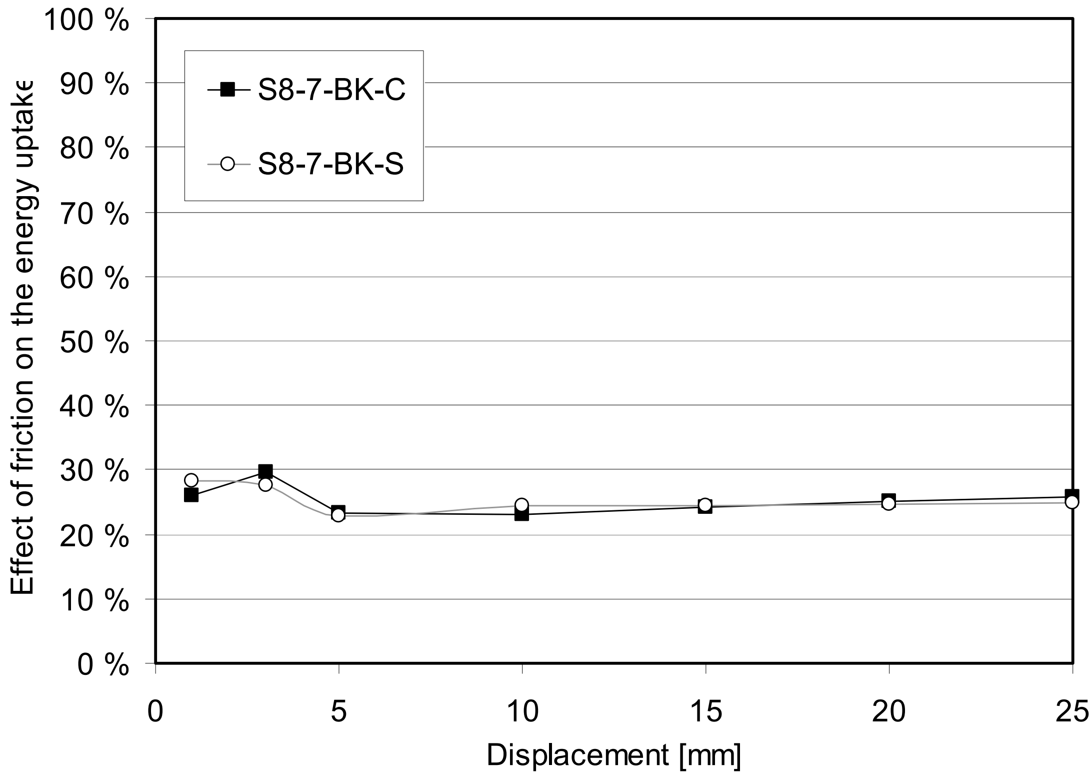


Fig. 6.10 Effect of friction on the average apparent energy uptake for the sets performed with steel support, as compared to the parallel sets performed with bedding of PVC+grease (Series 8)

6.2.3.2 Cast panels versus sprayed panels

For all three parallel sets with cast and sprayed panels the sprayed panels performed better than the cast ones, see Fig. 6.11 showing the ratio between cast and sprayed panels. The ratio varies a bit among the sets, and the ratio varies from 0.80 to 0.93 at 25 mm final displacement. It is notable that the ratio is quite invariable with regard to displacement beyond some mm. Overall average ratio is 0.90 at final displacement.

In sprayed concrete we normally assume that the air content becomes around 4-5 % irrespective of the air content before spraying. The air content before spraying is often higher than 4-5 % due to the fact that air entraining agents are often used to enhance pumping properties. Air content was however not measured during execution of Series 8. Still, we must assume that the air content before pumping (i.e. cast panels) was higher than the air content after spraying (i.e. sprayed panels). The fibre orientation may also be different in cast and sprayed panels. It is likely to believe that the spraying gives a more horizontal and beneficial orientation than casting. The two factors, lower air content and beneficial fibre orientation, may have contributed to better performance in sprayed panels.

Sprayed panels have somewhat higher w/c-ratio due to the water in the accelerator. The effect of this on the ability to take up energy is somewhat unclear, but resent tests (Series 10, to be reported) indicate that this also contributes to sprayed panels performing better than cast ones. Different degree of compaction in cast and sprayed panels may also be an issue, of course.

The amount of data on cast and sprayed panels from the same load of concrete is presently scarce. It is likely that the influencing factors (air content, fibre orientation, compaction, w/c-ratio) for cast and sprayed panels may vary from case to case and it is therefore uncertain whether the present results represent a general picture.

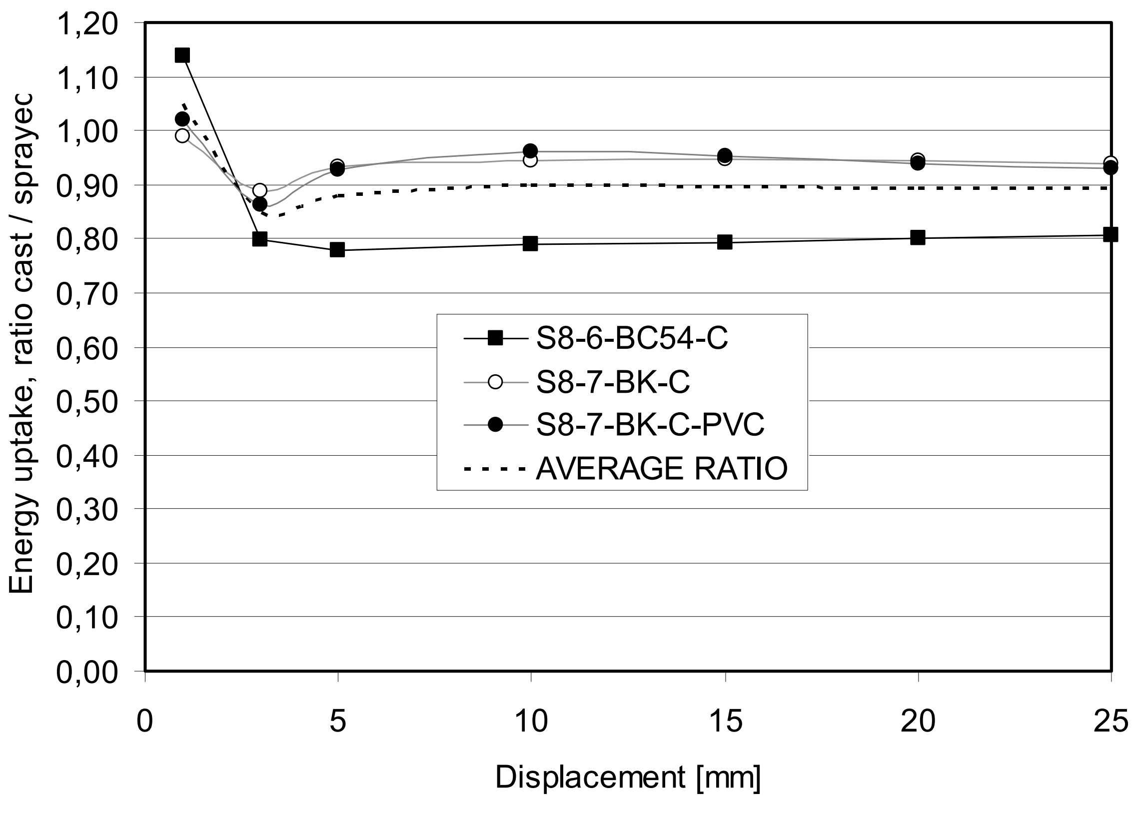


Fig. 6.11 Average energy absorption, ratio between cast panels and sprayed panels vs. displacement (Series 8).

7 Test results, Series 9

7.1 Supporting test results

7.1.1 Fresh concrete temperature and -air content, and compressive strength

The various concretes were more or less the same mix, except for the fibre type and -addition. Among the different sets there was some variation both in fresh concrete air content as well as in 28-days compressive strength (from cast cubes), see Table 6. It is evident from the results that the air content was not a main parameter with regard to the somewhat varying compressive strengths. This is surprising and means that other/unknown factors have played a role (varying compaction/air voids in the cubes?).

Table 6 Various results, Series 9

Set	Fresh concrete temperature	Fresh concrete air content	28-days cube strength (average of two cast cubes)
S9-20-D-S	10 °C	9.8 %	51.0 MPa
S9-40-D-S	16.2 °C	10 % (slump 230 mm)	45.8 MPa
S9-60-D-S	18.4 °C	11 %	51.8 MPa
S9-5-BK-S	18.8 °C	6 %	44.8 MPa
S9-7-BK-S	20.5 °C	10 %	48.8 MPa
S9-8-BK-S	21 °C	9 %	48.8 MPa

7.1.2 Fibre content measurements

The fibre measurements in Series 9 reveal that the fibre contents differed strongly from the nominal and intended dosages, see Table 7. The measurements from the fresh samples taken before spraying also differ strongly from those taken from the actual panels after testing. Note that in the three panels “S9-5-BK-S” it was found a mix of BK fibres and D fibres (should be only BK fibres). The automixer truck was obviously not cleaned sufficiently after switching between the two fibre types. See APPENDIX 4 for the fibre content of single panels.

Table 7 Measurements of fibre content in fresh concrete and from the tested panels. All numbers are pr. 1 m^3 of concrete (Series 9)

Set	Nominal fibre content	Fibre content from fresh concrete (1 sample)	Average fibre content from tested panels (average from 3 samples, one from each panel in the set)
S9-20-D-S	20 kg D	33.2 kg D	50.4 kg
S9-40-D-S	40 kg D	44.0 kg D	88.1 kg
S9-60-D-S	60 kg D	46.3 kg D	65.4 kg
S9-5-BK-S	5 kg BK	8.6 kg BK*⁾	8.8 kg BK and 5,2 kg D
S9-7-BK-S	7 kg BK	4.8 kg BK	8.2 kg
S9-8-BK-S	8 kg BK	8.5 kg BK	9.1 kg

D=Dramix steel fibre, BK=BarChip Kyodo PP fibre

**⁾ Some D fibres were seen in this sample, but it was not paid any attention to it*

7.2 Panel test results

7.2.1 *Panel thicknesses*

All measurements of panel geometries are given in APPENDIX 3, while an extract for Series 9 is given in the following. The average thickness for all panels was 100.3 mm. The thickest panel was 102.7 mm and the thinnest panel was 97.6 mm. The average standard deviation (STD) for all the panels was 1.3 mm. The highest STD for one panel was 2.8 mm, the lowest 0.7 mm.

Similar numbers for panel diameters are 600.7 mm as an average for all panels (average STD = 1.4 mm). Largest panel diameter was 603.3 mm and lowest was 599.3 mm (highest STD for one panel was 2.3 mm and lowest 0 mm).

7.2.2 *Crack pattern*

After end of testing, the panels were taken out of the test frame and the underside of the panels were photographed, see Fig. 7.2 through Fig. 7.7, including some examples of shear failure taken from the upper- and underside of the panel.

The series was dominated by shear failure in the panels, probably related to high loads due to the very high fibre contents. Four of the nine panels with steel fibres (D) and six of the nine with PP fibres (BK) showed shear failure. The panels developed 4-7 main radial cracks. In addition there were generally several minor cracks which arise from the main cracks. Hence, the cracking was both comprehensive and complex.

An example of an extreme shear failure for one panel is given in Fig. 7.1 (panel "S9-40-D-S-6"). The large shear crack has apparently reduced the energy uptake at large deflections. For the other two panels in this set the shear cracking were not so pronounced. It is notable though that the variation in this set is not higher than normal (COV=6.3% at 25 mm displacement).

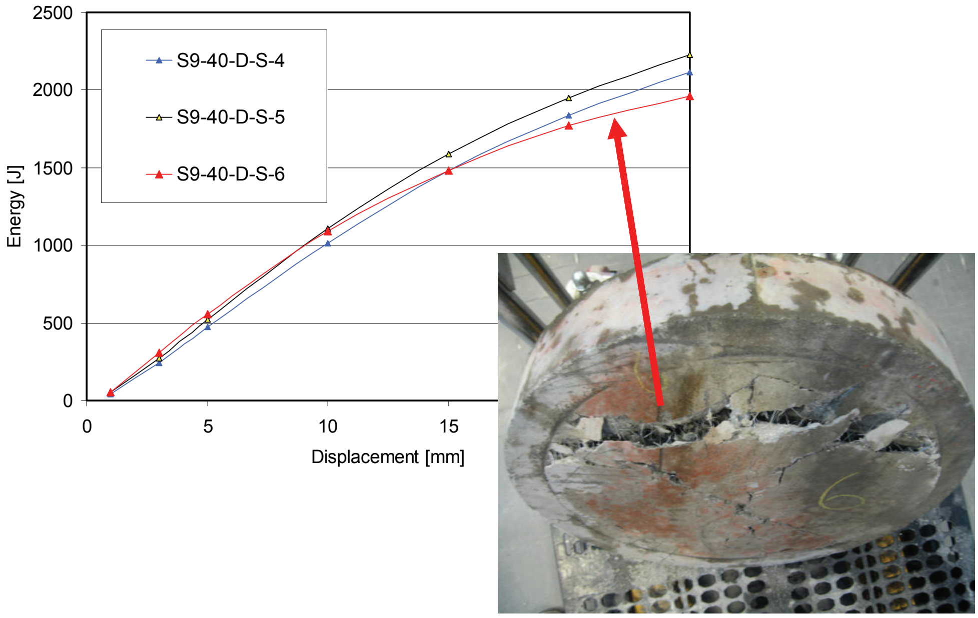


Fig. 7.1 Example of an extreme shear failure in the panel "S9-40-D-S-6"

Fig. 7.2 Crack pattern, S9-20-D-S (20 kg Dramix, Sprayed, no bedding)

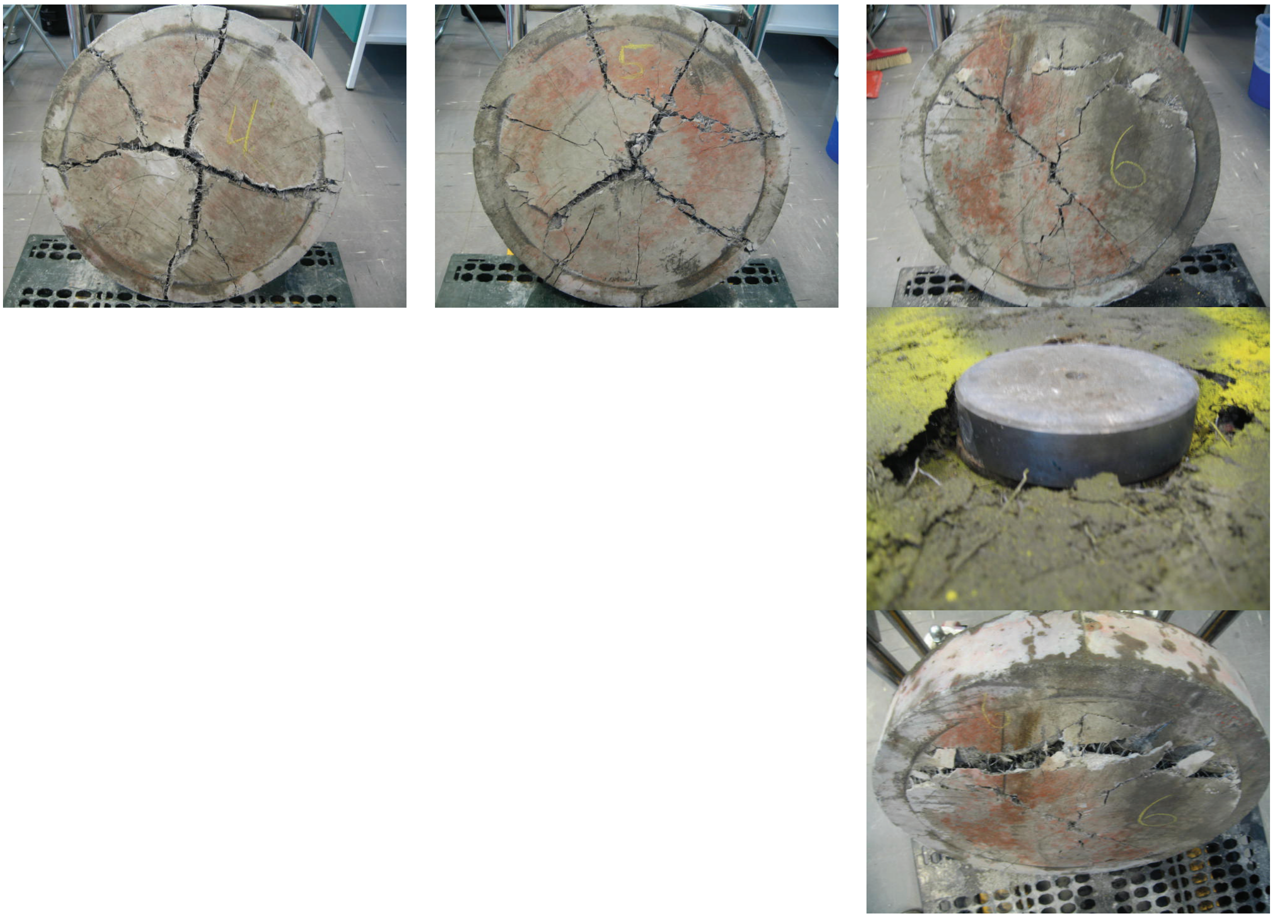


Fig. 7.3 Crack pattern, S9-40-D-S (40 kg Dramix, Sprayed, no bedding)

Fig. 7.4 Crack pattern, S9-60-D-S (60 kg Dramix, Sprayed, no bedding)

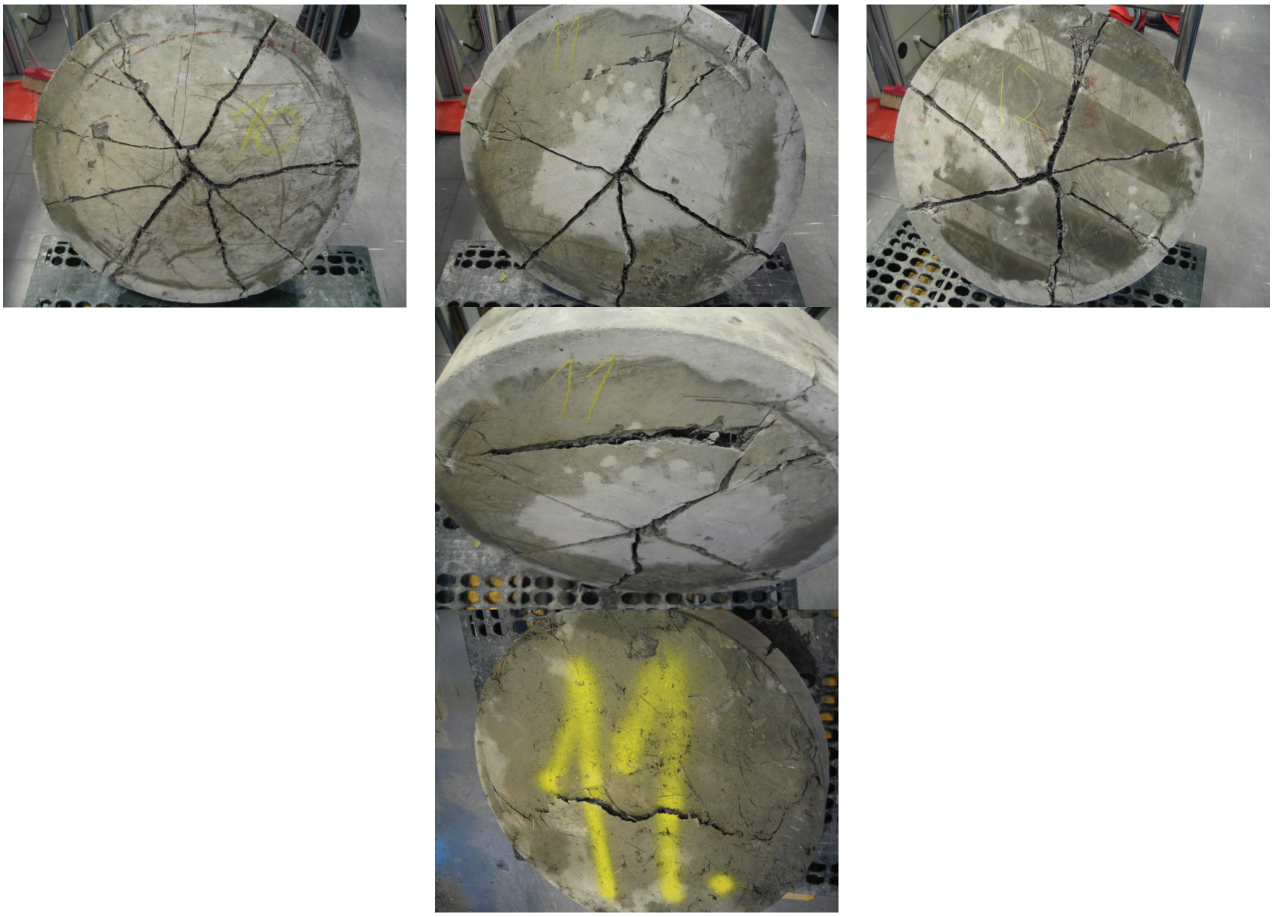


Fig. 7.5 Crack pattern, S9-5-BK-S (5 kg BarChip Kyodo, Sprayed, no bedding)

Fig. 7.6 Crack pattern, S9-7-BK-S (7 kg BarChip Kyodo, Sprayed, no bedding)

Fig. 7.7 Crack pattern, S9-8-BK-S (8 kg BarChip Kyodo, Sprayed, no bedding)

7.2.3 Energy absorption capacity (EAC)

The coefficient of variation (COV) for EAC vs. displacement, for each set of three panels, is shown in the table below. At low displacement, the variation is generally high. This is mainly due to small energy values. At 25 mm displacement COV varies from 0.5 % to 18.9 % among the different sets, and the average COV for all six individual sets is 8.3 %.

Table 8 Coefficient of variation (COV) of EAC for each set vs. displacement (Series 9)

(corrected) Displacement (mm)	COV S9-20-D-S	COV S9-40-D-S	COV S9-60-D-S	COV S9-5-BK-S	COV S9-7-BK-S*)	COV S9-8-BK-S
1	36,3 %	16,9 %	21,7 %	25,7 %	3,0 %	27,1 %
3	28,9 %	11,6 %	8,3 %	6,2 %	8,2 %	12,5 %
5	23,8 %	8,5 %	5,2 %	2,0 %	8,4 %	10,4 %
10	18,6 %	4,8 %	4,0 %	5,3 %	5,7 %	2,4 %
15	17,8 %	3,9 %	4,6 %	9,7 %	4,0 %	1,5 %
20	18,5 %	4,8 %	5,6 %	12,9 %	3,5 %	0,3 %
25	**18,9 %**	**6,3 %**	**6,0 %**	**14,2 %**	**4,0 %**	**0,5 %**

*) *Only two panels*

The average accumulated EAC at 25 mm final displacement is shown in Table 9, whereas the EAC over the whole displacement range is shown in Fig. 7.8. The EAC-development relative to the final EAC at 25 mm is shown in Fig. 7.9.

There is a systematic effect of fibre content on the EAC for both fibre types. The high dosages of D fibre led to the highest EAC-values. It is notable that for the three sets with BK fibre, with different nominal fibre contents, both the actual fibre content and the EAC-values varies very little. Average BK fibre content among the three sets is 8.7 kg/m^3 and average final EAC is 1352 Joule.

The EAC-development relative to the energy uptake at 25 mm displacement is shown in Fig. 7.9. The relative development is quite similar for all sets irrespective of dosage and type of fibre, also at low displacements. The set "S9-40-D-S" is an exception (note: the set with the highest actual fibre content of 88 kg!). Shear failure was quite predominant in this set.

Table 9: Actual fibre content, energy absorption as well as residual load at 25 mm (corrected) displacement, average results (Series 9)

Set	Average fibre content as measured from the panels [kg/m^3]	EAC, Final average accumulated energy absorption [J]	Average residual load [kN]
S9-20-D-S	50.4	1661	44
S9-40-D-S	88.1	2100	43
S9-60-D-S	65.4	1822	48
S9-5-BK-S	8.8	1368	39
S9-7-BK-S	8.2	1293	35
S9-8-BK-S	9.1	1395	37

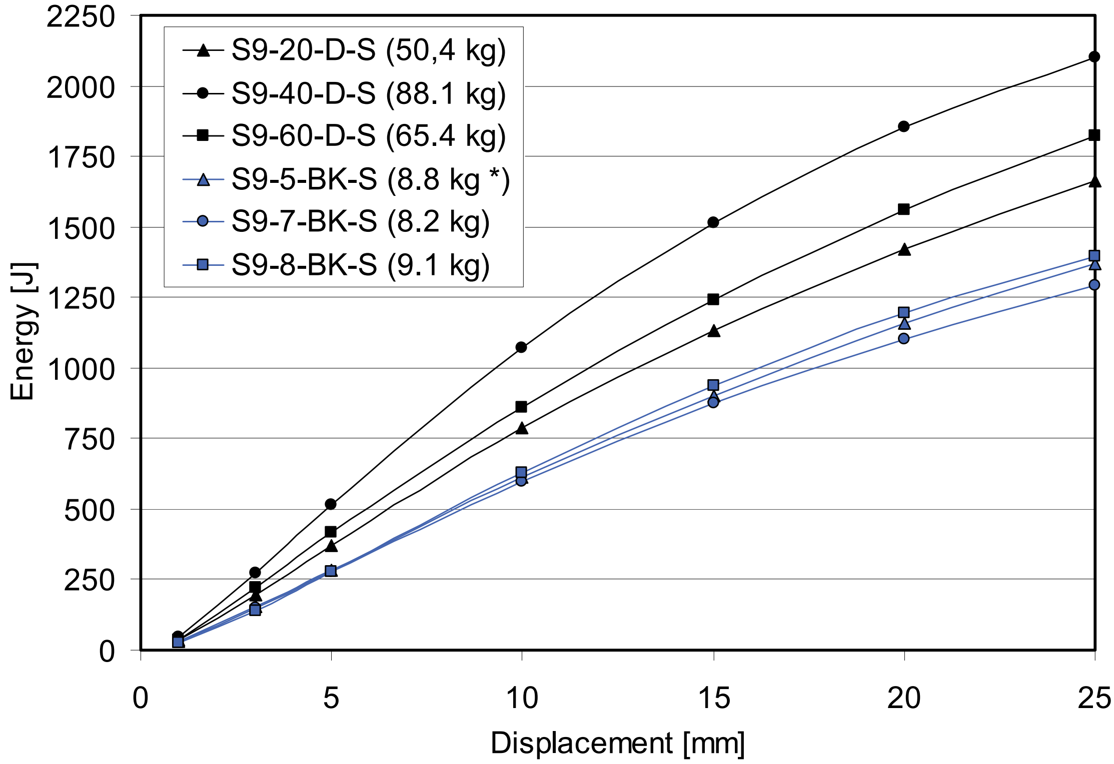


Fig. 7.8 Measured energy uptake, average for each set (Series 9)

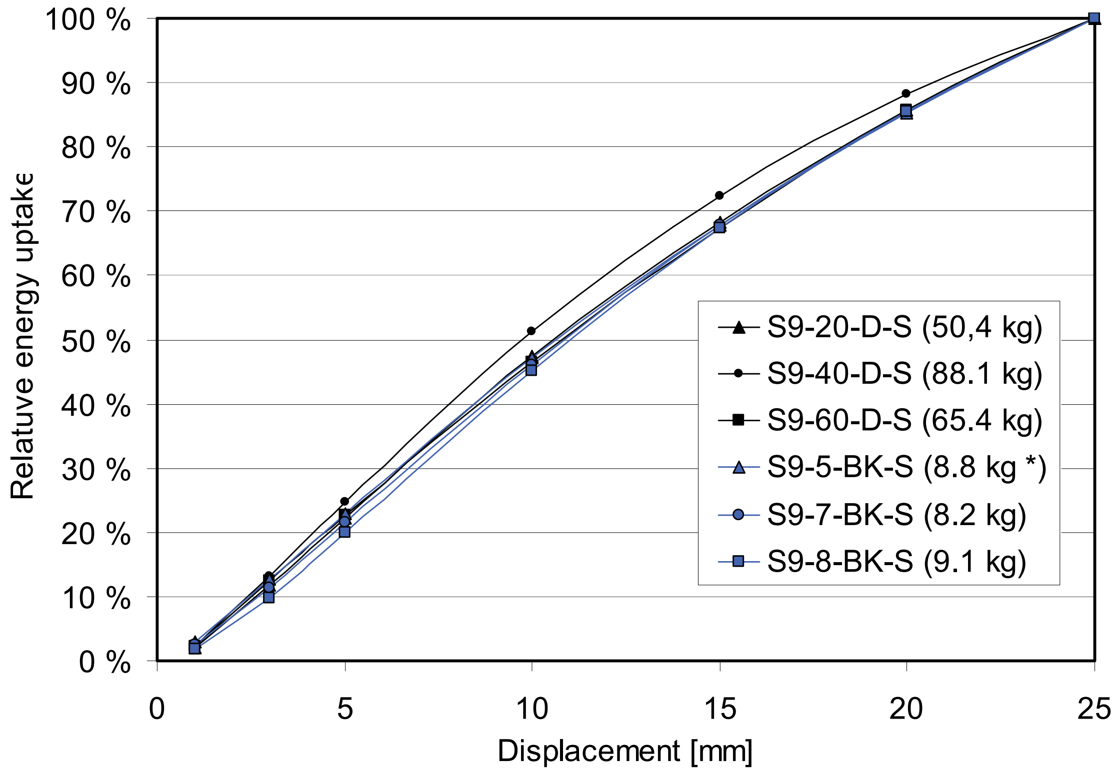


Fig. 7.9 Relative energy uptake, average for each set (Series 9)

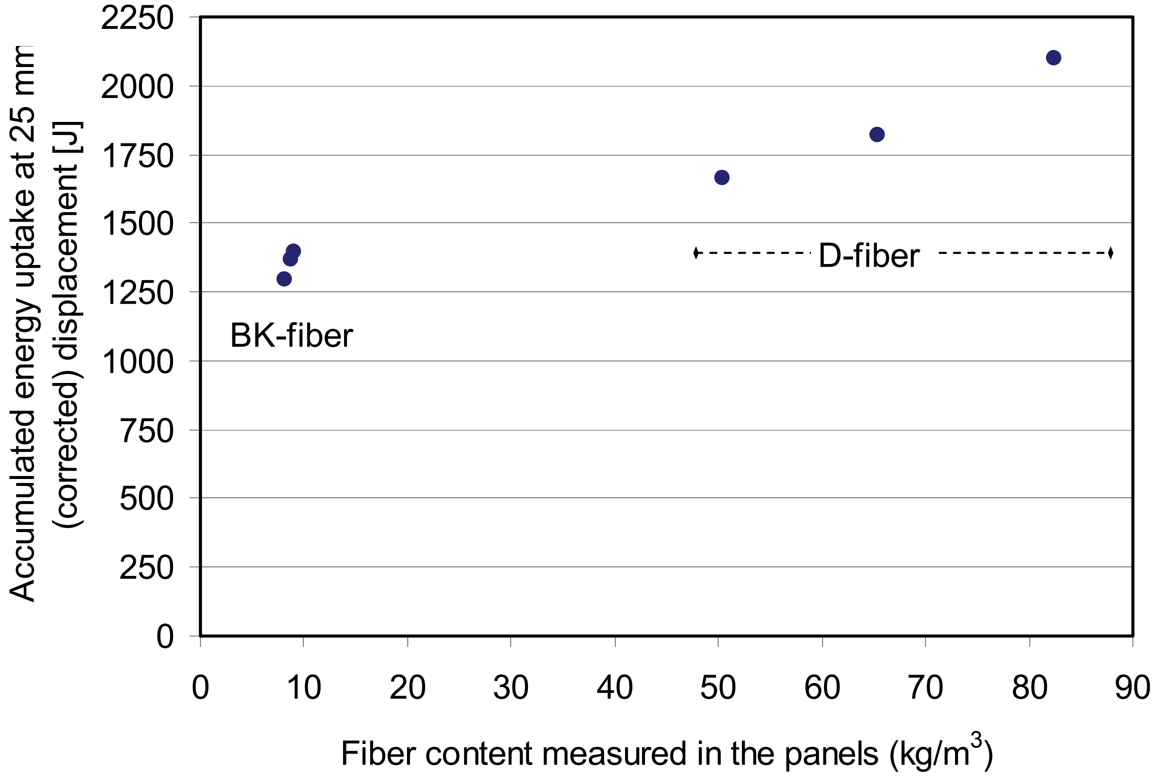


Fig. 7.10 Accumulated energy absorption at 25 mm (corrected) displacement vs. fibre content as measured in the panels. Average values for each set (Series 9)

8 Conclusions

The panel tests were performed on continuous steel support. Average coefficient of variation for the energy absorption capacity (EAC) at 25 mm displacement among all 6 individual sets in Series 8 was 7.1% and among the six sets in Series 9 it was 8.7%.

The average thickness for all panels was 102.3 mm in Series 8 and 100.3 mm in Series 9. Among all panels the highest panel thickness was 108 mm and the lowest thickness was 97.6 mm. The variation range for panel diameter was 603 mm to 598 mm. Hence, compared to the nominal panel diameter of 600 mm the variation is very little. Hence, for these results the panel diameter will only marginally influence the calculated energy uptake and it was therefore mot introduced as an correction factor when calculating the energy absorption. All presented values from the panel tests were only corrected for thickness.

Series 8

For the parallel sets performed with and without friction-reducing bedding material, the results show that friction between the panel and the supporting ring of steel constitutes 25.7% and 25.0% of what is taken to be energy absorbed by the panel at final displacement of 25 mm. These values are in line with the 28% friction effect that was found in Series 6 [14]. Hence, for these three individual results the overall average friction effect from a supporting ring of steel (with sharp inner edge) on the measured energy absorption capacity is 26.2%.

Similarly, when including the results from Series 6 with the present, the overall friction effect is 31.4% on the residual load measured at 25 mm displacement and 15.4% on the maximum load measured during the test.

For this particular study the cast panels had on average 90% energy absorption capacity compared to the sprayed panels. Possible influencing parameters are different air content, fibre orientation, compaction and w/c-ratio for cast and sprayed panels. The amounts of data on cast and sprayed panels from the same load are yet scarce and general conclusions cannot be drawn.

Series 9

This series was dominated by the fibre dosages being strongly overdosed on-site compared to the intended nominal dosages and, correspondingly, the energy absorption values became high, especially for the steel fibre mixes.

The intended three dosage levels of macro synthetic polypropylene (PP) fibre for the three sets turned out to become more or less one level. The average PP dosage for the three sets was 8.7 kg/m^3 and the average energy absorption at 25 mm final displacement was 1352 Joule. The steel fibres had nominal dosage levels of 20, 40 and 60 kg/m^3, whereas the fibre measurements taken from the tested panels showed 50, 88 and 65 kg/m^3, respectively. These actual fibre contents had, however, a systematic effect on the accumulated energy absorption at 25 mm displacement as more fibre led to higher energy uptake (average EAC at 25 mm span from 1661 Joule to 2100 Joule among the three sets).

Effect of fibre content, Series 8 and 9

The figure below, Fig. 8.1, shows average results for EAC at 25 mm displacement versus fibre content, both for Series 8 and for Series 9. The figure contains only the tests that were performed with sprayed panels placed directly on steel support (no bedding). Note that for Series 8 the values for fibre content are nominal values, whereas for Series 9 the fibre contents are actual dosages as measured from the tested panels. The lower energy absorption results in the figure (open symbols) have been multiplied with the factor 0.75, which then represent the EAC in each set without the extra energy caused by friction between the panel and the support. The factor 0.75 is a rounded number compared to the actual friction effect which is 26.5% on average (which really means that the factor should be 1-0.265=0.735).

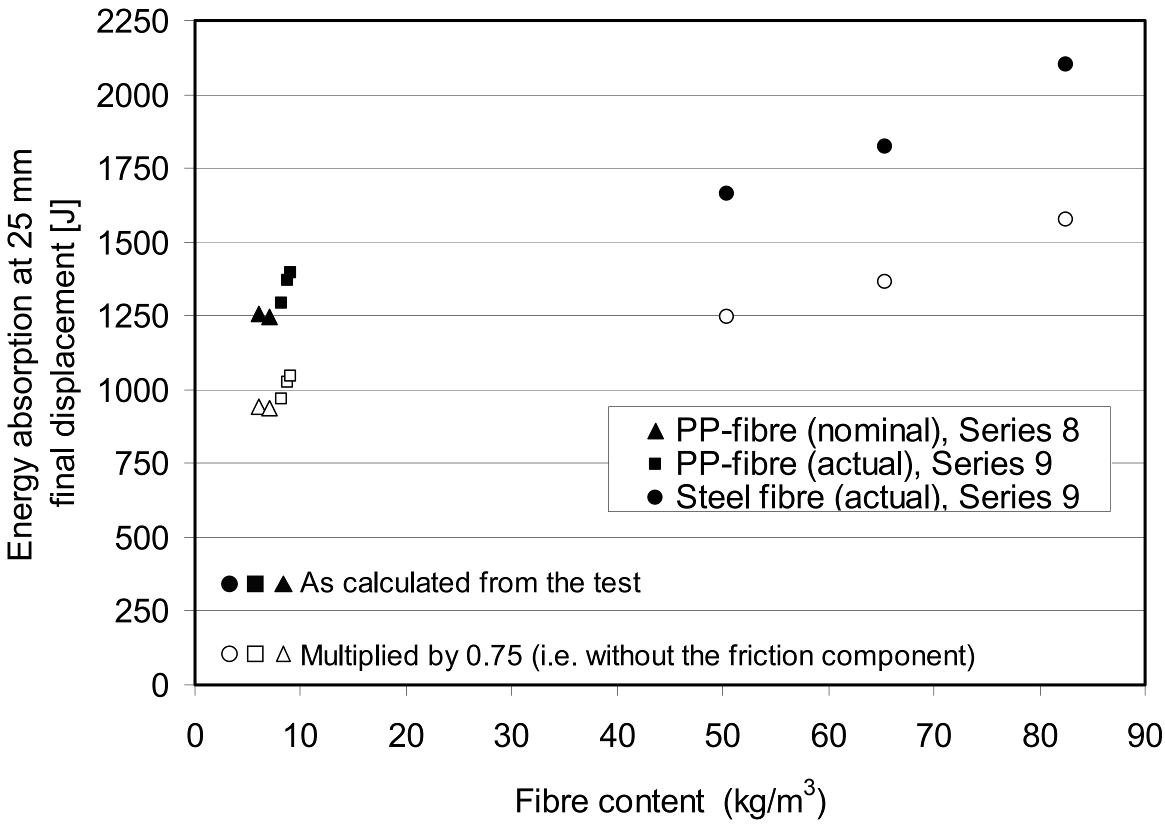


Fig. 8.1 Accumulated energy absorption at 25 mm displacement vs. fiber content in Series 8 and 9 for sprayed panels tested directly on steel support. Fibre contents are nominal values in Series 8 and actual values (measured in the panels) in Series 9.

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APPENDIX 1 Fibres, product data sheets

Produktdatablad

BarChip
Synthetic Reinforcing Fibre

Produktnavn

Kyodo

epc Elasto Plastic Concrete

Beskrivelse

48 mm lang Strukturell Syntetisk armeringsfiber som tilsettes betong og sprøytebetong for å erstatte stålarmeringsnett eller stålfiber.

Produktkarakteristikk

Karakteristikk	Materialegenskap
Base harpiks	Polyolefin
Lengde	48 mm
Strekkfasthet	550 MPa
Overflatestruktur	Uavbrutt forhøyet
Antall fiber pr. kg	>35 000
Spesifikk vekt	0,90 - 0,92
Elastitetsmodul	8,5 GPa
Smeltepunkt	150 -165 ° C
Tennpunkt	Over 450° C

Fordeler

- Kostnadsbesparende
- Fleksibel hardhet som stål
- Tryggere og enklere å håndtere enn stålfiber
- Ingen rust sikrer lenger holdbarhet
- Økt brannmotstand
- Redusert slitasje på utstyr

Dosering

Din lokale representant vil være behjelpelig vedrørende fiberdosering som passer til ditt prosjekt.

Testdata

Utstrakt forskning utført på Barchip "Kyodo" har bekreftet dens anvendelighet for armering av betong og sprøytebetong.

Vennligst spør din representant om mer informasjon om:

- fleksibelt energiopptak
- lang holdbarhet
- brannmotstand

Håndtering og lagring

- 5 kg oppløselige papirsekker

Lagring: Lagres i tørre omgivelser.
Sikkerhet: Ref. HMS-datablad.

epc Elasto Plastic Concrete www.elastoplastic.com

Annen relatert informasjon: Batching and Mixing - Placing and finishing — Prosjekt-referanser er tilgjengelige på vår web-side eller hos din Barchip konsulent. Barchip produseres i henhold til ISO-9001 standard.

Denne informasjonen er blitt gitt kun som en rettledning for utførelse under spesielle og overvåkede forhold. Brukeren rådes til selv å vurdere å benytte service fra profesjonelle for å bestemme produktets egnethet for spesielle prosjekter eller applikasjoner før den benyttes.

EPC Europa **call** +44 (0) 77 8070 2642 **email** europa@elastoplastic.com

Norwegian distributor:

Norm Tec AS
Grubeveien 10, 2208 Kongsvinger, Norway
E-mail: post@normtec.no
Telefon: +47 45 40 06 58
Fax: +47 62 81 55 06

1

Product Data Sheet

epc Elasto Plastic Concrete

BarChip54

Description

BarChip54, a Structural Synthetic Fibre from Elasto Plastic Concrete's range of copolymer fibres, evolved from EPC's "Future Fibre" research and development program. The aim of this program is to develop a range of fibres that achieve the highest performance levels ever seen in structural synthetic fibre reinforcement systems. The latest advances in copolymer technology, engineering design and manufacturing techniques have been incorporated into BarChip54 to deliver a fibre that is unequaled in usability, durability and service performance. BarChip54 is suitable for use in concrete applications with concrete strengths of 30 MPa or greater.

Close up of BarChip Fibre

Product Features

Characteristic	Material Property
Base Resin	Modified Olefin
Length	54mm
Tensile Strength	640 MPa
Surface Texture	Continuously embossed
No. fibres per kg	37,000
Specific Gravity	0.90 - 0.92
Youngs Modulus	10 GPa
Melting Point	159°C - 179°C
Ignition Point	Greater than 450°C

Benefits

- Lower cost per Joule fibre
- Weather proof pallet packaging
- Flexural toughness equal to steel
- Long term durability ~ corrosion free
- Safer and lighter to handle than steel
- Reduced fire damage ~ anti-spalling
- Reduced wear on concrete pumps and hoses

Dosage

EPC's BarChip54 has an effective dosage range of 3kg to 10kg per cubic metre. Dosage rates should be selected based on performance requirements. Typical dosage rates for Shotcrete applications in normal ground conditions range from 4kg to 6kg per cubic metre. For assistance in specifying a dosage rate for your project please contact an EPC representative.

Mixing

To achieve optimum fibre distribution during mixing it is recommended the total fibre requirement is added first "bags and all" to the mixer with the initial batch water. From this point normal loading procedures can be used. The mulchable bag will release the fibres which will be homogenously distributed throughout the mix after 5 minutes of mixing. 6kg of BarChip54 may reduce measured slump by between 10mm and 20mm dependent on mix design. For more detailed instructions please refer to EPC's Technical Sheet: "Batching and Mixing", available for download at http://www.elastoplastic.com.

Pumping

EPC's BarChip54 fibre can be pumped through 50mm rubber hoses without difficulty. Precaution should be taken to ensure the fibres can pass freely through the pump hopper grate.

Handling and Storage

- 3kg mulchable paper bag/432Kgs per pallet
- UV stabilized modified olefin fibre
- Shipped on durable plastic pallets
- Weather proof tarpee pallet covers
- Bulk bags available on request

EPC's UV stabilized BarChip54 fibre is supplied on durable recyclable plastic pallets with a fitted rain hood to allow storage outdoors with no environmental deterioration of product or packaging. Bags of BarChip54 stored individually must be protected from water damage to prevent bag deterioration.

For safety please refer to BarChip54 MSDS available for download at http://www.elastoplastic.com.

Product Data Sheet

epc Elasto Plastic Concrete

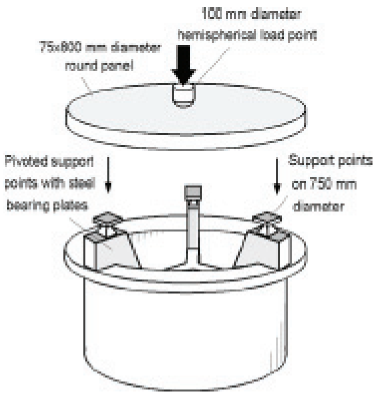
Testing

ASTM C 1550 Round Determinate Panel.

Suitable for analysis of concrete used in the following applications:

- Shotcrete
- Concrete Wall Construction
- Precast Products

ASTM C1550 round panel test offers designers, contractors and owners several important advantages over alternative forms of post-crack performance assessment. The most important of these is the low variability in sample results due to the repeat ability of the cracking pattern, but other advantages include the elimination of saw cutting during specimen production and the use of easy to prepare form work.



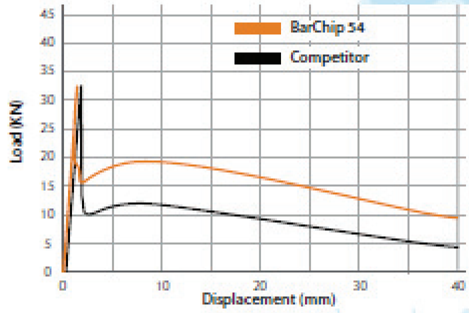
The test involves applying a point load at the centre of a round panel measuring 800mm x 75mm centred on three symmetrically arranged pivots located on a 750mm diameter circle. The loading piston is advanced at a constant rate of 4mm/min. The test proceeds to a total central deflection of 40mm after which the energy absorbed by the specimen (Joules) is measured as the area under the load-deflection curve.

Other test information is available on:

- Fire Resistance – anti-spalling
- Advanced Alkalinity Testing
- Long Term Durability – superior to steel fibre

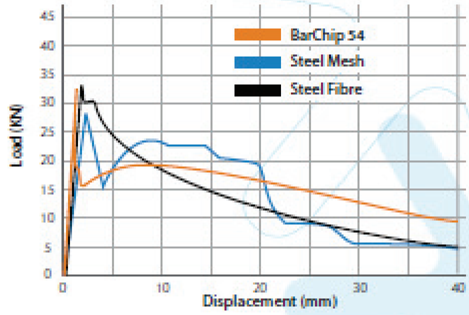
Results

EPC BarChip54 has been independently tested against competitors current fibres, as well as steel alternatives. The results below show the total energy absorption at a 40mm displacement.



Reinforcing Material	ASTM C1550 RDP	EFNARC
EPC BarChip54 @ 5kg/m³	470 Joules	1175 Joules
Competitor 58mm Fibre @ 5kg/m3	362 Joules	905 Joules

(Average results over 5 panel tests)



Reinforcing Material	ASTM C1550 RDP	EFNARC
EPC BarChip54 @ 5kg/m³	470 Joules	1175 Joules
Steel Mesh (500Mpa 4mm wire 100mm centres)	475 Joules	1187 Joules
Steel Fibre @ 30kg/m³	444 Joules	1110 Joules

(Average results over 5 panel tests)

epc Elasto Plastic Concrete www.elastoplastic.com

Disclaimer

This information has been provided as a guide to performance only, for specific and supervised conditions. The user is advised to undertake their own evaluation and use the services of professionals to determine the product suitability for any particular project or application prior to commercial use.

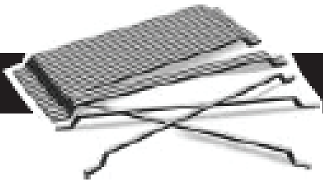
CE ISO 9001:2000 PS2314

EPC Australia	call +61 1300 131 158	email australia@elastoplastic.com
EPC Europe	call +44 (0) 77 8070 2642	email europe@elastoplastic.com
EPC Asia	call +65 6835 7716	email asia@elastoplastic.com
EPC N. America	call +1 704 843 8401	email na@elastoplastic.com
EPC S. America	call +56 32 271 5118	email sa@elastoplastic.com

Distributors are located in other regions. For contact details speak to your nearest regional office listed above.

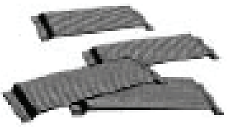
PRODUCT DATA SHEET

BEKAERT



Dramix®

Description:



Dramix® fibres are filaments of wire, deformed and cut to lengths, for reinforcement of concrete, mortar and other composite materials. Dramix® RC-65/35-BN is a cold drawn wire fibre, with hooked ends, and glued in bundles.

Applications:

- shotcrete
- screeds
- precast
- overlays
- compression layers

Geometry:

Length (l)
35 mm

Diameter (d)
0,55 mm

65 Performance class: 65

Aspect ratio (= l/d): 64

14 500 fibres/kg

Approvals:

Conforms to
ASTM A820

Quality System in
Belgian, Brasilian, Czech, Turkish and Chinese plants
ISO 9001

Product	Product
Belgium **ATG 04/1857**	Poland **AT-15-2117/2001**
Turkey **TS 10513**	Romania **007-01/068-2003**
Germany **Z-3.71-1745**	Slovak Republic **1402A/02/0771/1/C/C04**
Czech Republic **C.070-021415**	

Tensile strength:

- on the wire: minimum 1100 N/mm²
- low carbon conforms to EN 10016-2 - C9D

Coating: None

Technical data:

For shotcrete, ...
ask for specialized documentation.

1 Equivalent flexural strength

- $f_{fctm,eq,300}$, $f_{fctk,eq,300}$ = average and characteristic equivalent flexural strength to a deflection of 1,5 mm according to NBN B 15-238, 239, JSCE-SF4 and CUR35.
- $f_{fctm,eq,150}$, $f_{fctk,eq,150}$ = average and characteristic equivalent flexural strength to a deflection of 3 mm according to NBN B 15-238, 239, JSCE-SF4 and CUR35.

Dramix® RC-65/35-BN

$f_{ctm,fl}$ (1) ►	3,7 (C20/25) (2)		4,3 (C25/30)		4,8 (C30/37)		5,3 (C35/45)		5,8 (C40/50)	
Dosage ▼	$f_{fctm,eq,300}$	$f_{fctm,eq,150}$	$f_{fctm,eq,300}$	$f_{fctm,eq,150}$	$f_{fctm,eq,300}$	$f_{fctm,eq,150}$	$f_{fctm,eq,300}$	$f_{fctm,eq,150}$	$f_{fctm,eq,300}$	$f_{fctm,eq,150}$
20	2,3	1,9	2,6	2,2	2,8	2,4	2,9	2,6	3,1	2,7
25	2,6	2,2	2,9	2,5	3,0	2,7	3,2	2,9	3,4	3,0
30	2,8	2,5	3,1	2,7	3,2	3,0	3,5	3,2	3,6	3,3
35	3,1	2,8	3,4	3,0	3,5	3,2	3,8	3,4	3,9	3,5
40	3,3	3,1	3,6	3,3	3,8	3,4	4,0	3,6	4,2	3,7
45	3,5	3,2	3,8	3,4	4,0	3,5	4,2	3,7	4,4	3,8
50	3,7	3,3	4,0	3,5	4,2	3,6	4,4	3,8	4,6	3,9

(1) $f_{ctm,fl}$ = mean flexural tensile strength of plain concrete (N/mm²).
(2) Concrete class corresponding with $f_{ctm,fl}$ according to ENV 1992-1-1.
Boxed value [0,5] is replaced by the value 0,6 in formula (5.1).

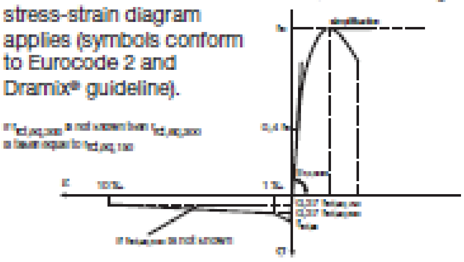
$f_{fctk,eq,300} = 0,7 \times f_{fctm,eq,300}$
$f_{fctk,eq,150} = 0,7 \times f_{fctm,eq,150}$
} According to Dramix® guideline unless more specific data available.

2 Equivalent axial tensile strength

- Equivalent axial tensile strength = 0,37 x equivalent flexural strength.

3 Stress-strain diagram

For steel fibre reinforced concrete, the following stress-strain diagram applies (symbols conform to Eurocode 2 and Dramix® guideline).



Dramix®

R C -65/35- B N

4 Equivalent shear strength

The design value of the increase in shear strength due to steelwire fibres:
τ_{fd} (N/mm²) - (material safety factor included).
The contribution of concrete and stirrups must be added to this contribution of the wire fibres.

Dramix® RC-65/35-BN

$f_{ctm,fl}$ (1) ▶	3,7 (C20/25) (2)	4,3 (C25/30)	4,8 (C30/37)	5,3 (C35/45)	5,8 (C40/50)
Dosage▼	τ_{fd}	τ_{fd}	τ_{fd}	τ_{fd}	τ_{fd}
20	0,16	0,19	0,21	0,23	0,26
25	0,18	0,22	0,24	0,27	0,30
30	0,21	0,25	0,27	0,30	0,34
35	0,23	0,27	0,30	0,33	0,38
40	0,25	0,30	0,33	0,36	0,41
45	0,26	0,32	0,35	0,39	0,44
50	0,28	0,33	0,37	0,41	0,46

(1) $f_{ctm,fl}$ = mean flexural tensile strength of plain concrete (N/mm²).
(2) Concrete class corresponding with $f_{ctm,fl}$ according to ENV 1992-1-1.
Boxed value [0,5] is replaced by the value 0,6 in formula (3.1).

Please also consult the Dramix® guideline

5 Toughness values

Dramix® RC-65/35-BN

Dosage ▼	Re1,5 (%)	Re3 (%)
20	58	50
25	64	56
30	69	62
35	75	67
40	80	72
45	84	75
50	88	77

Values based on concrete $f_{ctm,fl}$ = 4,8 N/mm². To be used up to C40/50.

6 Energy absorption - plate test

Energy absorption (J) of plate of poured concrete C30/37, according to Efnarc/SNCF:

Dramix® RC-65/35-BN

Dosage ▼	S25 (J)	Dosage ▼	S25 (J)
20	800	35	1130
25	910	40	1245
30	1015		

N.V. Bekaert S.A. - Bekaertstraat 2 - 8550 Zwevegem - Belgium
Tel. +32 (0) 56 / 76 69 86 - Fax +32 (0) 56 / 76 79 47
Internet: http://www.bekaert.com/building

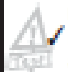
Recommendations - mixing

1. General

- ✓ preferably use a central batching plant mixer
- ✓ recommended maximum dosage:

Max. aggregate size (mm)	Dosage (kg/m³)	
	pour	pump
8	110	80
16	70	55
32	60	45

- ✓ a continuous grading is preferred
- ✓ mix until all glued fibres are separated into individual fibres. Fibres don't increase mixing time significantly.



- ✓ if special cements or admixtures are used, a preliminary test is recommended

2. Fibre addition

Bags are non-degradable and may not be thrown into the concrete.

2.1. In batching plant mixer

- ✓ never add fibres as first component in the mixer
- ✓ fibres can be introduced together with sand and aggregates, or can be added in freshly mixed concrete

2.2. Truckmixer

- ✓ run mixer at drum speed: 12-18 rpm
- ✓ adjust slump to a min. of 12 cm (preferably with water reducing agents or high water reducing agents)
- ✓ add fibres with maximum speed of 60 kg/min
- ✓ optional equipment: belt-hoist elevator
- ✓ after adding the fibres, continue mixing at highest speed for 4-5 min. (± 70 rotations)

2.3. Automatic dosing

- ✓ Fibres can be dosed from bulk at rates from 0 up to 3,5 kg/sec with a specially developed dosing equipment

Recommendations - storage

Protect the pallets against rain

Do not stack the pallets on top of each other

Delivered in

non water-soluble bags of 20 kg on pallet 1200 kg

big bag 1100 kg

APPENDIX 2 Concrete mixes – the note from each truck

Unicon AS
Kongshavnkai 1
0193 OSLO

Telefon 02880
Faks 67 55 25 80

unicon

Unicon AS - Kun internt bruk
Postboks 230
1301 SANDVIKA

Fabrikk 112 Sandvika
1336 SANDVIKA
Sven Kirschhausen 41589892

Følgebrev

Nummer .....: 86763
Dato ....: 01-02-2010
Side ....: 1
Bestilling ....: 582171 / 381026
Kundenummer: 131271
Rekvisisjon ...: fibertellingsprosjek
Rammeordre :
Kundens saks :
Ekspedert av : Ola Mytting
Bilnr. ....: 77
Sjåfør ....:
Følgebrev lest: ______

Opplysning om avtalt vare:

2,00 m3 Betong B35 M45 Cl 0,1
Høyfast sement
Finsats 8 mm
Sprøytebet. Alkaliefri aks.
Synkmål 180 mm.

LASS 1 20 kg/m³ Dramix

Opplysning om produsert resept:

Resept: 55330A
Standard: NS-EN 206-1
Betongtype: Egenskapsdefinert betong

Opplysning om tillegg som ikke omfattes av varens pris:

2,00 m3 Oppvarmet betong < 20 gr. (15/10-1/4)
40,00 kg Kort stålfiber
1,00 stk Hentegebyr

Opplysning om produksjons- og avtalt leveringstid:

Blandet 10:50 i Sandvika
Blandet av:
Ønsket levering 0:00 (10:45 - 11:25)
Bestilt mengde denne vare: 6,00
Levert inkl. dette lasset: 2,00

Ank. plass: ______
Tømming start 1050
Tømming slutt: 11 30
SP-reklamasjon: ______
SP-endring synk: ______
Returbetong: ______
Sjåfør bemerkning

Betongen er ikke i samsvar med NS-EN 206-1 (sett kryss) [ ]

Unicons kommentar:

Lass 2 40 kg kortstålfiber pr m3 + Lass 3 60 kg kortstålfiber pr m3
Lass 1 20 kg kortstålfiber Dramix pr m3

Kvittering:

Opplysningene ovenfor er i samsvar med det som er avtalt: ______

Org.nr.: 942822979 MVA

KONTROLLRÅDET for betongprodukter

Unicon AS
Kongshavnkai 1
0193 OSLO

Telefon 02880
Faks 67 55 25 80

unicon

Unicon AS - Kun Internt bruk
Postboks 230
1301 SANDVIKA

Fabrikk 112 Sandvika
1338 SANDVIKA
Sven Kirschhausen 41589892

Følgebrev

Nummer .....: 86784
Dato ....: 01-02-2010
Side ....: 1
Bestilling .....: 582171 / 381033
Kundenummer: 131271
Rekvisisjon ...: fibertellingsprosjek
Rammeordre :
Kundens saks :
Ekspedert av : Ola Mytting
Bilnr. ....: 77
Sjåfør ....:
Følgebrev lest: ____________

Opplysning om avtalt vare:

2,00 m3 Betong B35 M45 Cl 0,1
Høyfast sement
Finsats 8 mm
Sprøytebet. Alkaliefri aks.
Synkmål 220 mm.

LASS 2 40 kg/m3 Dramix

Opplysning om produsert resept:

Resept: 55330A
Standard: NS-EN 206-1
Betongtype: Egenskapsdefinert betong

Opplysning om tillegg som ikke omfattes av varens pris:

1,00 stk	Hentegebyr
2,00 m3	Synk 220 mm
2,00 m3	Oppvarmet betong >20 gr. (15/10-1/4)
80,00 kg	Kort stålfiber

Opplysning om produksjons- og avtalt leveringstid:

Blandet 11:41 i Sandvika
Blandet av:
Ønsket levering 0:00 (11:15 - 11:45)
Bestilt mengde denne vare: 6,00
Levert inkl. dette lasset: 4,00

Ank. plass: ____________
Tømming start ____________
Tømming slutt: ____________
SP-reklamasjon: ____________
SP-endring synk: ____________
Returbetong: ____________
Sjåfør bemerkning

Betongen er ikke i samsvar med NS-EN 206-1 (sett kryss) [ ]

Unicons kommentar:

Lass 2 40 kg kortstålfiber pr m3 + Lass 3 60 kg kortstålfiber pr m3

Kvittering:

Opplysningene ovenfor er i samsvar med det som er avtalt: ____________

Org.nr.: 942822979 MVA

KONTROLLRÅDET
for betongprodukter

Unicon AS
Kongshavnkai 1
0193 OSLO

Telefon 02880
Faks 67 55 25 80

unicon///

Unicon AS - Kun Internt bruk
Postboks 230
1301 SANDVIKA

Fabrikk 112 Sandvika
1336 SANDVIKA
Sven Kirschhausen 41589892

Følgebrev

Nummer .....: 86763
Dato ....: 01-02-2010
Side ....: 1
Bestilling .....: 582171 / 381026
Kundenummer: 131271
Rekvisisjon ...: fibertellingsprosjek
Rammeordre :
Kundens saks:
Ekspedert av : Ola Mytting
Bilnr. ....: 77
Sjåfør ....:
Følgebrev lest: ____________

Opplysning om avtalt vare:

2,00 m3 Betong B35 M45 Cl 0,1
Høyfast sement
Finsats 8 mm
Sprøytebet. Alkalifri aks.
Synkmål 180 mm

LASS 3 60 kg/m³ Dramix

Opplysning om produsert resept:

Resept: 55330A
Standard: NS-EN 206-1
Betongtype: Egenskapsdefiner betong

NB! Feil seddel (samme som for lass 1)

Opplysning om tillegg som ikke omfattes av varens pris:

2,00 m3	Oppvarmet betong < 20 gr. (15/10-1/4)
40,00 kg	Kort stålfiber
1,00 stk	Hentegebyr

Opplysning om produksjons- og avtalt leveringstid:

Blandet 10:50 i Sandvika
Blandet av:
Ønsket levering 0:00 (10:45 - 11:25)
Bestilt mengde denne vare: 8,00
Levert inkl. dette lasset: 2,00

Ank. plass: ____________
Tømming start ____________
Tømming slutt: ____________
SP-reklamasjon: ____________
SP-endring synk: ____________
Returbetong: ____________
Sjåfør bemerkning

Betongen er ikke i samsvar med NS-EN 206-1 (sett kryss) [ ]

Unicons kommentar:

Lass 2 40 kg kortstålfiber pr m3 + Lass 3 60 kg kortstålfiber pr m3
Lass 1 20 kg kortstålfiber Dramix pr m3

Kvittering:

Opplysningene ovenfor er i samsvar med det som er avtalt: ____________

Org.nr.: 942822979 MVA

KONTROLLRÅDET for betongprodukter

Unicon AS
Kongshavnkai 1
0193 OSLO

Telefon 02880
Faks 67 55 25 80

unicon

Unicon AS - Kun Internt bruk
Postboks 230
1301 SANDVIKA

Fabrikk 112 Sandvika
1336 SANDVIKA
Sven Kirschhausen 41589892

Følgebrev

Nummer .....: 86771
Dato ....: 01-02-2010
Side ....: 1
Bestilling .....: 582171 / 381048
Kundenummer: 131271
Rekvisisjon ...: fibertellingsprosjek
Rammeordre :
Kundens saks :
Ekspedert av : Ola Mytting
Bilnr. ....: 77
Sjåfør ....:
Følgebrev lest: ________________

Opplysning om avtalt vare:

2,00 m3 Betong B35 M45 Cl 0,1
Høyfast sement
Finsats 8 mm
Sprøytebet. Alkalefri aks.
Synkmål 220 mm.

LASS 4 5kg/m³ BarChip

Opplysning om produsert resept:

Resept: 55330A
Standard: NS-EN 206-1
Betongtype: Egenskapsdefinert betong

Opplysning om tillegg som ikke omfattes av varens pris:

1,00 stk	Hentegebyr	
2,00 m3	Synk 220 mm	
2,00 m3	Oppvarmet betong >20 gr. (15/10-1/4)	
10,00 kg	Konstruktiv plastfiber - Makro PP	

Opplysning om produksjons- og avtalt leveringstid:

Blandet 15:20 i Sandvika
Blandet av:
Ønsket levering 0:00 (15:00 - 15:30)
Bestilt mengde denne vare: 12,00
Levert inkl. dette lasset: 8,00

Ank. plass: ________
Tømming start ________
Tømming slutt: ________
SP-reklamasjon: ________
SP-endring synk: ________
Returbetong: ________
Sjåfør bemerkning

Betongen er ikke i samsvar med NS-EN 206-1 (sett kryss) [ ]

Unicons kommentar:

Lass 3 60 kg kortstålfiber pr m3 5 4 7

Kvittering:

Opplysningene ovenfor er i samsvar med det som er avtalt: ________________

Org.nr.: 942822979 MVA

KONTROLLRÅDET for betongprodukter

Unicon AS
Kongshavnkai 1
0193 OSLO

Telefon 02880
Faks 67 56 25 80

unicon

Unicon AS - Kun Internt bruk
Postboks 230
1301 SANDVIKA

Fabrikk 112 Sandvika
1336 SANDVIKA
Sven Kirschhausen 41589892

Følgebrev

Nummer ......: 86774
Dato ....: 01-02-2010
Side ....: 1
Bestilling .....: 582171 / 381050
Kundenummer: 131271
Rekvisisjon ..: fibertellingsprosjek
Rammeordre :
Kundens saks:
Ekspedert av : Ola Mytting
Bilnr. ....: 77
Sjåfør ....:
Følgebrev lest: ______________

Opplysning om avtalt vare:

2,00 m3 Betong B35 M45 Cl 0,1
Høyfast sement
Finsats 8 mm
Sprøytebet. Alkalifri aks.
Synkmål 220 mm

Opplysning om produsert resept: LASS 5 7 kg/m³ BarChip

Resept: 55330A
Standard: NS-EN 206-1
Betongtype: Egenskapsdefiner: betong

Opplysning om tillegg som ikke omfattes av varens pris:

1,00 stk	Hentegebyr
2,00 m3	Synk 220 mm
2,00 m3	Oppvarmet betong >20 gr. (15/10-1/4)
14,00 kg	Konstruktiv plastfiber - Makro PP

Opplysning om produksjons- og avtalt leveringstid:

Blandet 15:47 i Sandvika
Blandet av:
Ønsket levering 0:00 (15:45 - 16:15)
Bestilt mengde denne vare: 12,00
Levert inkl. dette lasset: 10,00

Ank. plass: ______
Tømming start ______
Tømming slutt: ______
SP-reklamasjon: ______
SP-endring synk: ______
Returbetong: ______
Sjåfør bemerkning

Betongen er ikke i samsvar med NS-EN 206-1 (sett kryss) [ ]

Unicons kommentar:

Lass 3 60 kg kortstålfiber pr m3

Kvittering:

Opplysningene ovenfor er i samsvar med det som er avtalt: ______________

Org.nr.: 942822979 MVA

KONTROLLRÅDET
for betongprodukter

Unicon AS
Kongshavnkai 1
0193 OSLO

Telefon 02880
Faks 67 55 25 80

unicon

Unicon AS - Kun internt bruk
Postboks 230
1301 SANDVIKA

Følgebrev

Nummer ......: 86775
Dato ....: 01-02-2010
Side ....: 1
Bestilling .....: 582171 / 381051
Kundenummer: 131271
Rekvisisjon ..: fibertellingsprosjek
Rammeordre :
Kundens saks:
Ekspedert av : Ola Mytting
Bilnr. ....: 77
Sjåfør ....:
Følgebrev lest: ____________

Fabrikk 112 Sandvika
1336 SANDVIKA
Sven Kirschhausen 41589892

Opplysning om avtalt vare:

2,00 m3 Betong B35 M45 Cl 0,1
Høyfast sement
Finsats 8 mm
Sprøytebet. Alkalifri aks.
Synkmål 220 mm

LASS 6 8 kg/m³ BarChip

Opplysning om produsert resept:

Resept: 55330A
Standard: NS-EN 206-1
Betongtype: Egenskapsdefiner: betong

Opplysning om tillegg som ikke omfattes av varens pris:

1,00 stk	Hentegebyr
2,00 m3	Synk 220 mm
2,00 m3	Oppvarmet betong >20 gr. (15/10-1/4)
16,00 kg	Konstruktiv plastfiber - Makro PP

Opplysning om produksjons- og avtalt leveringstid:

Blandet 16:14 i Sandvika
Blandet av:
Ønsket levering 0:00 (16:45 - 17:15)
Bestilt mengde denne vare: 12,00
Levert inkl. dette lasset: 12,00

Ank. plass: ____________
Tømming start ____________ 16 30
Tømming slutt: ____________ 1645
SP-reklamasjon: ____________
SP-endring synk: ____________
Returbetong: ____________
Sjåfør bemerkning

Betongen er ikke i samsvar med NS-EN 206-1 (sett kryss) [ ]

Unicons kommentar:

Lass 3 60 kg kortstålfiber pr m3

Kvittering:

Opplysningene ovenfor er i samsvar med det som er avtalt: ____________

Org.nr.: 942822979 MVA

KONTROLLRÅDET for betongprodukter

APPENDIX 3 Measurements of panel thickness and -diameter

Series 8

Thickness measurements along cracks, after testing

S8-6-BC54-C	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Meas. 5	Meas. 6	Meas. 7	Meas. 8	Meas. 9	Meas. 10	Meas. 11	Meas. 12	Average	Std. dev	COV
Panel 1	106,6	102,5	107,5	104,7	99,2	98,1	110,6	109,9	112,0	113,0	115,3	116,6	**108,0**	**6,0**	**5,6 %**
Panel 2	103,2	106,0	107,4	107,8	106,0	107,0	103,1	107,9	108,3	107,1	107,9	104,4	**106,3**	**1,8**	**1,7 %**
Panel 3	100,4	100,3	105,1	106,1	106,3	101,3	101,4	104,4	103,8	102,6	100,3	100,3	**102,7**	**2,3**	**2,3 %**
												Average =	105,7	3,4	3,2 %
												Highest =	108,0	6,0	5,6 %
												Lowest =	102,7	1,8	1,7 %

S8-6-BC54-S	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Meas. 5	Meas. 6	Meas. 7	Meas. 8	Meas. 9	Meas. 10	Meas. 11	Meas. 12	Average	Std. dev	COV
Panel 4	103,4	106,7	107,0	107,7	107,7	107,5	103,5	99,5	104,5	101,4	101,3	98,4	**104,1**	**3,3**	**3,2 %**
Panel 5	102,6	104,1	103,4	102,6	105,0	105,0	98,3	101,9	103,6	102,5	101,4	97,2	**102,3**	**2,4**	**2,4 %**
Panel 6	98,3	99,0	100,5	100,8	99,5	98,0	97,9	97,9	97,8	101,2	98,9	100,4	**99,2**	**1,3**	**1,3 %**
												Average =	101,8	2,3	2,3 %
												Highest =	104,1	3,3	3,2 %
												Lowest =	99,2	1,3	1,3 %

S8-7-BK-C	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Meas. 5	Meas. 6	Meas. 7	Meas. 8	Meas. 9	Meas. 10	Meas. 11	Meas. 12	Average	Std. dev	COV
Panel 10	102,3	102,0	101,4	102,1	102,2	102,8	97,9	100,6	101,3	100,2	99,3	100,0	**101,0**	**1,5**	**1,4 %**
Panel 11	100,7	102,0	102,7	102,5	100,6	100,9	103,4	103,5	102,9	103,0	101,5	102,5	**102,2**	**1,0**	**1,0 %**
Panel 18	99,4	98,5	99,0	102,0	102,3	101,1	100,7	103,7	103,9	103,4	101,8	102,4	**101,5**	**1,8**	**1,8 %**
Panel 22	102,8	105,6	107,7	105,4	103,6	102,9	103,5	105,6	107,4	106,3	103,9	104,2	**104,9**	**1,7**	**1,6 %**
Panel 23	100,0	100,4	103,1	102,8	100,0	99,5	103,3	104,7	104,3	103,3	103,9	103,7	**102,4**	**1,9**	**1,8 %**
												Average =	102,4	1,6	1,5 %
												Highest =	104,9	1,9	1,8 %
												Lowest =	101,0	1,0	1,0 %

S8-7-BK-C-PVC	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Meas. 5	Meas. 6	Meas. 7	Meas. 8	Meas. 9	Meas. 10	Meas. 11	Meas. 12	Average	Std. dev	COV
Panel 12	100,4	99,9	99,6	102,7	102,8	100,9	102,4	103,0	102,0	101,1	101,0	102,2	**101,5**	**1,2**	**1,2 %**
Panel 16	97,6	99,1	100,8	100,3	100,4	100,1	98,6	100,2	101,1	101,7	100,9	100,3	**100,1**	**1,1**	**1,1 %**
Panel 17	102,6	105,0	108,5	108,7	109,1	109,4	105,1	106,8	107,2	102,8	99,9	100,8	**105,5**	**3,3**	**3,2 %**
Panel 24	101,1	101,6	101,8	99,8	98,7	99,2	100,9	101,2	101,4	102,1	101,2	101,3	**100,9**	**1,1**	**1,0 %**
												Average =	102,0	1,7	1,6 %
												Highest =	105,5	3,3	3,2 %
												Lowest =	100,1	1,1	1,0 %

S8-7-BK-S	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Meas. 5	Meas. 6	Meas. 7	Meas. 8	Meas. 9	Meas. 10	Meas. 11	Meas. 12	Average	Std. dev	COV
Panel 13	100,3	100,7	100,2	100,5	99,9	99,7	100,0	101,9	100,9	100,9	100,4	100,4	**100,5**	**0,6**	**0,6 %**
Panel 14	100,1	102,8	100,3	100,3	101,1	100,3	102,3	103,4	102,4	101,8	102,6	102,0	**101,6**	**1,2**	**1,1 %**
Panel 15	101,0	104,5	104,7	104,0	99,9	100,1	102,2	101,2	103,5	102,8	102,6	102,9	**102,5**	**1,6**	**1,6 %**
												Average =	101,5	1,1	1,1 %
												Highest =	102,5	1,6	1,6 %
												Lowest =	100,5	0,6	0,6 %

S8-7-BK-S-PVC															
Panel 19	101,3	101,2	100,8	100,7	101,7	100,4	99,4	100,0	100,0	100,7	100,5	102,7	**100,8**	**0,9**	**0,9 %**
Panel 20	99,0	99,0	98,8	98,7	100,2	100,2	98,9	99,7	98,9	99,3	100,6	102,2	**99,6**	**1,0**	**1,0 %**
Panel 21	99,1	99,7	100,2	101,7	99,3	99,2	100,1	100,5	100,9	100,0	99,3	99,8	**100,0**	**0,8**	**0,8 %**
												Average =	100,1	0,9	0,9 %
												Highest =	100,8	1,0	1,0 %
												Lowest =	99,6	0,8	0,8 %

Measurments of panel diameter before testing

S8-6-BC54-C	Meas. 1	Meas. 2	Meas. 3	Average	Std. dev	COV
Panel 1	608	604	598	**603,3**	**5,0**	**0,8 %**
Panel 2	600	600	604	**601,3**	**2,3**	**0,4 %**
Panel 3	600	600	602	**600,7**	**1,2**	**0,2 %**
			Average =	601,8	2,8	0,5 %
			Highest =	603,3	5,0	0,8 %
			Lowest =	600,7	1,2	0,2 %

S8-6-BC54-S	Meas. 1	Meas. 2	Meas. 3	Average	Std. dev	COV
Panel 4	600	600	604	**601,3**	**2,3**	**0,4 %**
Panel 5	600	604	603	**602,3**	**2,1**	**0,3 %**
Panel 6	595	600	600	**598,3**	**2,9**	**0,5 %**
			Average =	600,7	2,4	0,4 %
			Highest =	602,3	2,9	0,5 %
			Lowest =	598,3	2,1	0,3 %

S8-7-BK-C	Meas. 1	Meas. 2	Meas. 3	Average	Std. dev	COV
Panel 10	595	600	605	**600,0**	**5,0**	**0,8 %**
Panel 11	-	-	-	**-**	**-**	**-**
Panel 18	594	605	600	**599,7**	**5,5**	**0,9 %**
Panel 22	605	600	600	**601,7**	**2,9**	**0,5 %**
Panel 23	600	-	-	**600,0**	**-**	**-**
			Average =	600,3	4,5	0,7 %
			Highest =	601,7	5,5	0,9 %
			Lowest =	599,7	2,9	0,5 %

S8-7-BK-C-PVC	Meas. 1	Meas. 2	Meas. 3	Average	Std. dev	COV
Panel 12	604	598	601	**601,0**	**3,0**	**0,5 %**
Panel 16	602	602	600	**601,3**	**1,2**	**0,2 %**
Panel 17	600	605	600	**601,7**	**2,9**	**0,5 %**
Panel 24	597	602	600	**599,7**	**2,5**	**0,4 %**
			Average =	600,9	2,4	0,4 %
			Highest =	601,7	3,0	0,5 %
			Lowest =	599,7	1,2	0,2 %

S8-7-BK-S	Meas. 1	Meas. 2	Meas. 3	Average	Std. dev	COV
Panel 13	598	602	602	**600,7**	**2,3**	**0,4 %**
Panel 14	605	598	599	**600,7**	**3,8**	**0,6 %**
Panel 15	599	601	600	**600,0**	**1,0**	**0,2 %**
			Average =	600,4	2,4	0,4 %
			Highest =	600,7	3,8	0,6 %
			Lowest =	600,0	1,0	0,2 %

S8-7-BK-S-PVC	Meas. 1	Meas. 2	Meas. 3	Average	Std. dev	COV
Panel 19	597	603	600	**600,0**	**3,0**	**0,5 %**
Panel 20	602	600	597	**599,7**	**2,5**	**0,4 %**
Panel 21	600	600	595	**598,3**	**2,9**	**0,5 %**
			Average =	599,3	2,8	0,5 %
			Highest =	600,0	3,0	0,5 %
			Lowest =	598,3	2,5	0,4 %

Series 9

Thickness measurements along cracks, after testing

S9-20-D-S	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Meas. 5	Meas. 6	Meas. 7	Meas. 8	Meas. 9	Meas. 10	Meas. 11	Meas. 12	Average	Std. dev	COV
Panel 1	101,0	101,6	99,6	101,6	101,7	101,6	100,4	100,2	101,8	99,7	100,0	101,1	**100,9**	**0,8**	**0,8 %**
Panel 2	98,3	100,3	99,4	100,3	100,2	101,7	99,1	100,1	99,0	99,8	99,4	97,9	**99,6**	**1,0**	**1,0 %**
Panel 3	100,9	97,6	96,6	96,0	103,1	103,5	98,2	96,6	96,1	99,8	100,5	95,2	**98,7**	**2,8**	**2,9 %**
												Average =	99,7	1,6	1,6 %
												Highest =	100,9	2,8	2,9 %
												Lowest =	98,7	0,8	0,8 %

S9-40-D-S	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Meas. 5	Meas. 6	Meas. 7	Meas. 8	Meas. 9	Meas. 10	Meas. 11	Meas. 12	Average	Std. dev	COV
Panel 4	101,3	101,6	103,5	102,7	101,8	101,7	102,4	103,1	104,4	102,8	103,0	104,1	**102,7**	**1,0**	**1,0 %**
Panel 5	101,1	101,1	99,3	100,5	101,1	100,1	100,0	101,1	101,2	99,7	101,0	100,3	**100,5**	**0,7**	**0,6 %**
Panel 6*													**-**	**-**	**-**
												Average =	101,6	0,8	0,8 %
												Highest =	102,7	1,0	1,0 %
												Lowest =	100,5	0,7	0,6 %

S9-60-D-S	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Meas. 5	Meas. 6	Meas. 7	Meas. 8	Meas. 9	Meas. 10	Meas. 11	Meas. 12	Average	Std. dev	COV
Panel 7	101,7	100,2	99,6	99,0	102,2	101,8	99,1	98,3	97,9	101,6	101,4	102,4	**100,4**	**1,6**	**1,6 %**
Panel 8	101,3	100,1	99,1	99,3	99,0	100,6	99,8	98,5	99,0	100,0	99,6	99,2	**99,6**	**0,8**	**0,8 %**
Panel 9	102,0	101,0	102,5	102,6	101,7	101,7	101,5	100,9	103,2	101,9	99,8	99,8	**101,6**	**1,0**	**1,0 %**
												Average =	100,5	1,1	1,1 %
												Highest =	101,6	1,6	1,6 %
												Lowest =	99,6	0,8	0,8 %

S9-5-BK-S	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Meas. 5	Meas. 6	Meas. 7	Meas. 8	Meas. 9	Meas. 10	Meas. 11	Meas. 12	Average	Std. dev	COV
Panel 10	97,3	97,9	102,4	99,6	99,7	101,5	103,8	102,4	100,1	100,6	99,3	102,4	**100,6**	**2,0**	**2,0 %**
Panel 11	97,7	99,2	99,5	99,1	98,4	99,1	99,9	101,7	100,7	100,2	99,0	99,5	**99,5**	**1,0**	**1,1 %**
Panel 12	98,6	98,8	100,9	98,9	99,9	99,2	98,2	98,1	99,5	98,6	100,0	99,4	**99,2**	**0,8**	**0,8 %**
												Average =	99,8	1,3	1,3 %
												Highest =	100,6	2,0	2,0 %
												Lowest =	99,2	0,8	0,8 %

S9-7-BK-S	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Meas. 5	Meas. 6	Meas. 7	Meas. 8	Meas. 9	Meas. 10	Meas. 11	Meas. 12	Average	Std. dev	COV
Panel 13	98,9	100,4	101,6	98,7	99,9	102,0	99,1	102,7	102,3	103,0	104,9	103,6	**101,4**	**2,0**	**2,0 %**
Panel 14	99,1	100,8	100,1	98,8	98,3	99,3	99,9	99,9	104,0	101,9	101,0	101,6	**100,4**	**1,6**	**1,6 %**
Panel 15	100,7	100,1	98,6	98,1	100,4	100,7	101,6	99,2	100,0	98,5	99,2	101,2	**99,9**	**1,1**	**1,1 %**
												Average =	100,6	1,6	1,6 %
												Highest =	101,4	2,0	2,0 %
												Lowest =	99,9	1,1	1,1 %

S9-8-BK-S	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Meas. 5	Meas. 6	Meas. 7	Meas. 8	Meas. 9	Meas. 10	Meas. 11	Meas. 12	Average	Std. dev	COV
Panel 16	104,4	100,6	104,7	103,5	102,1	101,6	100,3	102,5	104,4	101,5	101,8	100,7	**102,3**	**1,6**	**1,5 %**
Panel 17	100,4	99,5	100,4	100,5	97,5	100,8	100,2	99,1	100,3	101,1	101,0	100,7	**100,1**	**1,0**	**1,0 %**
Panel 18	93,2	95,4	96,9	97,7	100,3	100,9	97,1	97,8	98,4	97,4	96,9	98,9	**97,6**	**2,0**	**2,1 %**
												Average =	100,0	1,5	1,5 %
												Highest =	102,3	2,0	2,1 %
												Lowest =	97,6	1,0	1,0 %

Measurments of panel diameter before testing

S9-20-D-S	Meas. 1	Meas. 2	Meas. 3	Average	Std. dev	COV
Panel 1	602,0	602,0	598,0	600,7	2,3	0,4 %
Panel 2	600,0	604,0	602,0	602,0	2,0	0,3 %
Panel 3	600,0	602,0	598,0	600,0	2,0	0,3 %
			Average =	600,9	2,1	0,4 %
			Highest =	602,0	2,3	0,4 %
			Lowest =	600,0	2,0	0,3 %

S9-40-D-S	Meas. 1	Meas. 2	Meas. 3	Average	Std. dev	COV
Panel 4	602,0	600,0	600,0	600,7	1,2	0,2 %
Panel 5	600,0	600,0	600,0	600,0	0,0	0,0 %
Panel 6*	600,0	600,0	600,0	600,0	0,0	0,0 %
			Average =	600,2	0,4	0,1 %
			Highest =	600,7	1,2	0,2 %
			Lowest =	600,0	0,0	0,0 %

S9-60-D-S	Meas. 1	Meas. 2	Meas. 3	Average	Std. dev	COV
Panel 7	604,0	600,0	601,0	601,7	2,1	0,3 %
Panel 8	600,0	600,0	602,0	600,7	1,2	0,2 %
Panel 9	599,0	600,0	599,0	599,3	0,6	0,1 %
			Average =	600,6	1,3	0,2 %
			Highest =	601,7	2,1	0,3 %
			Lowest =	599,3	0,6	0,1 %

S9-5-BK-S	Meas. 1	Meas. 2	Meas. 3	Average	Std. dev	COV
Panel 10	599,0	600,0	601,0	600,0	1,0	0,2 %
Panel 11	600,0	602,0	600,0	600,7	1,2	0,2 %
Panel 12	600,0	603,0	602,0	601,7	1,5	0,3 %
			Average =	600,8	1,2	0,2 %
			Highest =	601,7	1,5	0,3 %
			Lowest =	600,0	1,0	0,2 %

S9-7-BK-S	Meas. 1	Meas. 2	Meas. 3	Average	Std. dev	COV
Panel 13	602,0	602,0	598,0	600,7	2,3	0,4 %
Panel 14	602,0	598,0	602,0	600,7	2,3	0,4 %
Panel 15	600,0	600,0	599,0	599,7	0,6	0,1 %
			Average =	600,3	1,7	0,3 %
			Highest =	600,7	2,3	0,4 %
			Lowest =	599,7	0,6	0,1 %

S9-8-BK-S	Meas. 1	Meas. 2	Meas. 3	Average	Std. dev	COV
Panel 16	600,0	603,0	602,0	601,7	1,5	0,3 %
Panel 17	602,0	603,0	605,0	603,3	1,5	0,3 %
Panel 18	598,0	600,0	601,0	599,7	1,5	0,3 %
			Average =	601,6	1,5	0,3 %
			Highest =	603,3	1,5	0,3 %
			Lowest =	599,7	1,5	0,3 %

Panel 6: Was not able to split his panel*

APPENDIX 4 Fibre measurements from the panels (Series 9)

Panel	Sample thickness (mm)	Weight in air (kg)	Weight in water (kg)	Volume (l)	Density (kg/l)	Fiber content (g)	Fiber content (g/l)	Fiber content (g/l) Average	Std.dev.
1	100,9	2,875	1,604	1,272	2,260	67,1	52,75		
2	99,6	2,860	1,603	1,256	2,277	63,7	50,72	**50,4**	**2,5**
3	98,7	2,849	1,596	1,252	2,275	59,9	47,84		
4	102,7	2,555	1,451	1,104	2,314	92,5	83,79		
5	100,5	2,735	1,561	1,175	2,328	95,5	81,28	**88,1**	**9,8**
6	Not measured	2,877	1,761	1,116	2,578	110,8	99,28		
7	100,4	3,601	2,013	1,589	2,266	120,2	75,65		
8	99,6	4,108	2,271	1,837	2,236	105,7	57,54	**65,4**	**9,3**
9	101,6	3,304	1,850	1,454	2,273	91,7	63,07		
10	100,6	2,930	1,611	1,318	2,223	10,2 / 15,3*	7,74 (only BK)		
11	99,5	5,307	3,034	2,274	2,334	18,2 / 4,7*	8,00 (only BK)	**8,8**	**1,6**
12	99,7	3,723	2,170	1,554	2,396	16,5/ 3,1 *	10,62 (only BK)		
13	101,4	3,331	1,819	1,512	2,203	11,7	7,74		
14	100,4	4,838	2,658	2,180	2,219	20,2	9,27	**8,2**	**0,9**
15	99,9	4,360	2,392	1,968	2,216	15,2	7,72		
16	102,3	2,388	1,312	1,076	2,219	9,4	8,74		
17	100,1	4,420	2,424	1,995	2,215	16,2	8,12	**9,1**	**1,2**
18	97,6	4,167	2,285	1,882	2,214	19,7	10,47		

APPENDIX 5 Data from each panels test, Series 8

Project:	Sprayed concrete, Veidekke panels	Panel production date:	24.09.2009
Specimen ID:	S8-6-BC54-S-01		
Test date:	02.03.2010	Fibre type:	BarChip BC54 (54mm)
Concrete test age (d):	159	Nom. fibre dosage:	6 kg
Comments:	Panel goes from thin to thick	Cast/sprayed:	Sprayed

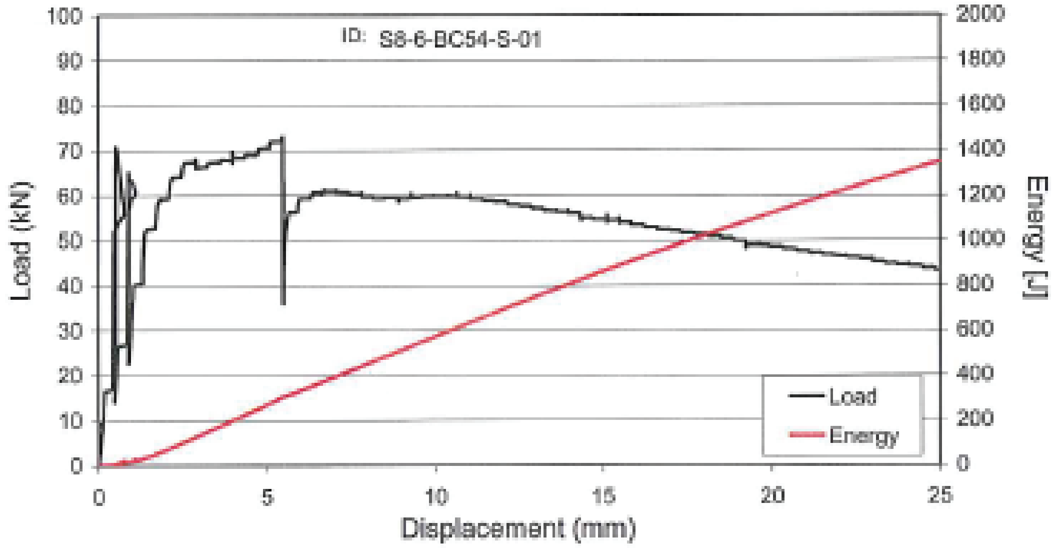
	Type yes/no
Correct for thickness:	yes
Correct for diameter:	no
Correct for early non-linearity:	no

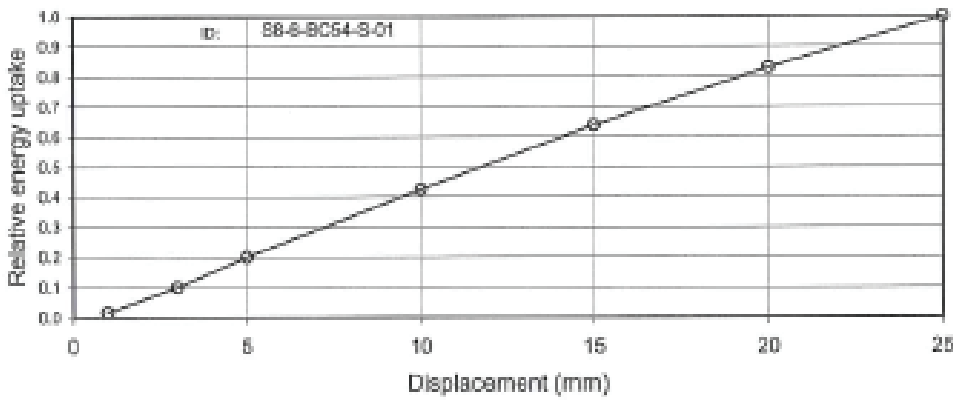
Average plate thickness =	108.0	[mm]
Nominal plate thichness =	100.0	[mm]
Average plate diameter =	603.3	[mm]
Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_t = 0.926 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	23	59	0.02		
3.0	134	66	0.10		
5.0	270	70	0.20		
10.0	574	60	0.42		
15.0	862	50	0.64		
20.0	1120	49	0.83		
25.0	1350	43.3	1.00	1550	114.8 %

Maximum load (corr) =	73.0	[kN]
Defl. at max. load =	5.5	[mm]





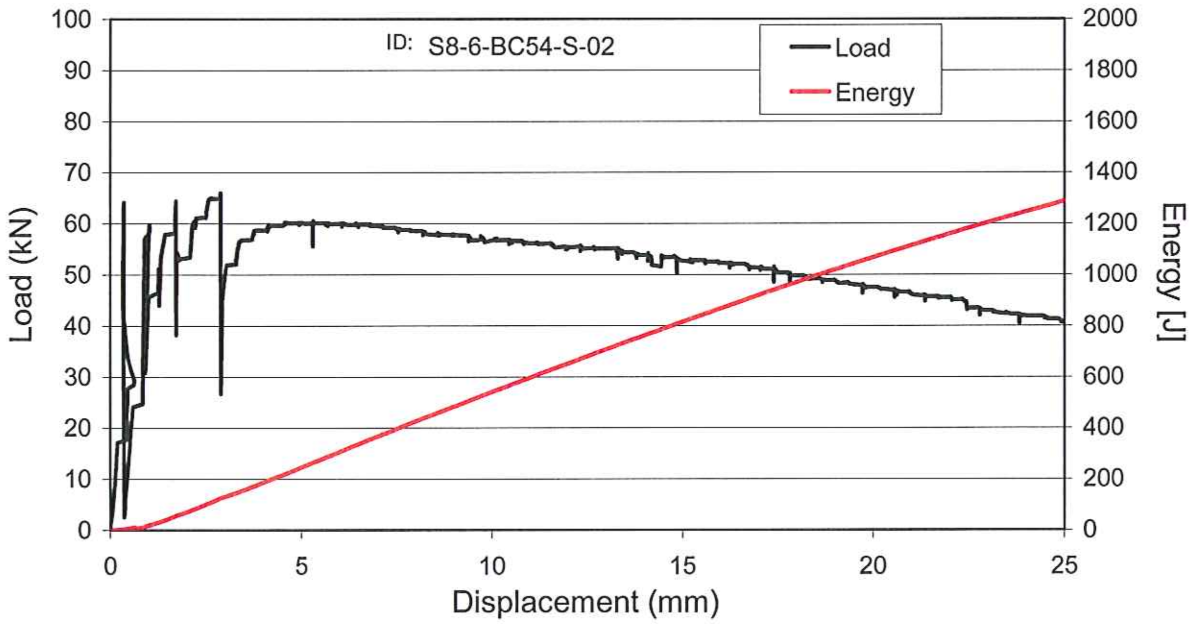
Project:	Sprayed concrete, Veidekke panels	**Panel production date:**	24.09.2009
Specimen ID:	S8-6-BC54-S-02		
Test date:	02.03.2010	**Fibre type:**	BarChip BC54 (54mm)
Concrete test age (d):	159	**Nom. fibre dosage:**	6 kg
Comments:		**Cast/sprayed:**	Sprayed

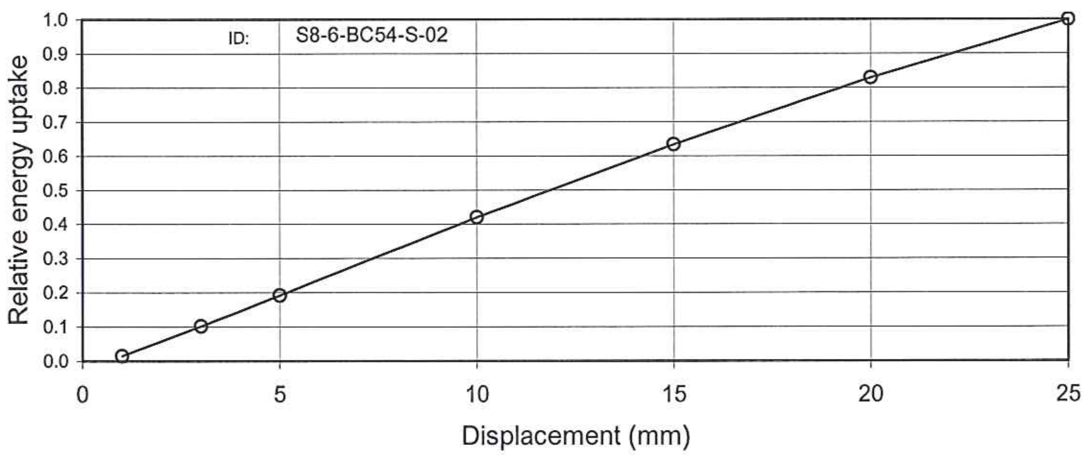
	Type yes/no			
Correct for thickness:	**yes**	Average plate thickness =	**106.3**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**601.3**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 0.941 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	**19**	**45**	**0.01**		
3.0	**131**	**50**	**0.10**		
5.0	**247**	**60**	**0.19**		
10.0	**541**	**57**	**0.42**		
15.0	**816**	**53**	**0.63**		
20.0	**1068**	**48**	**0.83**		
25.0	**1288**	**40.7**	**1.00**	1437	111.5 %

Maximum load (corr) =	65.9	[kN]
Defl. at max. load =	2.9	[mm]





Project: Sprayed concrete, Veidekke panels **Panel production date:** 24.09.2009
Specimen ID: S8-6-BC54-S-03
Test date: 02.03.2010 **Fibre type:** BarChip BC54 (54mm)
Concrete test age (d): 159 **Nom. fibre dosage:** 6 kg
Comments: **Cast/sprayed:** Sprayed

	Type yes/no
Correct for thickness:	**yes**
Correct for diameter:	**no**
Correct for early non-linearity:	**no**

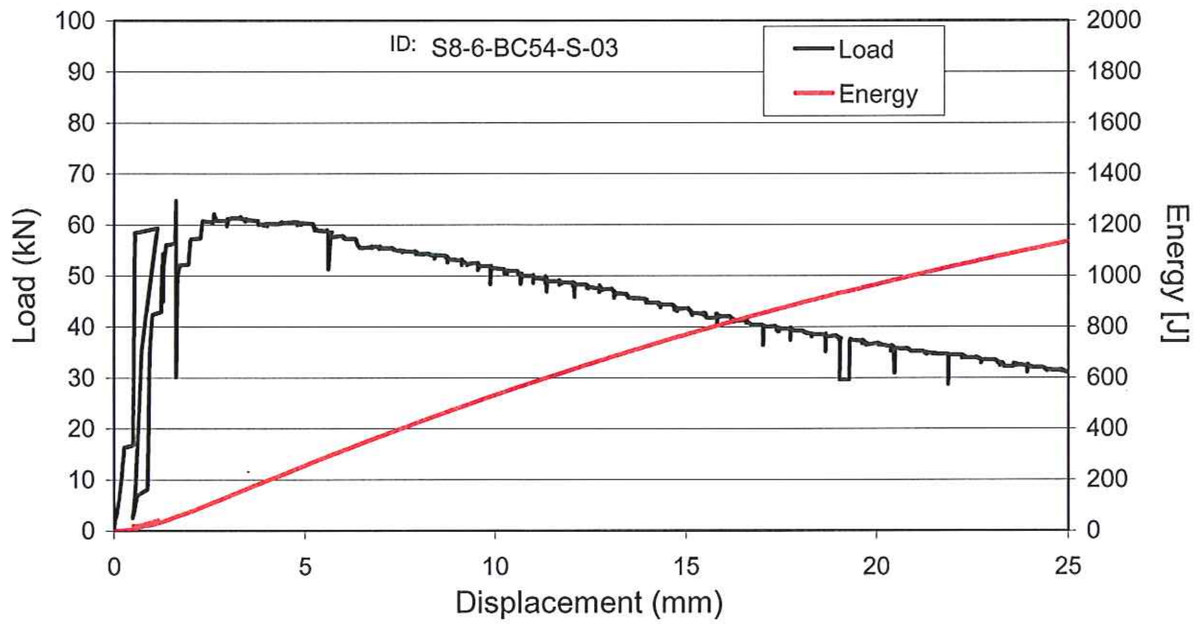
Average plate thickness = **102.7** [mm]
Nominal plate thichness = 100.0 [mm]

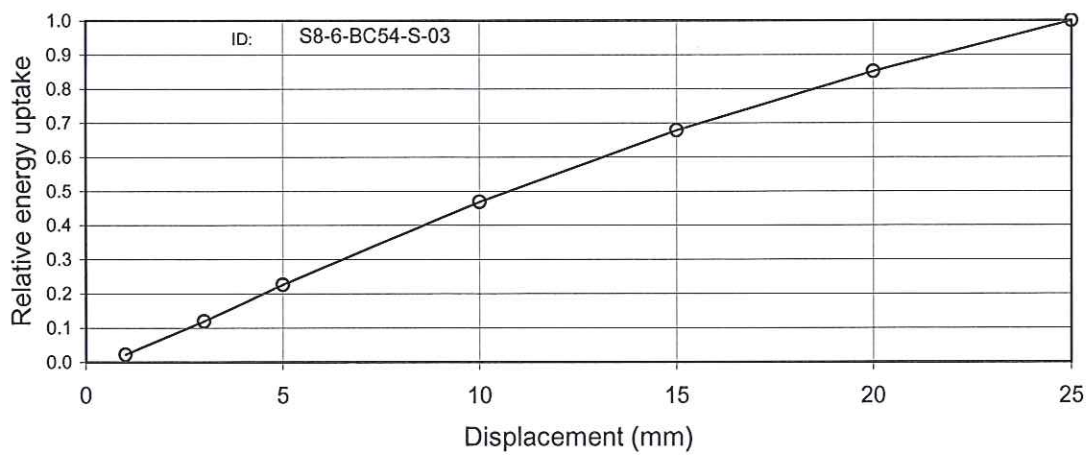
Average plate diameter = **600.7** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.974 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	**25**	**42**	**0.02**		
3.0	**135**	**61**	**0.12**		
5.0	**257**	**60**	**0.23**		
10.0	**532**	**51**	**0.47**		
15.0	**770**	**44**	**0.68**		
20.0	**967**	**37**	**0.85**	Uncorr. Energy	Rel. uncorr/corr
25.0	**1135**	**31.0**	**1.00**	1188	104.6 %

Maximum load (corr) =	64.7	[kN]
Defl. at max. load =	1.6	[mm]





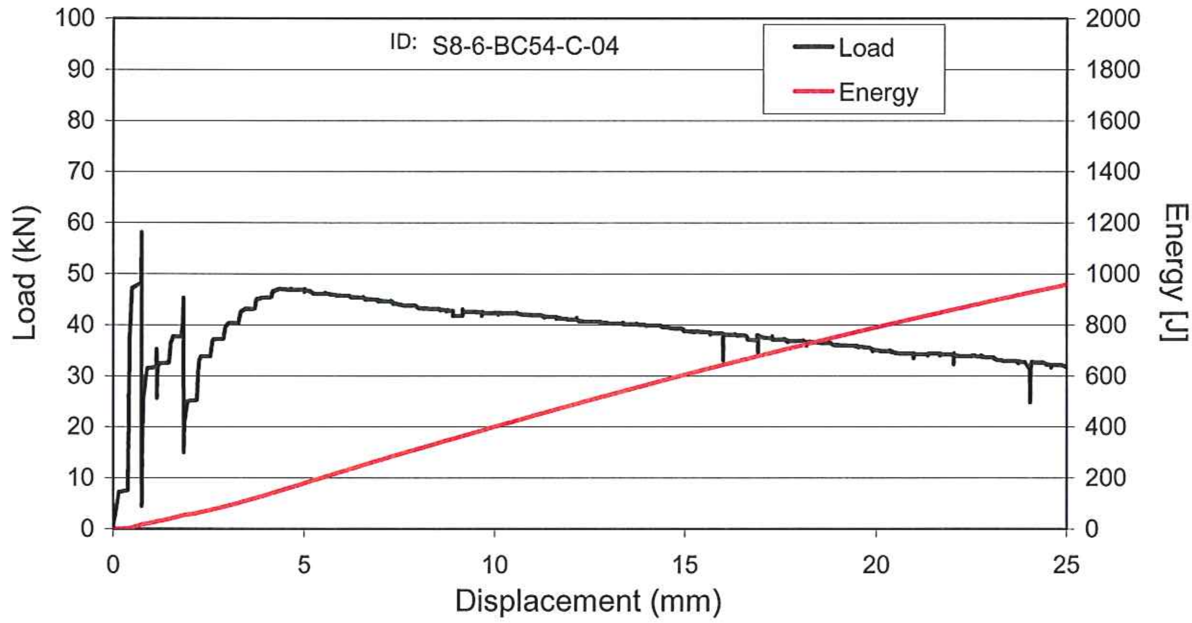
Project: Sprayed concrete, Veidekke panels **Panel production date:** 24.09.2009
Specimen ID: S8-6-BC54-C-04
Test date: 02.03.2010 **Fibre type:** BarChip BC54 (54mm)
Concrete test age (d): 159 **Nom. fibre dosage:** 6 kg
Comments: **Cast/sprayed:** Cast

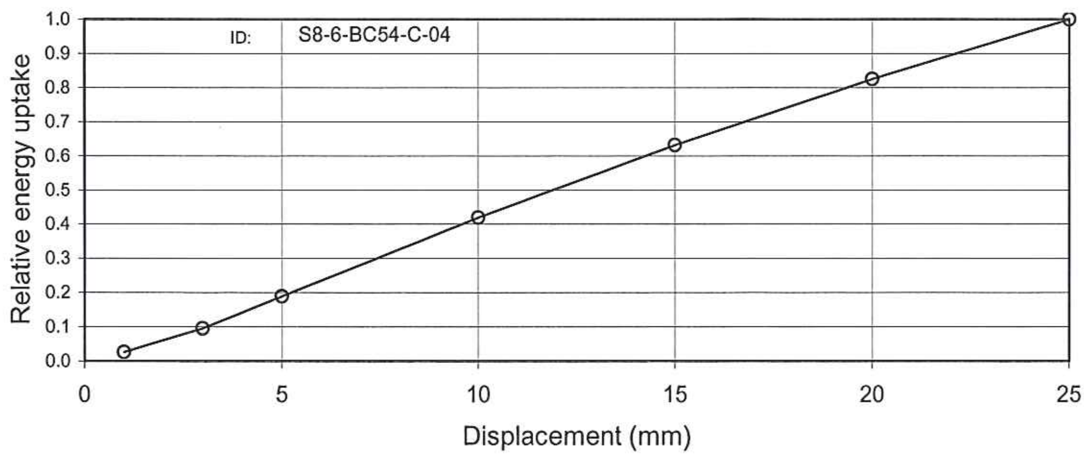
Type yes/no				
Correct for thickness:	**yes**	Average plate thickness =	**104.1**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**601.3**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 0.961 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	**25**	**32**	**0.03**		
3.0	**91**	**40**	**0.10**		
5.0	**181**	**47**	**0.19**		
10.0	**401**	**42**	**0.42**		
15.0	**605**	**39**	**0.63**		
20.0	**791**	**35**	**0.83**	Uncorr. Energy	Rel. uncorr/corr
25.0	**959**	**31.7**	**1.00**	1031	107.5 %

Maximum load (corr) =	58.0	[kN]
Defl. at max. load =	0.7	[mm]





Project: Sprayed concrete, Veidekke panels		**Panel production date:** 24.09.2009	
Specimen ID: S8-6-BC54-C-05			
Test date: 02.03.2010		**Fibre type:** BarChip BC54 (54mm)	
Concrete test age (d): 159		**Nom. fibre dosage:** 6 kg	
Comments:		**Cast/sprayed:** Cast	

Type yes/no

Correct for thickness: **yes**
Correct for diameter: **no**
Correct for early non-linearity: **no**

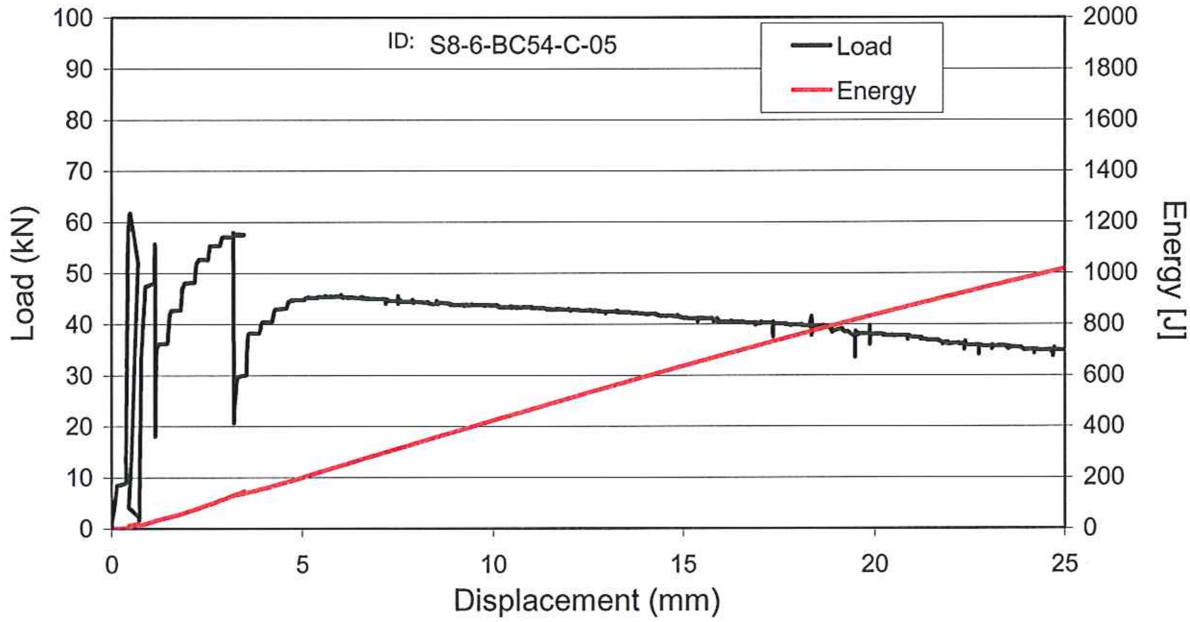
Average plate thickness = **102.3** [mm]
Nominal plate thichness = 100.0 [mm]

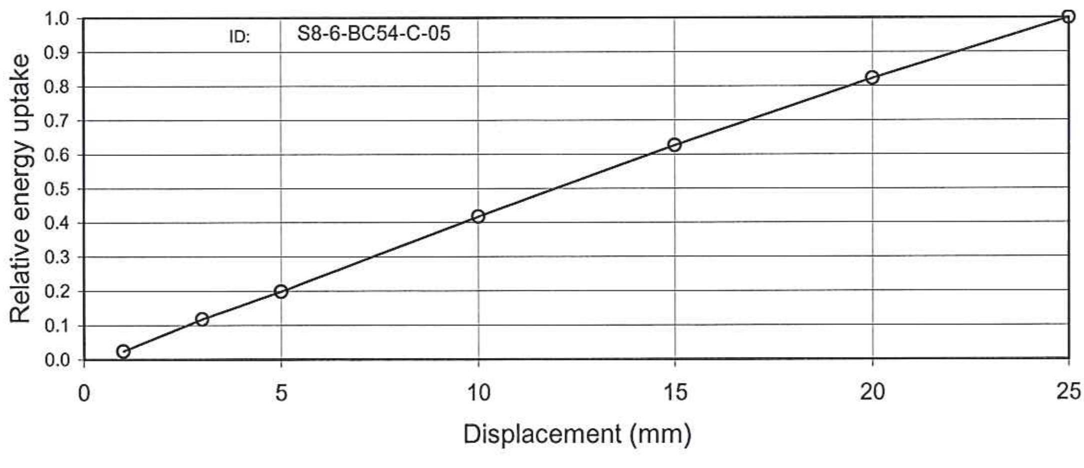
Average plate diameter = **602.3** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.978 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	**25**	**48**	**0.02**		
3.0	**120**	**57**	**0.12**		
5.0	**201**	**45**	**0.20**		
10.0	**424**	**44**	**0.42**		
15.0	**637**	**41**	**0.63**		
20.0	**837**	**38**	**0.82**	Uncorr. Energy	Rel. uncorr/corr
25.0	**1018**	**34.9**	**1.00**	1061	104.3 %

Maximum load (corr) = 61.7 [kN]
Defl. at max. load = 0.5 [mm]





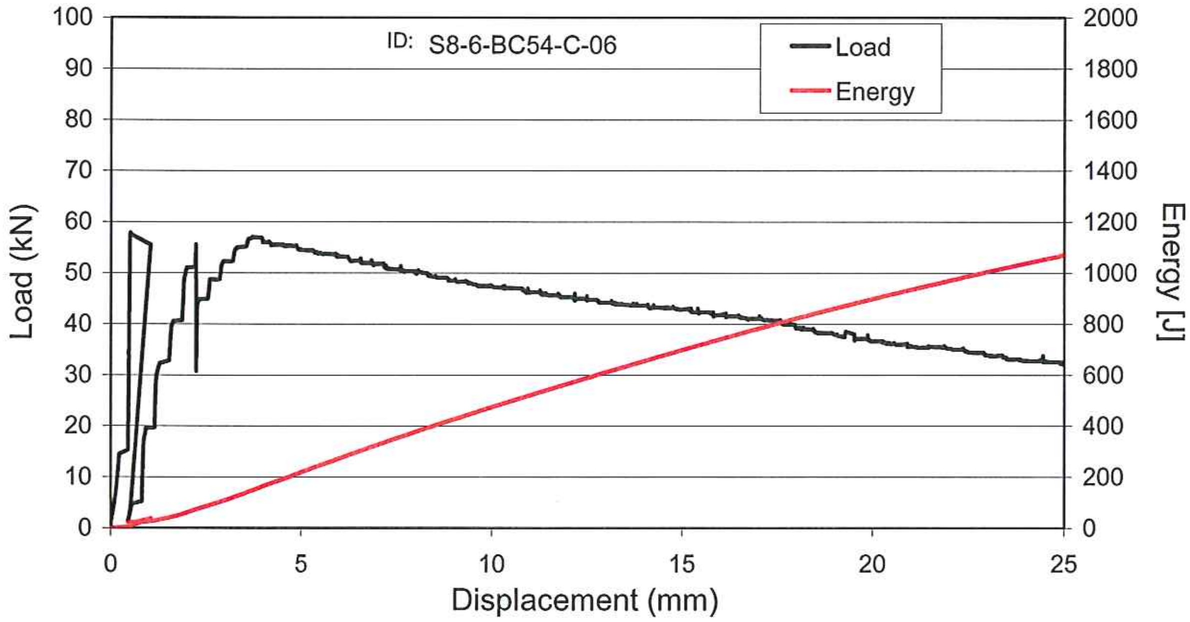
Project: Sprayed concrete, Veidekke panels		**Panel production date:** 24.09.2009	
Specimen ID: S8-6-BC54-C-06			
Test date: 02.03.2010		**Fibre type:** BarChip BC54 (54mm)	
Concrete test age (d): 159		**Nom. fibre dosage:** 6 kg	
Comments:		**Cast/sprayed:** Cast	

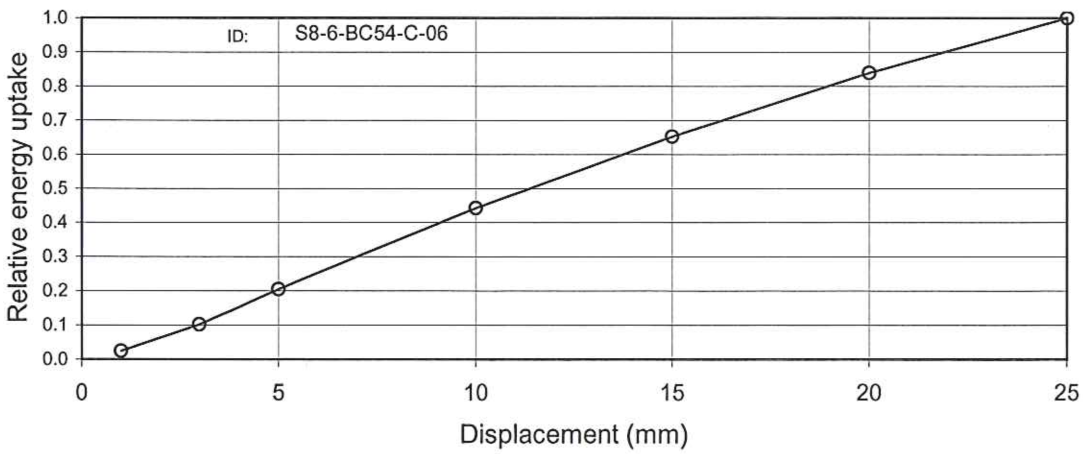
	Type yes/no			
Correct for thickness:	**yes**	Average plate thickness =	**99.2**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**598.3**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 1.008 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	**26**	**20**	**0.02**		
3.0	**109**	**52**	**0.10**		
5.0	**220**	**55**	**0.21**		
10.0	**474**	**47**	**0.44**		
15.0	**699**	**43**	**0.65**		
20.0	**899**	**37**	**0.84**		
25.0	**1071**	**32.0**	**1.00**	1056	98.6 %

Maximum load (corr) =	57.8	[kN]
Defl. at max. load =	0.5	[mm]





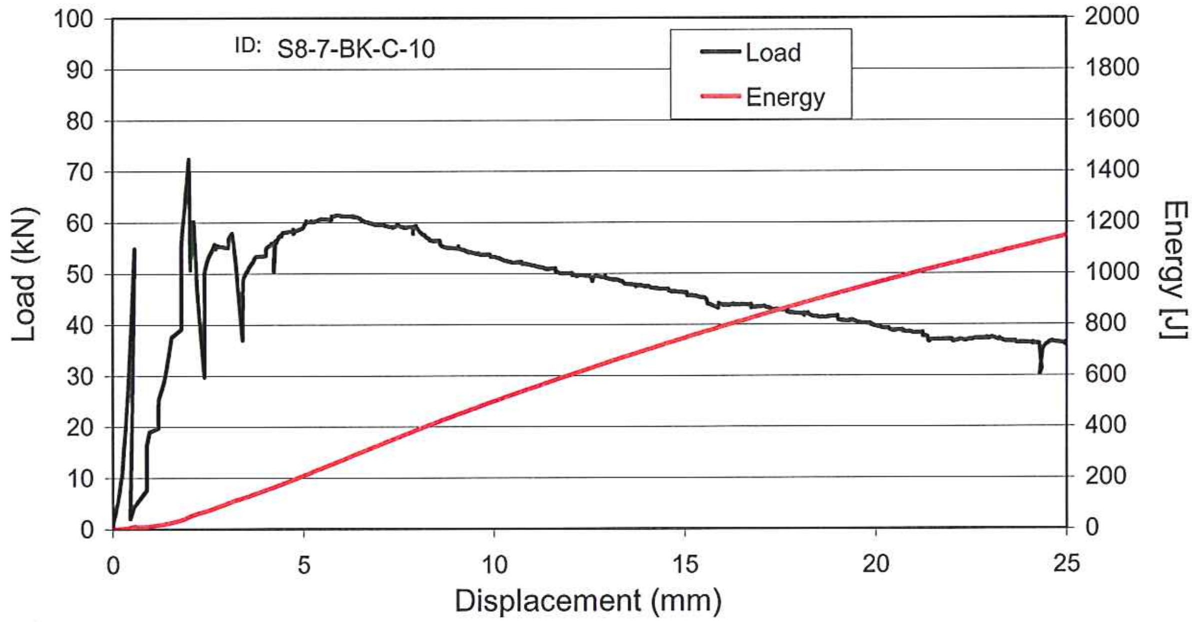
Project:	Sprayed concrete, Veidekke panels	**Panel production date:**	24.09.2009
Specimen ID:	S8-7-BK-C-10		
Test date:	02.03.2010	**Fibre type:**	BarChip Kyodo (48mm)
Concrete test age (d):	159	**Nom. fibre dosage:**	7 kg
Comments:	Minor shear	**Cast/sprayed:**	Cast

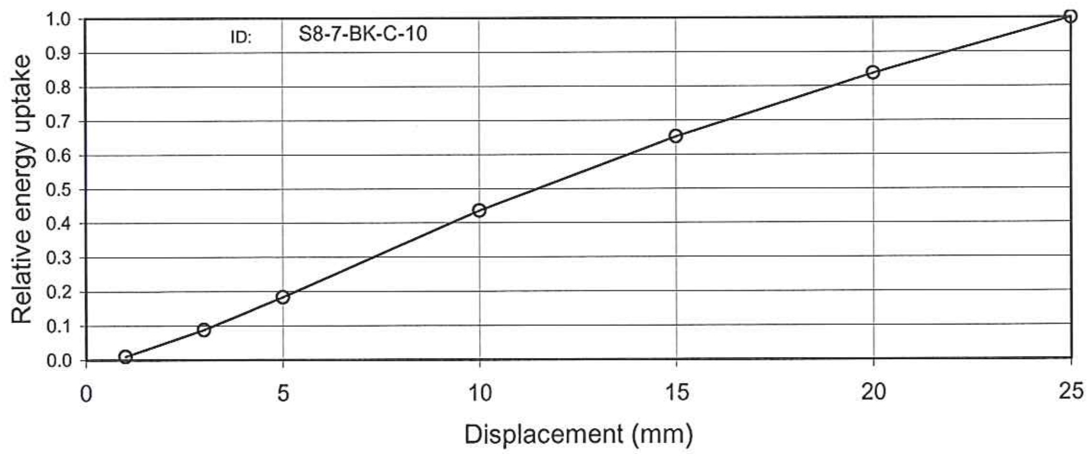
	Type yes/no			
Correct for thickness:	**yes**	Average plate thickness =	**101.0**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**600.0**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 0.990 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	12	19	0.01		
3.0	101	55	0.09		
5.0	210	59	0.18		
10.0	501	53	0.44		
15.0	748	46	0.65		
20.0	962	40	0.84		
25.0	1148	36.0	1.00	1168	101.8 %

Maximum load (corr) =	72.3	[kN]
Defl. at max. load =	2.0	[mm]





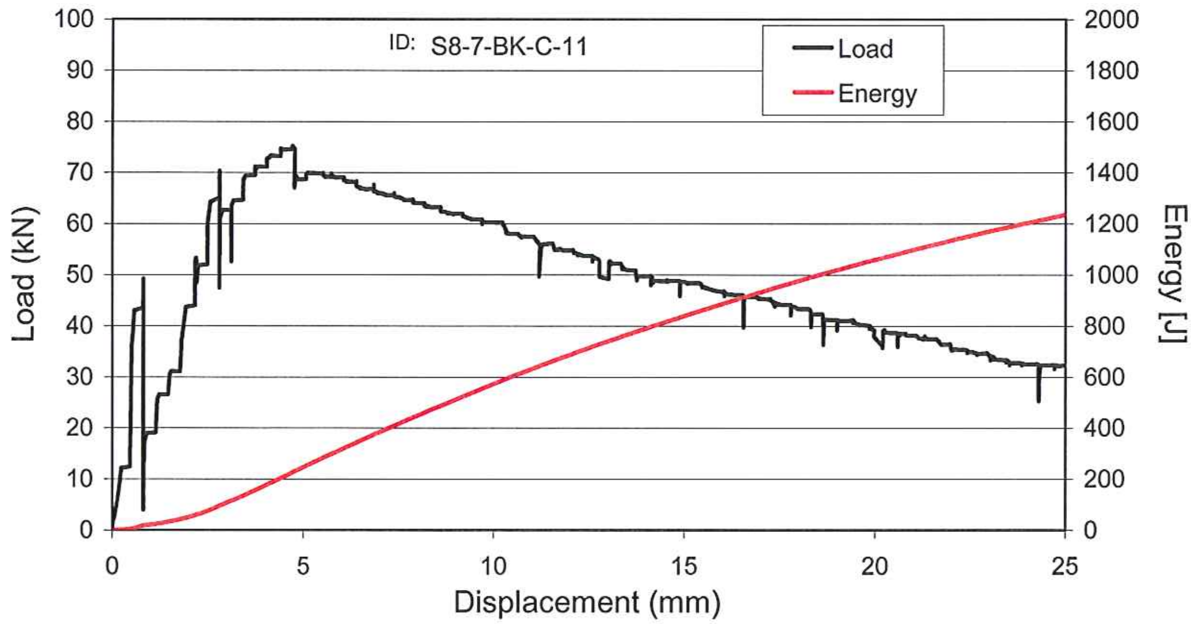
Project:	Sprayed concrete, Veidekke panels	**Panel production date:**	24.09.2009
Specimen ID:	S8-7-BK-C-11		
Test date:	02.03.2010	**Fibre type:**	BarChip Kyodo (48mm)
Concrete test age (d):	159	**Nom. fibre dosage:**	7 kg
Comments:	Shear failure, D not meas.	**Cast/sprayed:**	Cast

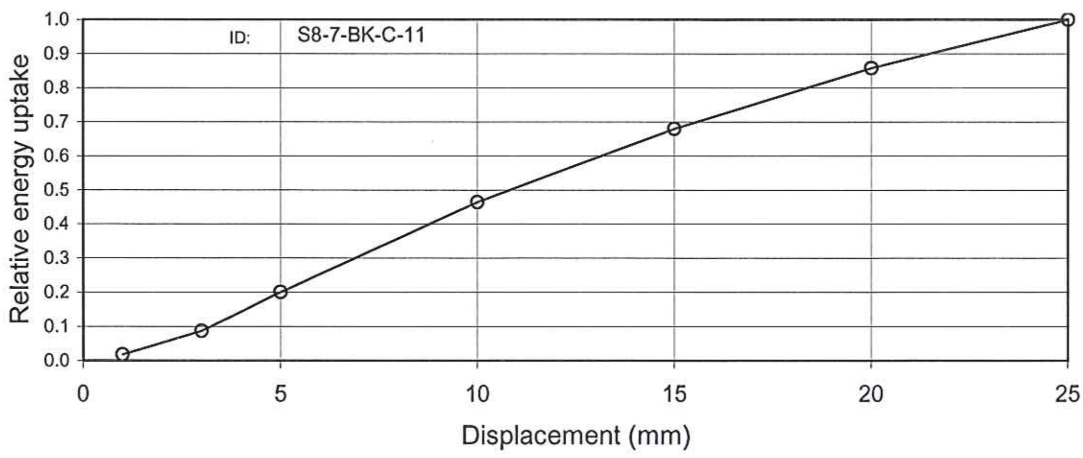
	Type yes/no			
Correct for thickness:	**yes**	Average plate thickness =	**102.2**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**600.0**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 0.978 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	22	19	0.02		
3.0	107	63	0.09		
5.0	247	69	0.20		
10.0	573	60	0.46		
15.0	840	49	0.68		
20.0	1060	38	0.86		
25.0	1236	32.2	1.00	1281	103.6 %

Maximum load (corr) =	75.2	[kN]
Defl. at max. load =	4.7	[mm]





Project:	Sprayed concrete, Veidekke panels	**Panel production date:**	24.09.2009
Specimen ID:	S8-7-BK-C-18		
Test date:	02.03.2010	**Fibre type:**	BarChip Kyodo (48mm)
Concrete test age (d):	159	**Nom. fibre dosage:**	7 kg
Comments:	U-formed, Shear failure	**Cast/sprayed:**	Cast

Type yes/no

Correct for thickness: **yes**
Correct for diameter: **no**
Correct for early non-linearity: **no**

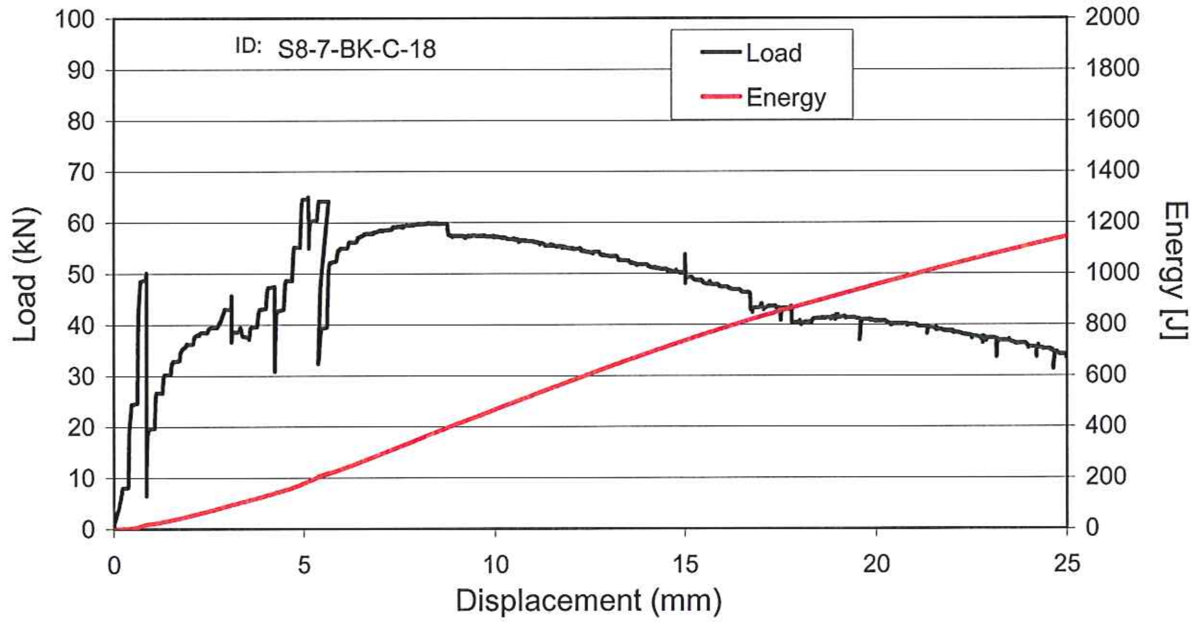
Average plate thickness = **101.5** [mm]
Nominal plate thichness = 100.0 [mm]

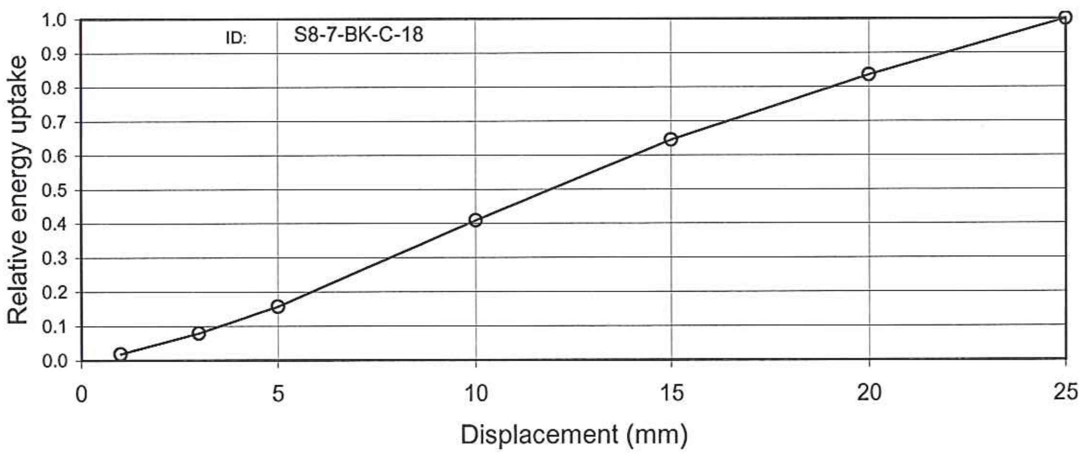
Average plate diameter = **599.7** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.985 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	**21**	**20**	**0.02**		
3.0	**91**	**43**	**0.08**		
5.0	**180**	**65**	**0.16**		
10.0	**469**	**57**	**0.41**		
15.0	**738**	**50**	**0.64**		
20.0	**957**	**41**	**0.84**	Uncorr. Energy	Rel. uncorr/corr
25.0	**1146**	**34.0**	**1.00**	1176	102.6 %

Maximum load (corr) = 64.9 [kN]
Defl. at max. load = 5.1 [mm]





Project: Sprayed concrete, Veidekke panels
Panel production date: 24.09.2009
Specimen ID: S8-7-BK-C-22
Test date: 02.03.2010
Fibre type: BarChip Kyodo (48mm)
Concrete test age (d): 159
Nom. fibre dosage: 7 kg
Comments:
Cast/sprayed: Cast

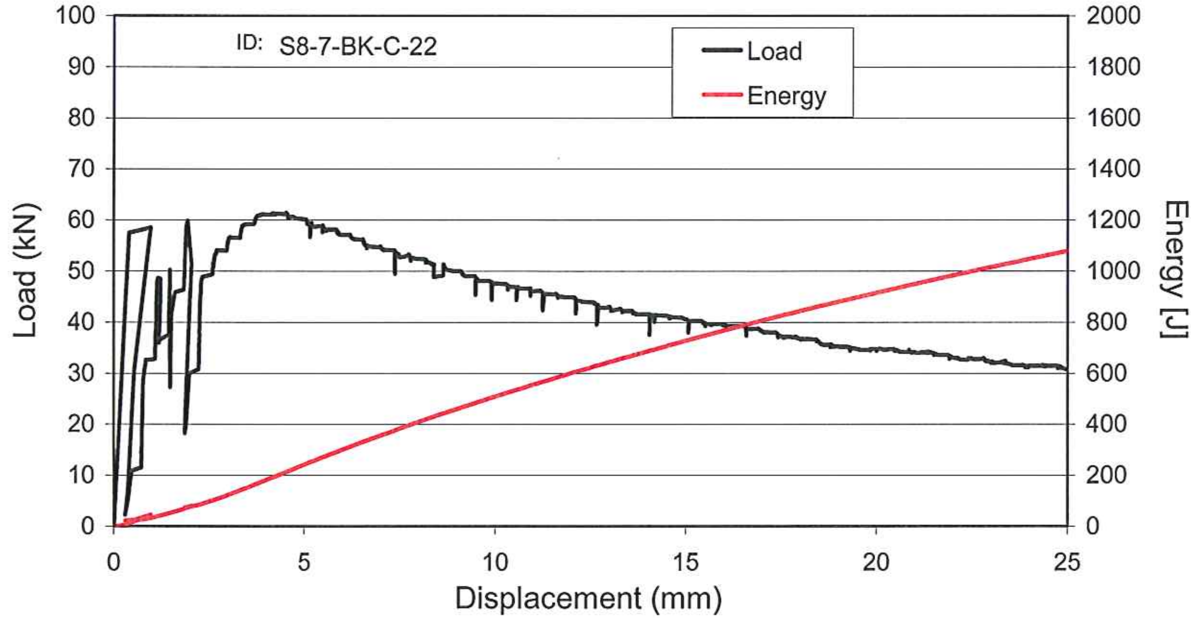
Type yes/no
Correct for thickness: **yes**
Correct for diameter: **no**
Correct for early non-linearity: **yes**

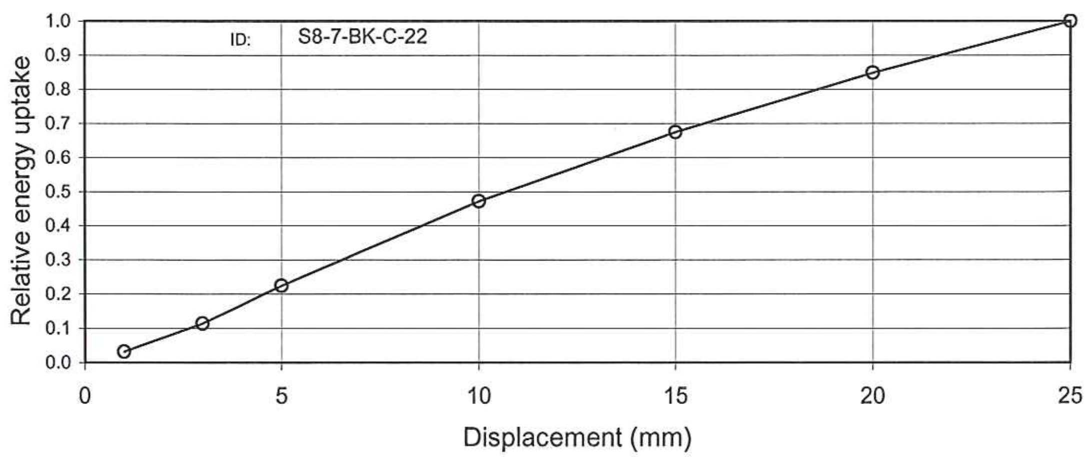
Average plate thickness = **104.9** [mm]
Nominal plate thichness = 100.0 [mm]
Average plate diameter = **601.7** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.953 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	34	33	0.03		
3.0	123	56	0.11		
5.0	243	60	0.22		
10.0	509	48	0.47		
15.0	728	41	0.67		
20.0	915	34	0.85		
25.0	1079	30.7	1.00	1161	107.5 %

Maximum load (corr) = 61.4 [kN]
Defl. at max. load = 4.5 [mm]





Project: Sprayed concrete, Veidekke panels
Panel production date: 24.09.2009
Specimen ID: S8-7-BK-C-23
Test date: 02.03.2010
Fibre type: BarChip Kyodo (48mm)
Concrete test age (d): 159
Nom. fibre dosage: 7 kg
Comments: Shear failure
Cast/sprayed: Cast

	Type yes/no
Correct for thickness:	**yes**
Correct for diameter:	**no**
Correct for early non-linearity:	**no**

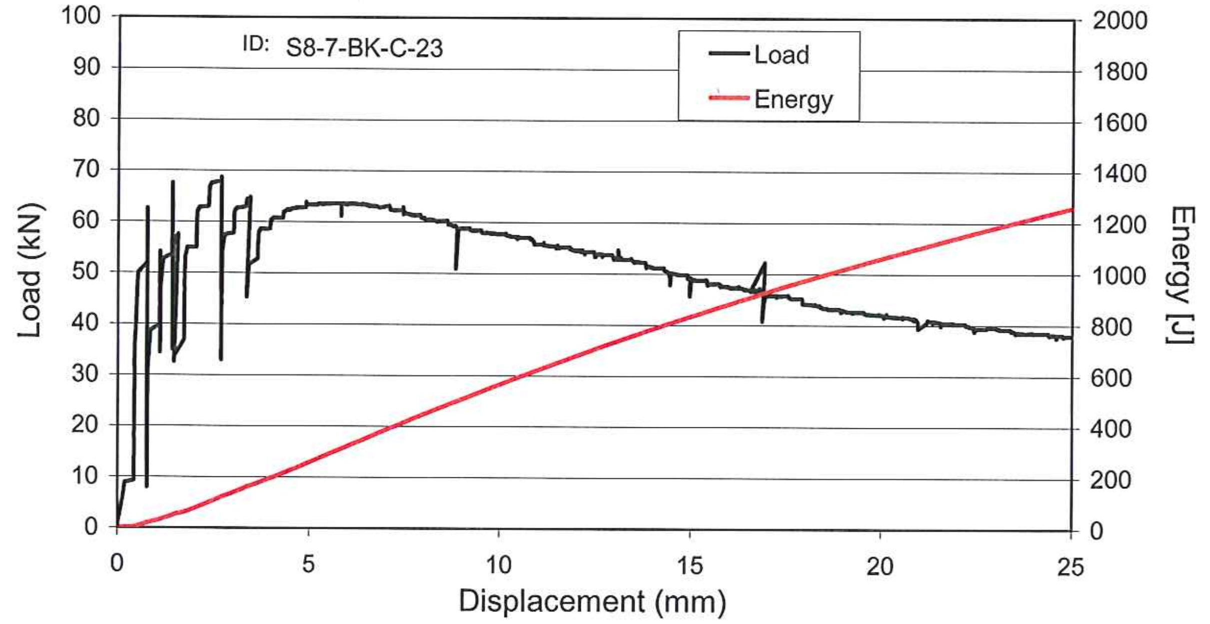
Average plate thickness = **102.4** [mm]
Nominal plate thichness = 100.0 [mm]

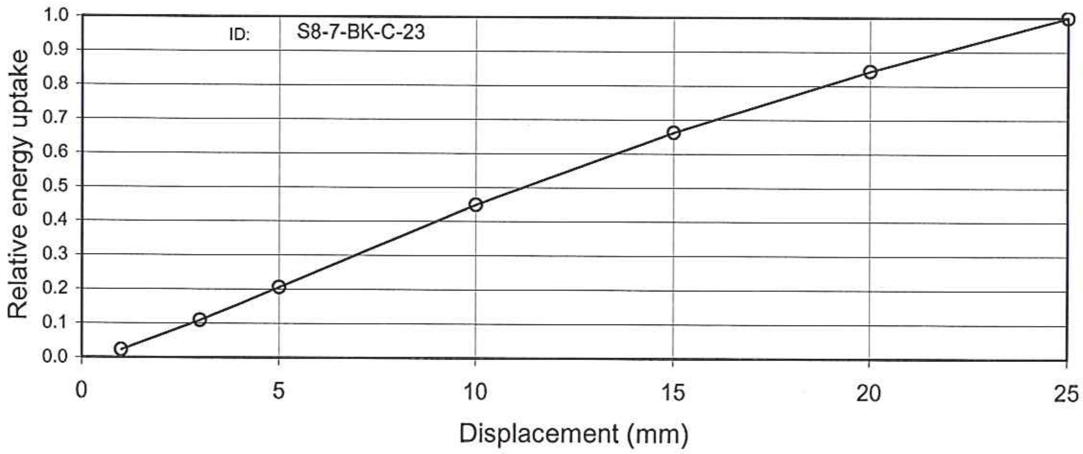
Average plate diameter = **600.0** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.977 [-]
Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	28	39	0.02		
3.0	138	58	0.11		
5.0	259	63	0.21		
10.0	566	58	0.45		
15.0	835	49	0.66		
20.0	1062	42	0.84		
25.0	1261	37.9	1.00	1314	104.2 %

Maximum load (corr) = 68.7 [kN]
Defl. at max. load = 2.7 [mm]





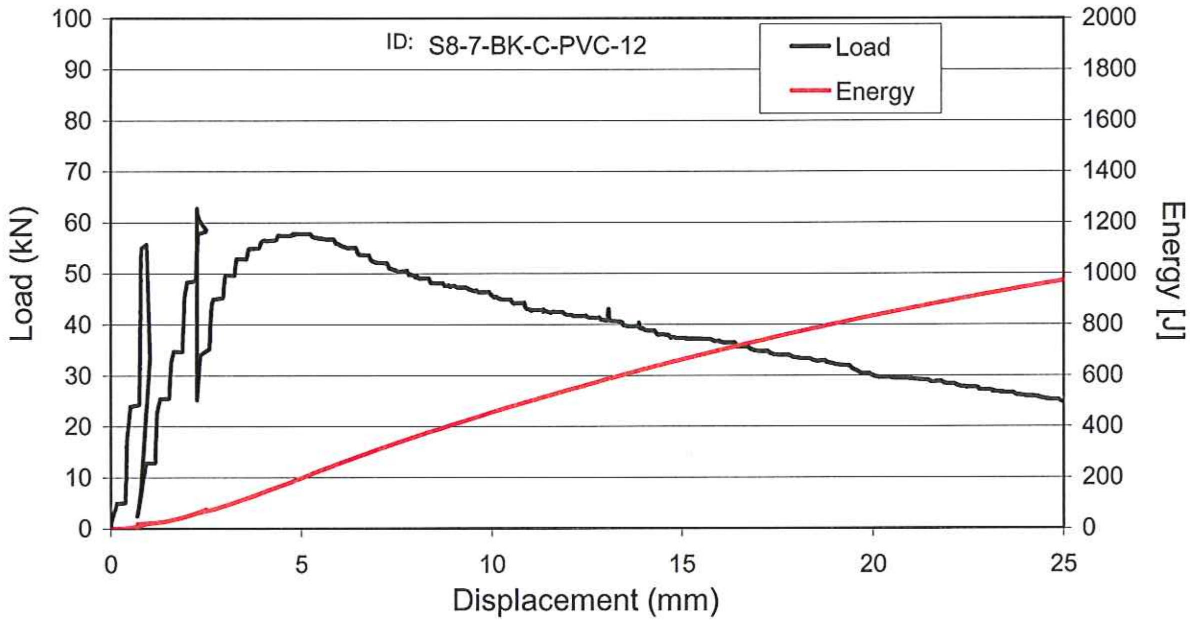
Project:	Sprayed concrete, Veidekke panels	**Panel production date:**	24.09.2009
Specimen ID:	S8-7-BK-C-PVC-12		
Test date:	02.03.2010	**Fibre type:**	BarChip Kyodo (48mm)
Concrete test age (d):	159	**Nom. fibre dosage:**	7 kg
Comments:		**Cast/sprayed:**	Cast

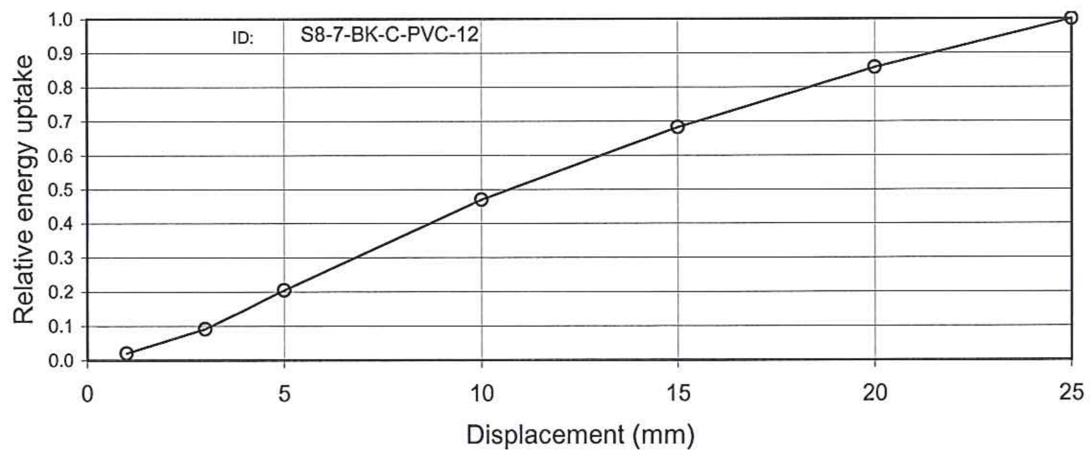
	Type yes/no			
Correct for thickness:	**yes**	Average plate thickness =	**101.5**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**601.0**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 0.985 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	20	13	0.02		
3.0	89	48	0.09		
5.0	199	58	0.21		
10.0	456	46	0.47		
15.0	663	37	0.68		
20.0	834	30	0.86	Uncorr. Energy	Rel. uncorr/corr
25.0	972	24.8	1.00	996	102.5 %

Maximum load (corr) =	62.7	[kN]
Defl. at max. load =	2.3	[mm]





Project: Sprayed concrete, Veidekke panels | **Panel production date:** 24.09.2009
Specimen ID: S8-7-BK-C-PVC-16
Test date: 02.03.2010 | **Fibre type:** BarChip Kyodo (48mm)
Concrete test age (d): 159 | **Nom. fibre dosage:** 7 kg
Comments: | **Cast/sprayed:** Cast

	Type yes/no
Correct for thickness:	**yes**
Correct for diameter:	**no**
Correct for early non-linearity:	**no**

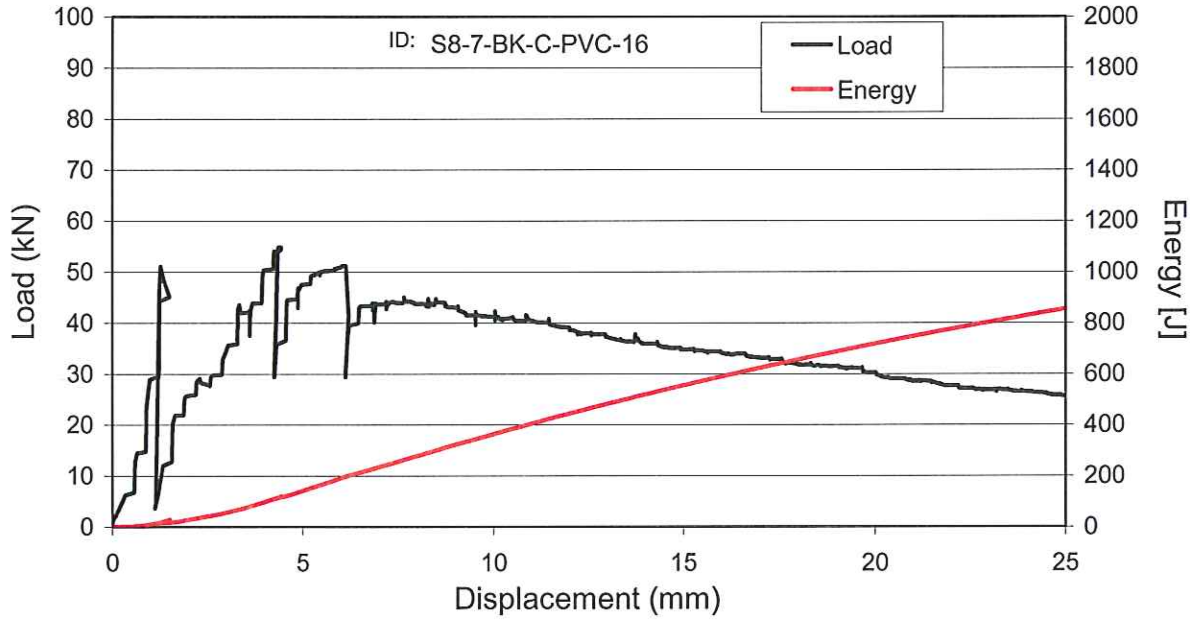
Average plate thickness = **100.1** [mm]
Nominal plate thichness = 100.0 [mm]

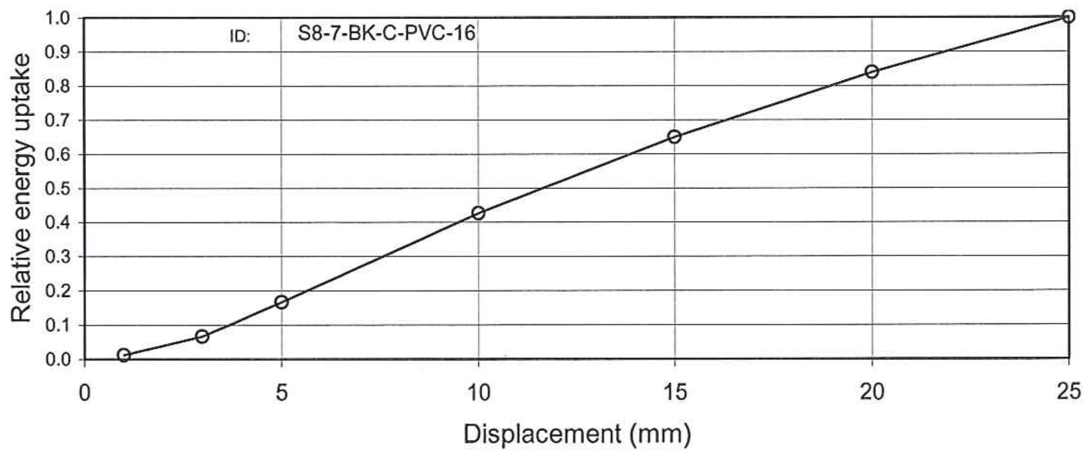
Average plate diameter = **601.3** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.999 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	10	29	0.01		
3.0	57	34	0.07		
5.0	143	48	0.17		
10.0	365	41	0.43		
15.0	555	35	0.65		
20.0	719	30	0.84		
25.0	856	25.6	1.00	857	100.2 %

Maximum load (corr) = 54.8 [kN]
Defl. at max. load = 4.4 [mm]





Project:	Sprayed concrete, Veidekke panels	**Panel production date:**	24.09.2009
Specimen ID:	S8-7-BK-C-PVC-17		
Test date:	02.03.2010	**Fibre type:**	BarChip Kyodo (48mm)
Concrete test age (d):	159	**Nom. fibre dosage:**	7 kg
Comments:	Panel is thicker at center	**Cast/sprayed:**	Cast

	Type yes/no
Correct for thickness:	**yes**
Correct for diameter:	**no**
Correct for early non-linearity:	**no**

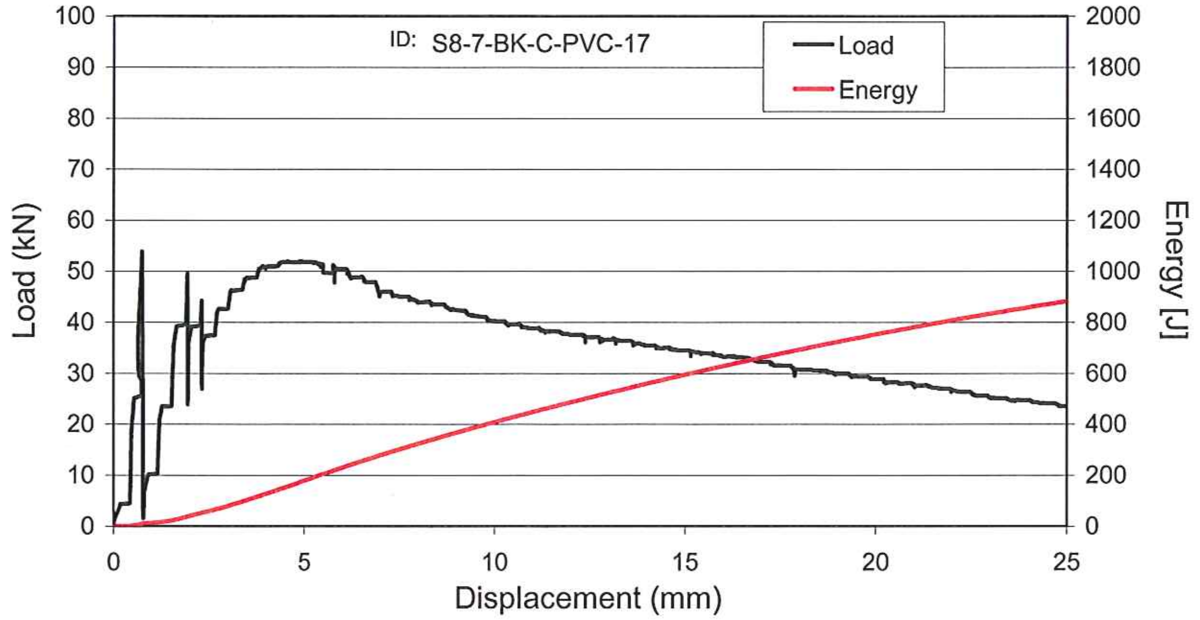
Average plate thickness = **105.5** [mm]
Nominal plate thichness = 100.0 [mm]

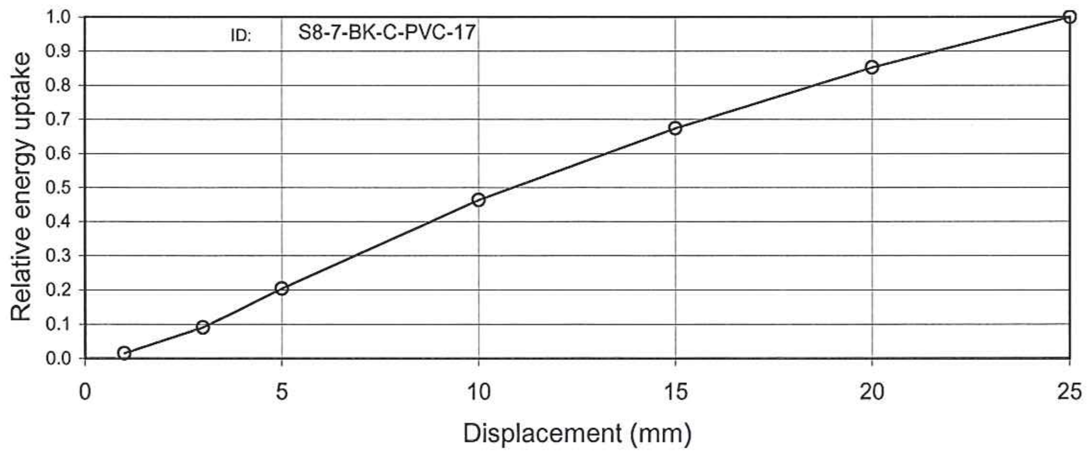
Average plate diameter = **601.7** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.948 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	13	10	0.02		
3.0	80	43	0.09		
5.0	180	52	0.20		
10.0	409	40	0.46		
15.0	595	35	0.67		
20.0	754	29	0.85		
25.0	884	23.5	1.00	965	109.2 %

Maximum load (corr) = 53.8 [kN]
Defl. at max. load = 0.8 [mm]





Project: Sprayed concrete, Veidekke panels
Panel production date: 24.09.2009
Specimen ID: S8-7-BK-C-PVC-24
Test date: 02.03.2010
Fibre type: BarChip Kyodo (48mm)
Concrete test age (d): 159
Nom. fibre dosage: 7 kg
Comments: Logg failure - STOP/RESTART after 13,7 mm!
Cast/sprayed: Cast

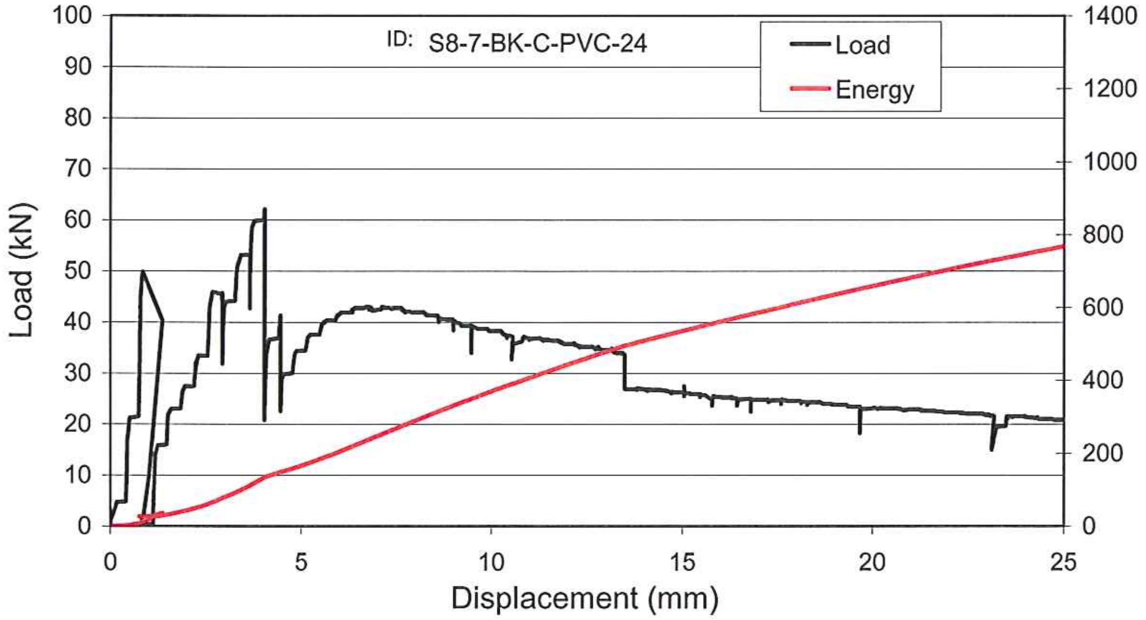
	Type yes/no
Correct for thickness:	**yes**
Correct for diameter:	**no**
Correct for early non-linearity:	**no**

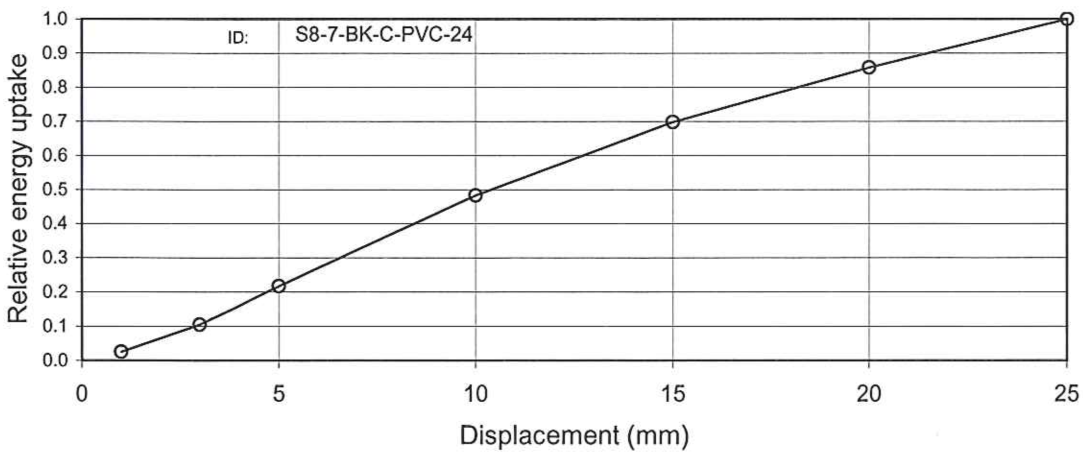
Average plate thickness =	**100.9**	[mm]
Nominal plate thichness =	100.0	[mm]
Average plate diameter =	**599.7**	[mm]
Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 0.991 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	19	47	0.03		
3.0	80	43	0.10		
5.0	167	34	0.22		
10.0	371	38	0.48		
15.0	536	26	0.70		
20.0	659	23	0.86		
25.0	769	20.8	1.00	780	101.5 %

Maximum load (corr) = 62.1 [kN]
Defl. at max. load = 4.0 [mm]





Project: Sprayed concrete, Veidekke panels		**Panel production date:**	24.09.2009
Specimen ID: S8-7-BK-S-13			
Test date: 02.03.2010		**Fibre type:**	BarChip Kyodo (48mm)
Concrete test age (d): 159		**Nom. fibre dosage:**	7 kg
Comments: Shear failure		**Cast/sprayed:**	Sprayed

	Type yes/no
Correct for thickness:	**yes**
Correct for diameter:	**no**
Correct for early non-linearity:	**no**

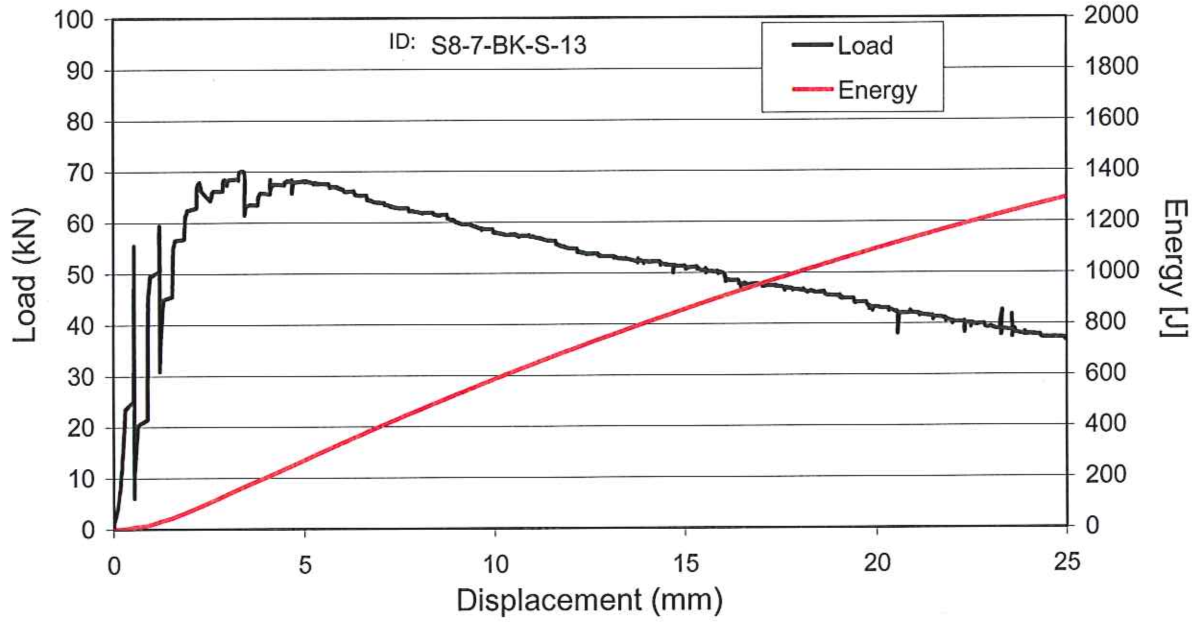
Average plate thickness = **100.5** [mm]
Nominal plate thichness = 100.0 [mm]

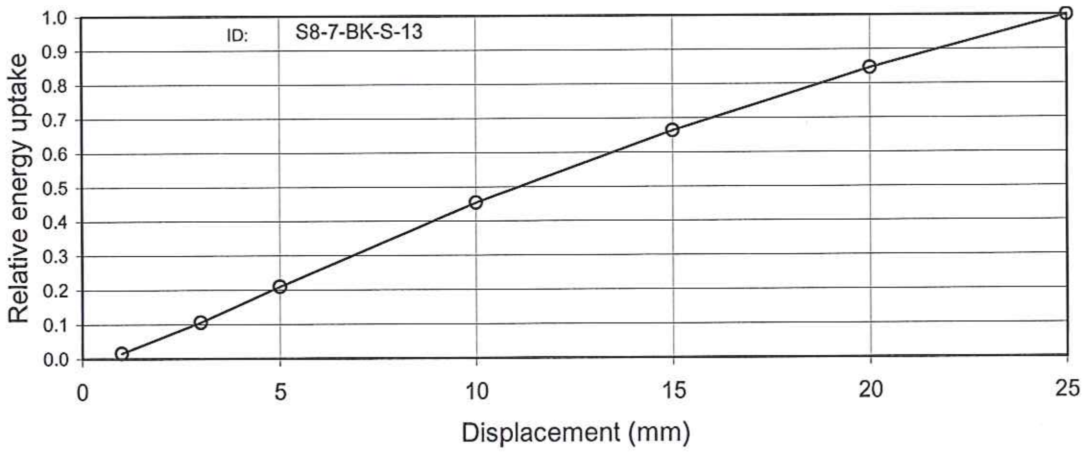
Average plate diameter = **600.7** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.995 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	20	50	0.02		
3.0	137	68	0.11		
5.0	271	68	0.21		
10.0	587	58	0.45		
15.0	858	51	0.66		
20.0	1095	43	0.85		
25.0	1294	36.8	1.00	1305	100.9 %

Maximum load (corr) = 70.1 [kN]
Defl. at max. load = 3.4 [mm]





Project:	Sprayed concrete, Veidekke panels	**Panel production date:**	24.09.2009
Specimen ID:	S8-7-BK-S-14		
Test date:	02.03.2010	**Fibre type:**	BarChip Kyodo (48mm)
Concrete test age (d):	159	**Nom. fibre dosage:**	7 kg
Comments:		**Cast/sprayed:**	Sprayed

Type yes/no

Correct for thickness: **yes**
Correct for diameter: **no**
Correct for early non-linearity: **no**

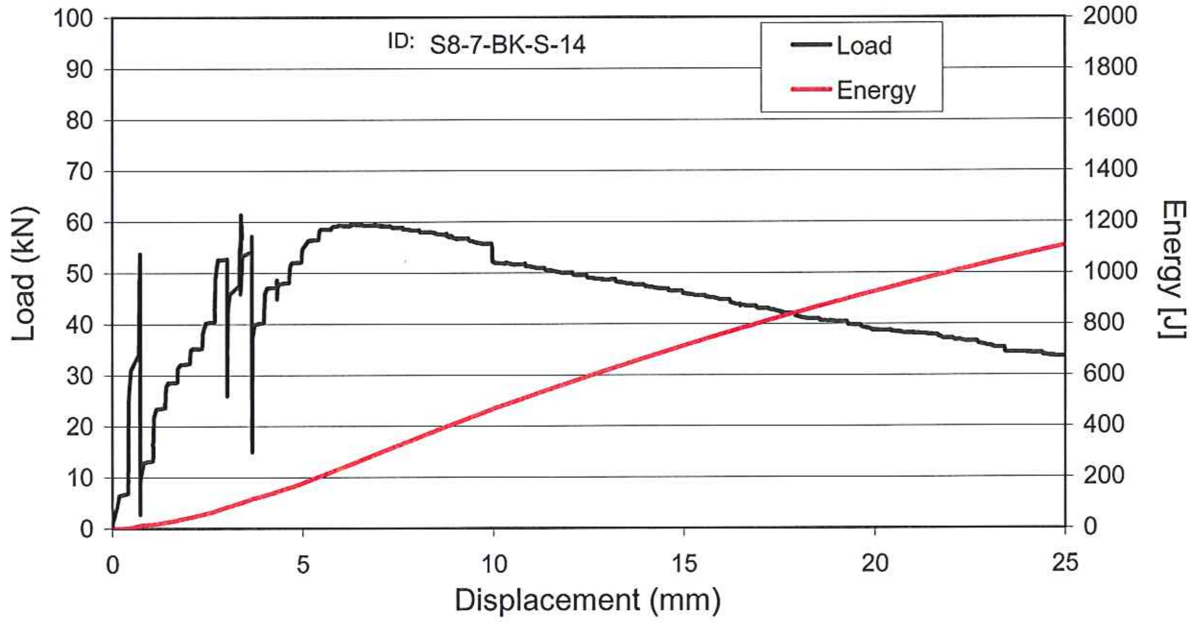
Average plate thickness = **101.6** [mm]
Nominal plate thichness = 100.0 [mm]

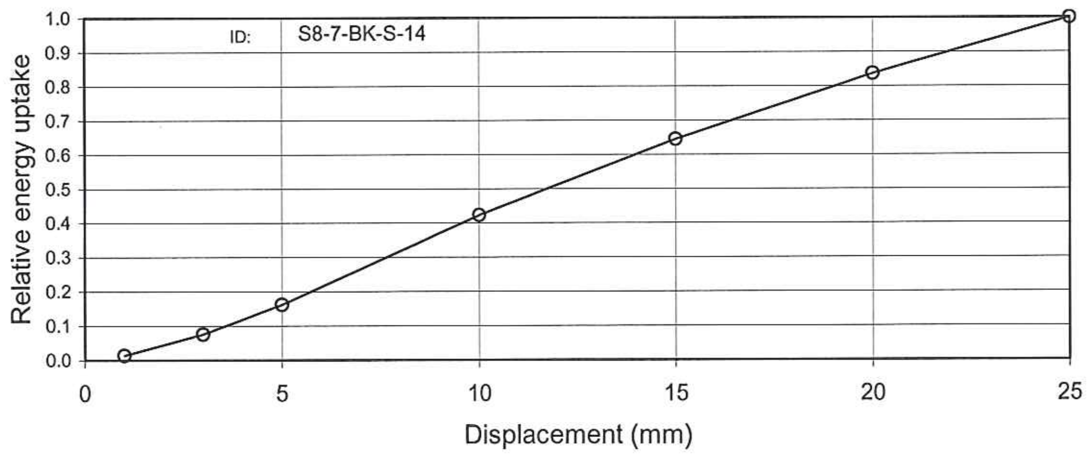
Average plate diameter = **600.7** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.984 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	16	13	0.01		
3.0	84	53	0.08		
5.0	179	55	0.16		
10.0	468	52	0.42		
15.0	714	46	0.64		
20.0	927	39	0.84	Uncorr. Energy	Rel. uncorr/corr
25.0	1108	33.6	1.00	1139	102.8 %

Maximum load (corr) = 61.3 [kN]
Defl. at max. load = 3.4 [mm]





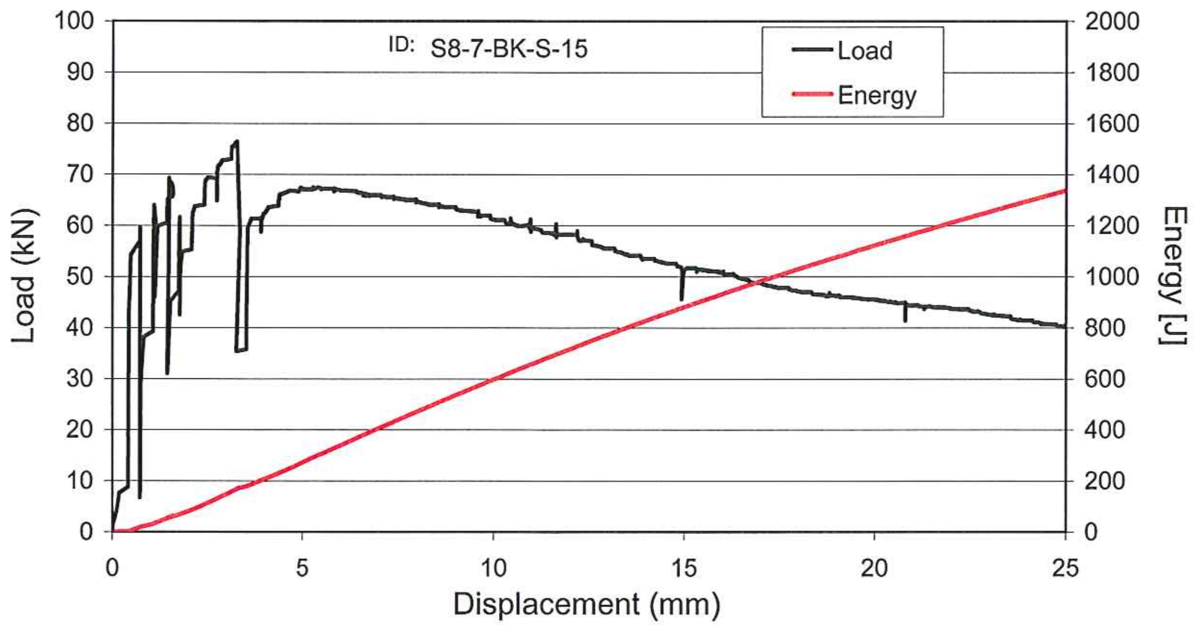
Project:	Sprayed concrete, Veidekke panels	**Panel production date:**	24.09.2009
Specimen ID:	S8-7-BK-S-15		
Test date:	02.03.2010	**Fibre type:**	BarChip Kyodo (48mm)
Concrete test age (d):	159	**Nom. fibre dosage:**	7 kg
Comments:		**Cast/sprayed:**	Sprayed

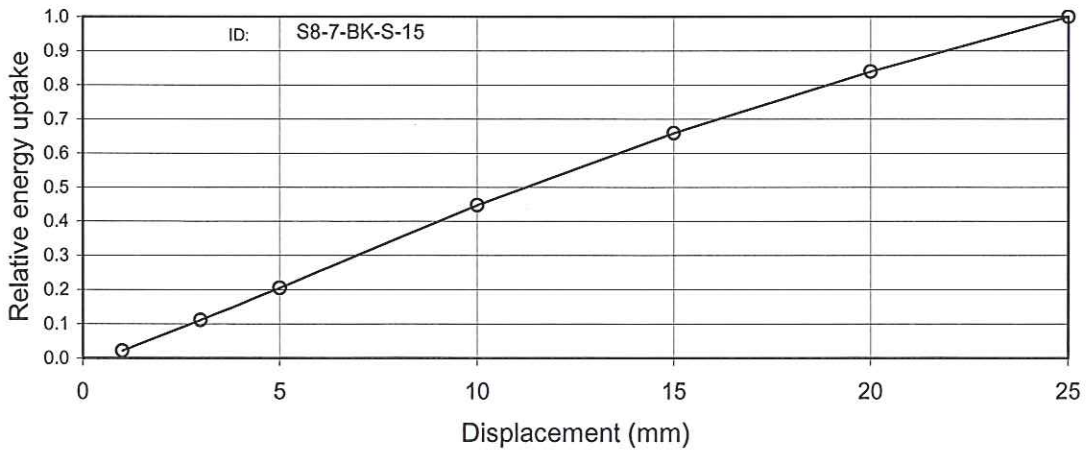
	Type yes/no			
Correct for thickness:	**yes**	Average plate thickness =	**102.5**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**600.0**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 0.976 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	**29**	**39**	**0.02**		
3.0	**149**	**73**	**0.11**		
5.0	**274**	**67**	**0.20**		
10.0	**599**	**61**	**0.45**		
15.0	**882**	**51**	**0.66**		
20.0	**1123**	**46**	**0.84**	Uncorr. Energy	Rel. uncorr/corr
25.0	**1338**	**40.3**	**1.00**	1397	104.4 %

Maximum load (corr) =	76.4	[kN]
Defl. at max. load =	3.3	[mm]





Project: Sprayed concrete, Veidekke panels | **Panel production date:** 24.09.2009
Specimen ID: S8-7-BK-S-PVC-19
Test date: 02.03.2010 | **Fibre type:** BarChip Kyodo (48mm)
Concrete test age (d): 159 | **Nom. fibre dosage:** 7 kg
Comments: (looks cast?) | **Cast/sprayed:** Sprayed

Type yes/no
Correct for thickness: **yes**
Correct for diameter: **no**
Correct for early non-linearity: **no**

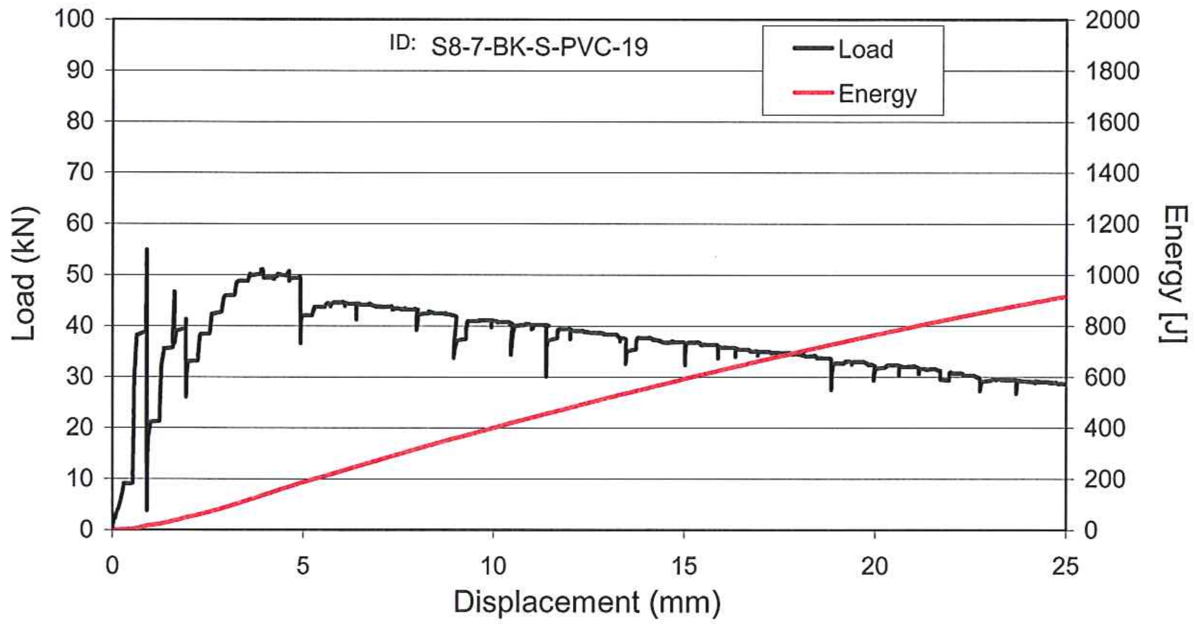
Average plate thickness = **100.8** [mm]
Nominal plate thichness = 100.0 [mm]

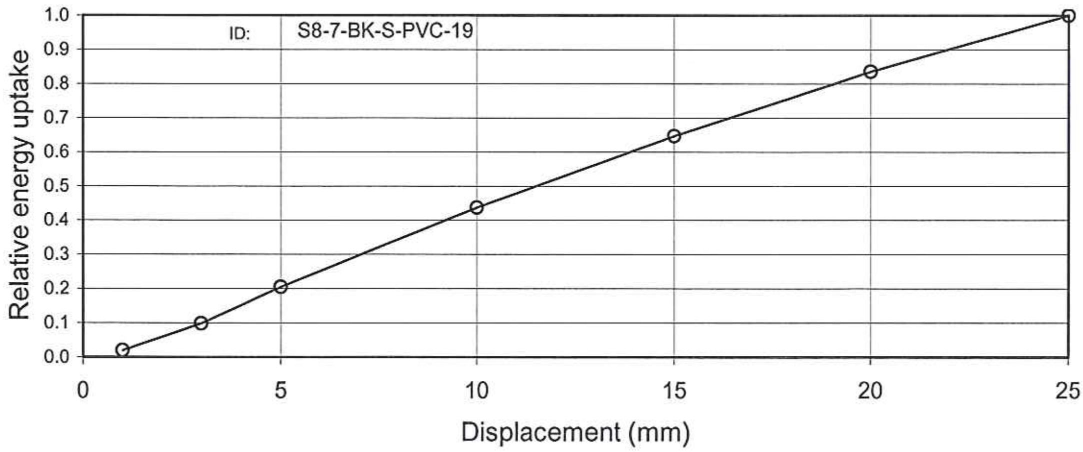
Average plate diameter = **600.0** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.992 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	**18**	**21**	**0.02**		
3.0	**90**	**46**	**0.10**		
5.0	**188**	**42**	**0.20**		
10.0	**401**	**41**	**0.44**		
15.0	**593**	**37**	**0.65**		
20.0	**766**	**31**	**0.83**	Uncorr. Energy	Rel. uncorr/corr
25.0	**917**	**28.7**	**1.00**	930	101.4 %

Maximum load (corr) = 54.8 [kN]
Defl. at max. load = 0.9 [mm]





Project: Sprayed concrete, Veidekke panels
Panel production date: 24.09.2009
Specimen ID: S8-7-BK-S-PVC-20
Test date: 02.03.2010
Fibre type: BarChip Kyodo (48mm)
Concrete test age (d): 159
Nom. fibre dosage: 7 kg
Comments: (looks cast?)
Cast/sprayed: Sprayed

	Type yes/no
Correct for thickness:	**yes**
Correct for diameter:	**no**
Correct for early non-linearity:	**no**

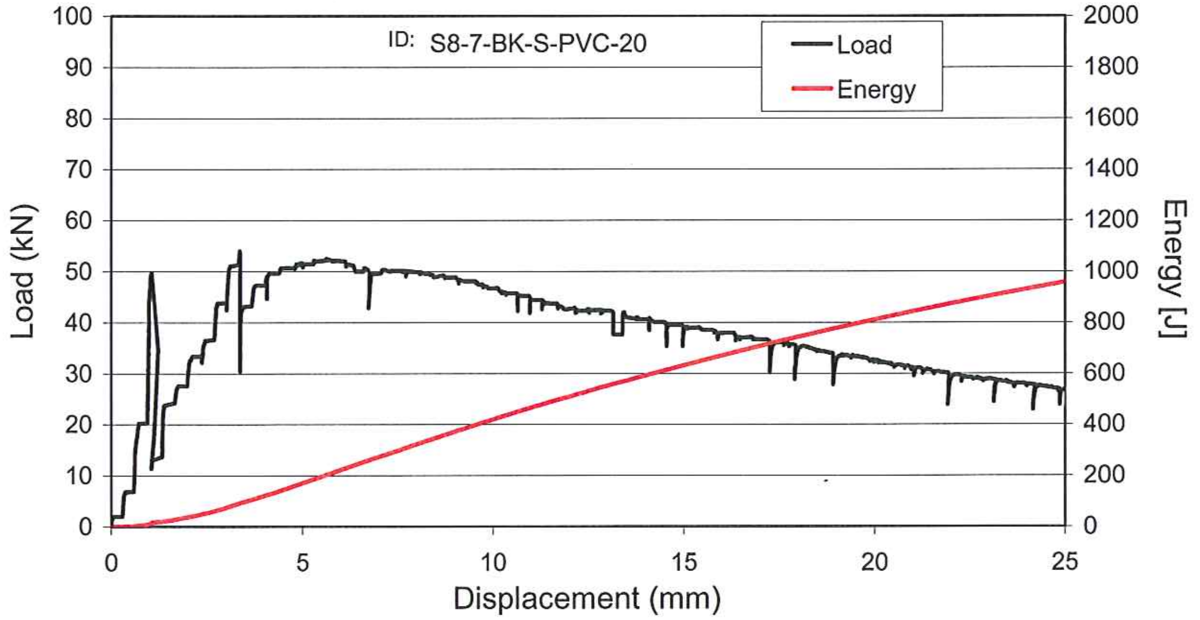
Average plate thickness = **99.6** [mm]
Nominal plate thichness = 100.0 [mm]

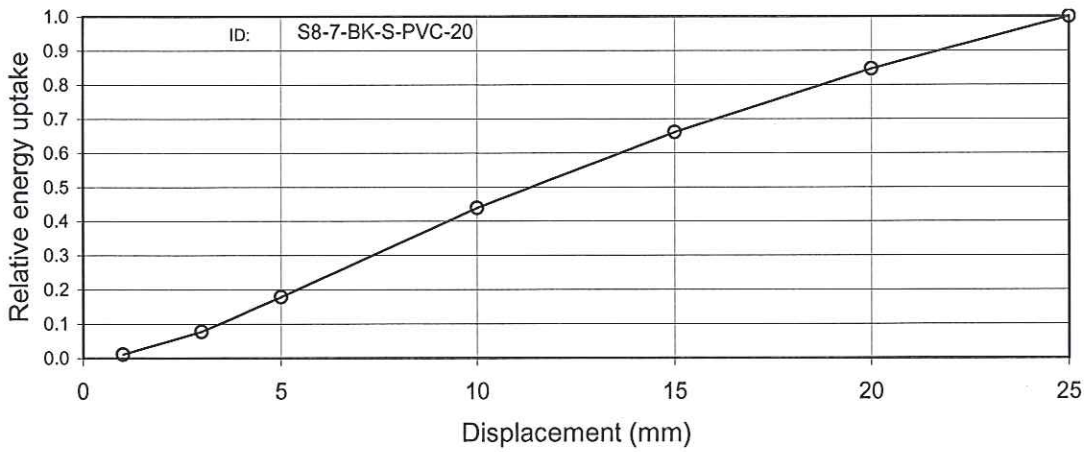
Average plate diameter = **599.7** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 1.004 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	11	44	0.01		
3.0	75	44	0.08		
5.0	172	51	0.18		
10.0	421	47	0.44		
15.0	633	39	0.66		
20.0	812	32	0.85		
25.0	958	26.9	1.00	952	99.3 %

Maximum load (corr) = 53.9 [kN]
Defl. at max. load = 3.4 [mm]





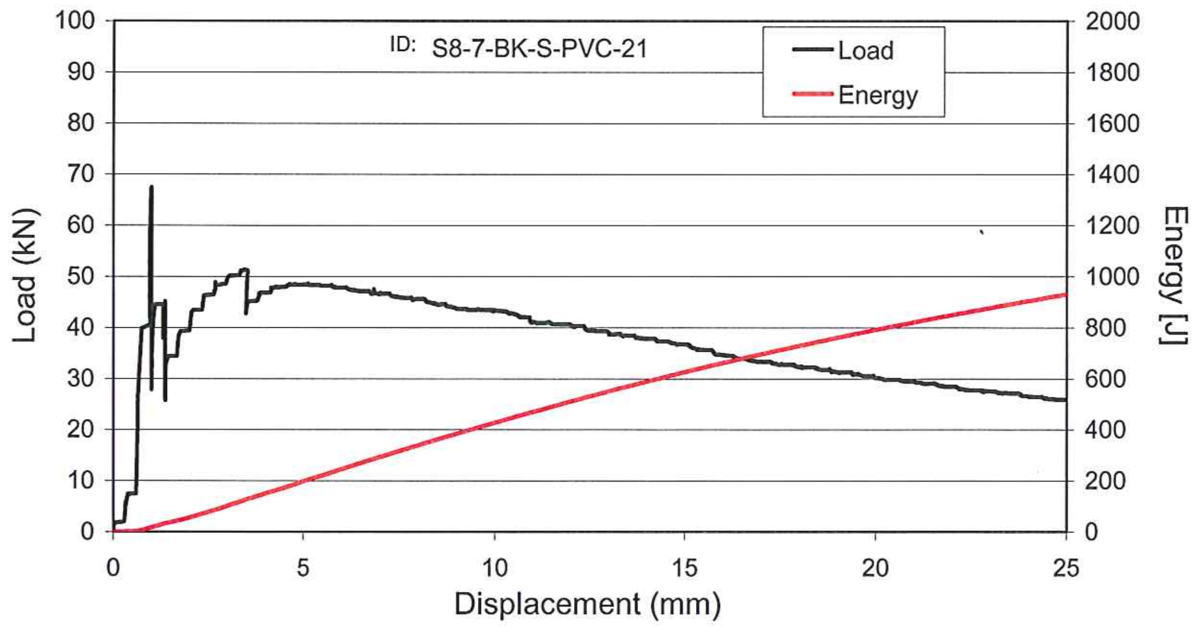
Project:	Sprayed concrete, Veidekke panels	**Panel production date:**	24.09.2009
Specimen ID:	S8-7-BK-S-PVC-21		
Test date:	02.03.2010	**Fibre type:**	BarChip Kyodo (48mm)
Concrete test age (d):	159	**Nom. fibre dosage:**	7 kg
Comments:	(looks cast?)	**Cast/sprayed:**	Sprayed

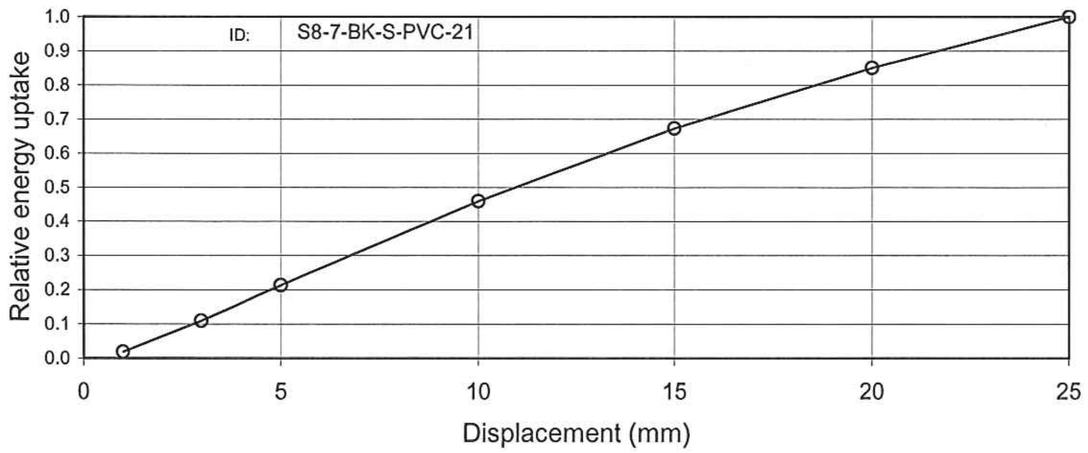
	Type yes/no			
Correct for thickness:	**yes**	Average plate thickness =	**100.0**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**598.3**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 1.000 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	17	67	0.02		
3.0	102	50	0.11		
5.0	198	48	0.21		
10.0	428	43	0.46		
15.0	627	37	0.67		
20.0	792	30	0.85		
25.0	931	25.9	1.00	931	100.0 %

Maximum load (corr) =	67.4	[kN]
Defl. at max. load =	1.0	[mm]





APPENDIX 6 Data from each panels test, Series 9

Project:	Series 9 Sprayed panels	Panel production date:	01.02.2010
Specimen ID:	S9-20-D-S-1		
Test date:	03.03.2010	Fibre type:	Dramix 65/35
Concrete test age (d):	30	Nom. fibre dosage:	20 kg
Comments:	Shear failure	Cast/sprayed:	Sprayed

	Type yes/no
Correct for thickness:	yes
Correct for diameter:	no
Correct for early non-linearity:	no

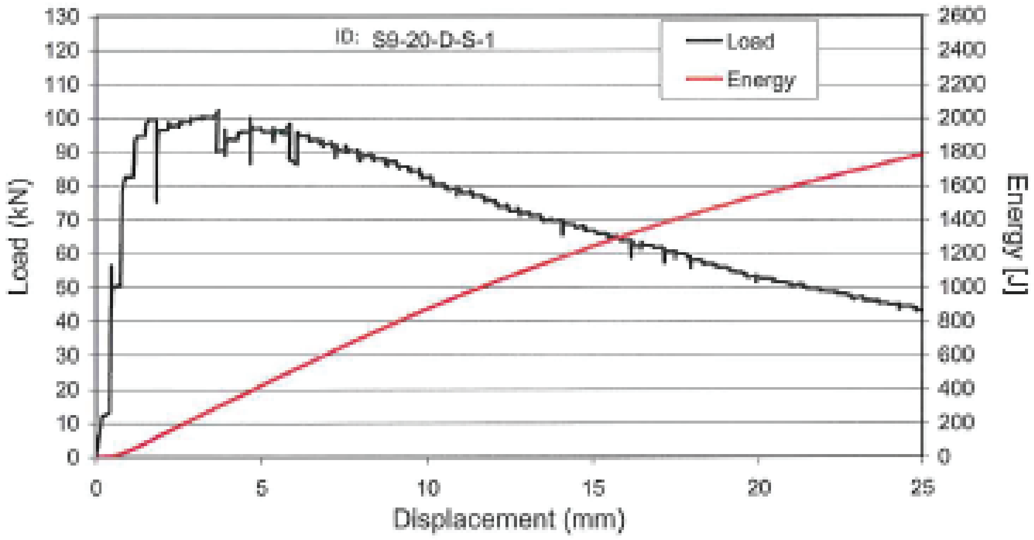
Average plate thickness = 100.9 [mm]
Nominal plate thichness = 100.0 [mm]

Average plate diameter = 600.7 [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_t = 0.991 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [-/J]	Uncorr. Energy	Rel. uncorr/corr
1.0	39	83	0.02		
3.0	232	100	0.13		
5.0	425	96	0.24		
10.0	877	83	0.49		
15.0	1246	67	0.70		
20.0	1545	53	0.87		
25.0	1785	43.2	1.00	1811	101.5 %

Maximum load (corr) = 102.2 [kN]
Defl. at max. load = 3.7 [mm]



Project: Series 9 Sprayed panels
Panel production date: 01.02.2010
Specimen ID: S9-20-D-S-2
Test date: 03.03.2010
Fibre type: Dramix 65/35
Concrete test age (d): 30
Nom. fibre dosage: 20 kg
Comments: Shear failure tendency
Cast/sprayed: Sprayed

	Type yes/no
Correct for thickness:	**yes**
Correct for diameter:	**no**
Correct for early non-linearity:	**no**

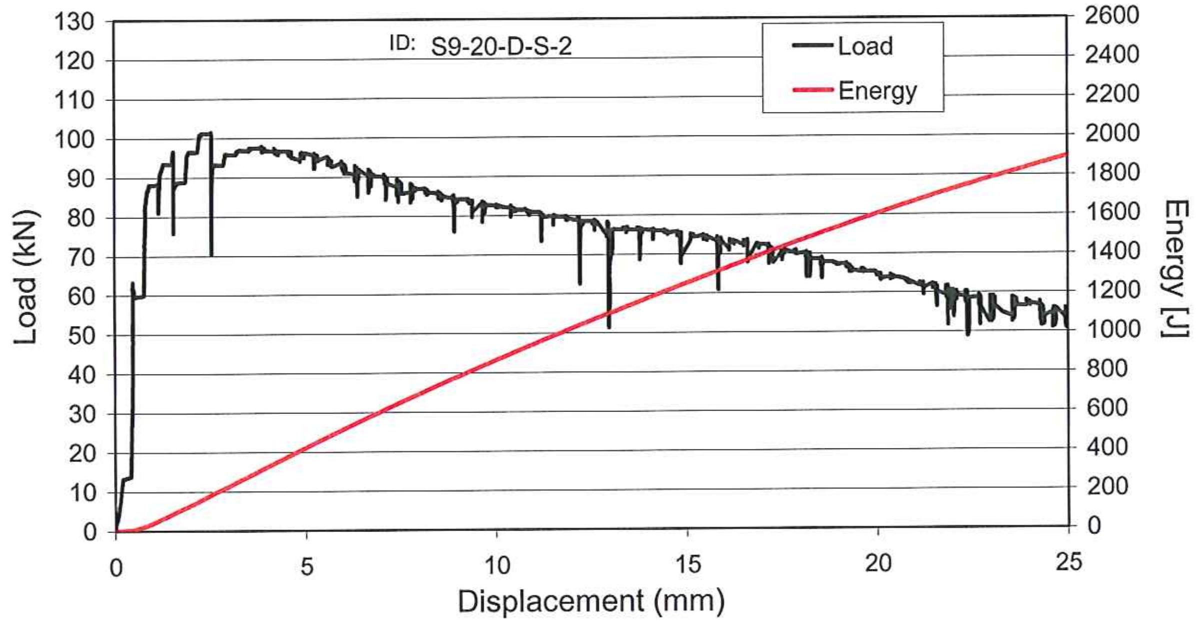
Average plate thickness = **99.6** [mm]
Nominal plate thichness = 100.0 [mm]

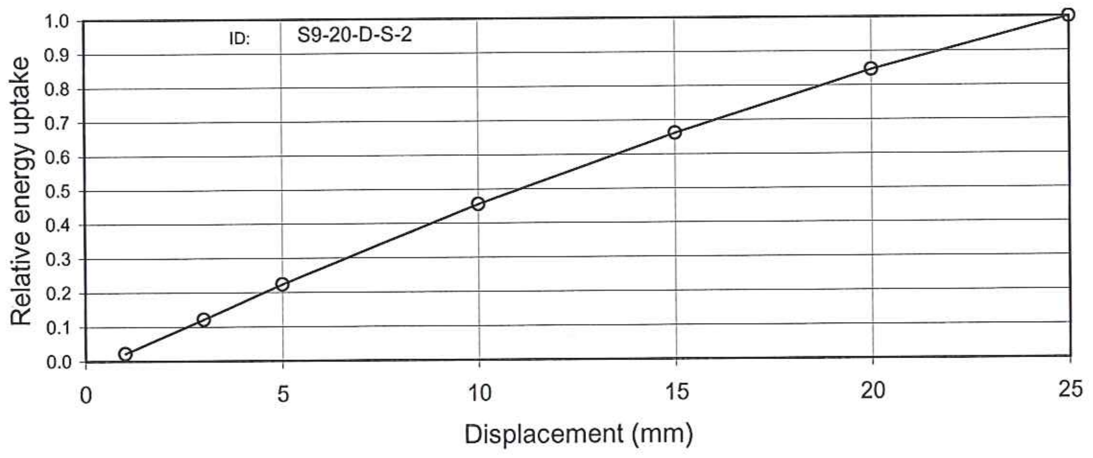
Average plate diameter = **602.0** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 1.004 [-]
Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	43	88	0.02		
3.0	230	96	0.12		
5.0	423	96	0.22		
10.0	864	83	0.46		
15.0	1253	72	0.66		
20.0	1603	65	0.85	Uncorr. Energy	Rel. uncorr/corr
25.0	1895	55.0	1.00	1883	99.3 %

Maximum load (corr) = 101.4 [kN]
Defl. at max. load = 2.5 [mm]





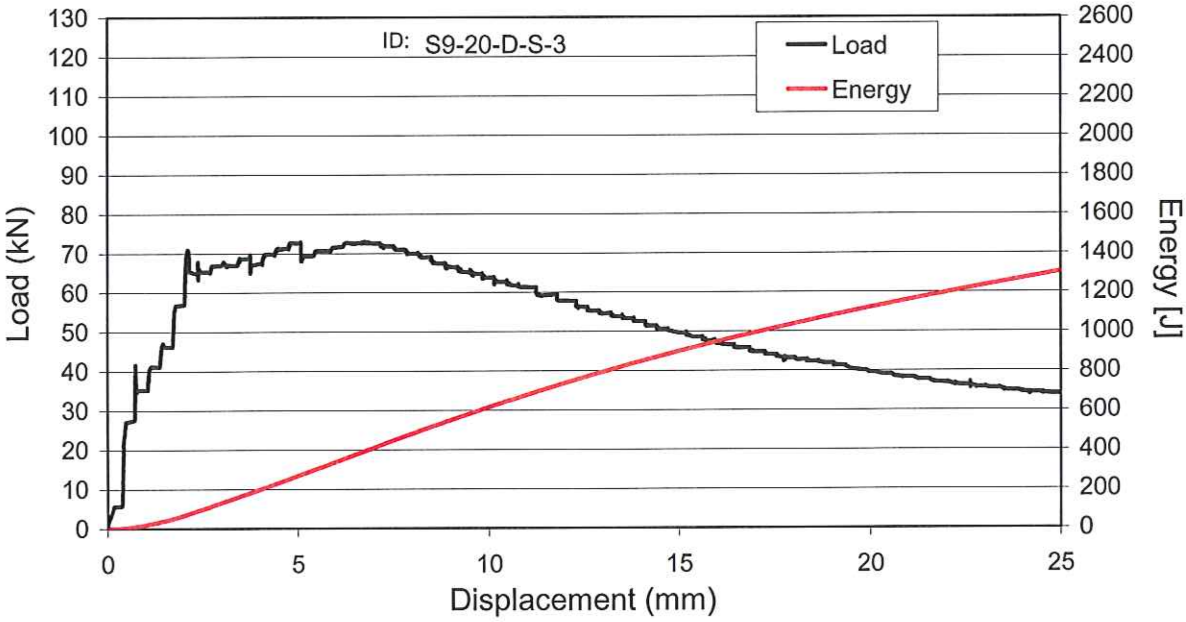
Project:	Series 9 Sprayed panels	**Panel production date:**	01.02.2010
Specimen ID:	S9-20-D-S-3		
Test date:	03.03.2010	**Fibre type:**	Dramix 65/35
Concrete test age (d):	30	**Nom. fibre dosage:**	20 kg
Comments:		**Cast/sprayed:**	Sprayed

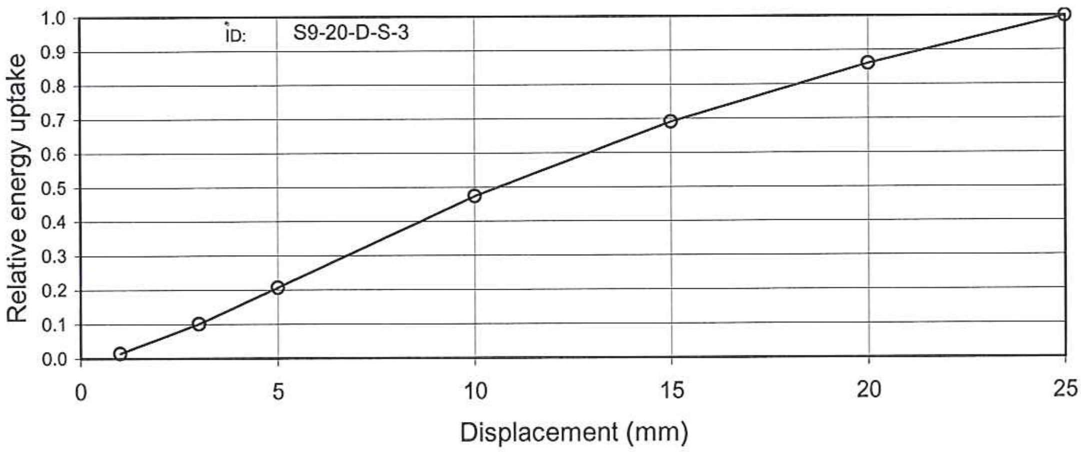
	Type yes/no			
Correct for thickness:	**yes**	Average plate thickness =	**98.7**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**600.0**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 1.013 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	**20**	**35**	**0.02**		
3.0	**132**	**67**	**0.10**		
5.0	**270**	**73**	**0.21**		
10.0	**618**	**64**	**0.47**		
15.0	**900**	**50**	**0.69**		
20.0	**1121**	**40**	**0.86**		
25.0	**1304**	**33.9**	**1.00**	1276	97.9 %

Maximum load (corr) =	73.0	[kN]
Defl. at max. load =	6.7	[mm]





Project:	Series 9 Sprayed panels	**Panel production date:**	01.02.2010
Specimen ID:	S9-40-D-S-4		
Test date:	03.03.2010	**Fibre type:**	Dramix 65/35
Concrete test age (d):	30	**Nom. fibre dosage:**	40 kg
Comments:	Large number small radial cracks	**Cast/sprayed:**	Sprayed

	Type yes/no
Correct for thickness:	**yes**
Correct for diameter:	**no**
Correct for early non-linearity:	**no**

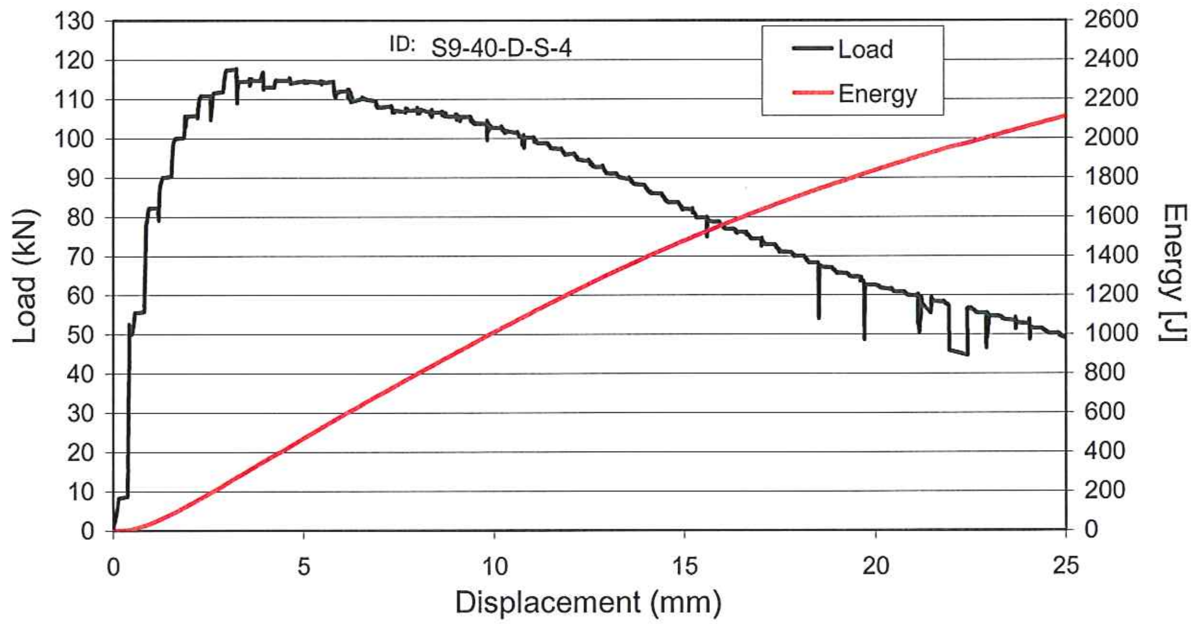
Average plate thickness = **102.7** [mm]
Nominal plate thichness = 100.0 [mm]

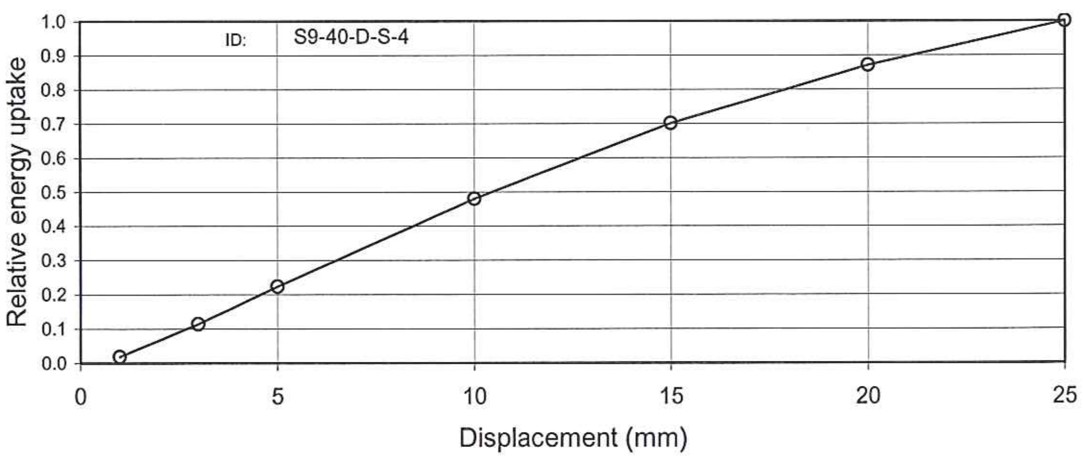
Average plate diameter = **600.7** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.974 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	39	82	0.02		
3.0	242	117	0.11		
5.0	471	114	0.22		
10.0	1013	103	0.48		
15.0	1480	82	0.70		
20.0	1839	63	0.87		
25.0	2112	49.0	1.00	2203	104.3 %

Maximum load (corr) = 117.8 [kN]
Defl. at max. load = 3.2 [mm]





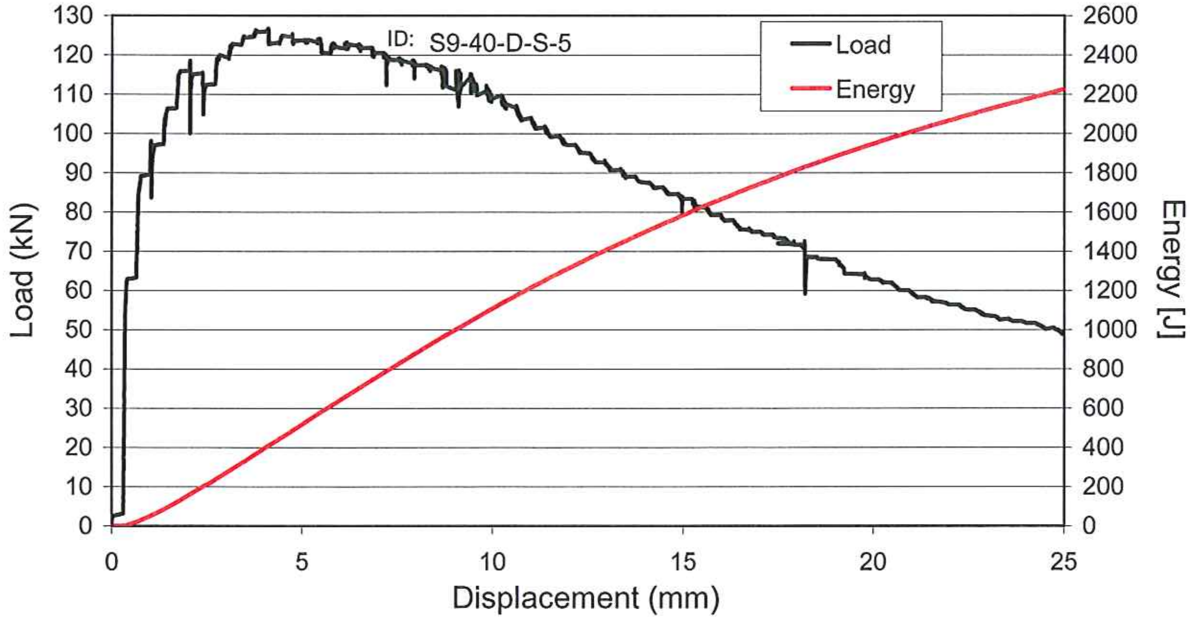
Project:	Series 9 Sprayed panels	**Panel production date:**	01.02.2010
Specimen ID:	S9-40-D-S-5		
Test date:	03.03.2010	**Fibre type:**	Dramix 65/35
Concrete test age (d):	30	**Nom. fibre dosage:**	40 kg
Comments:	Great shear failure + many small radial cracks	**Cast/sprayed:**	Sprayed

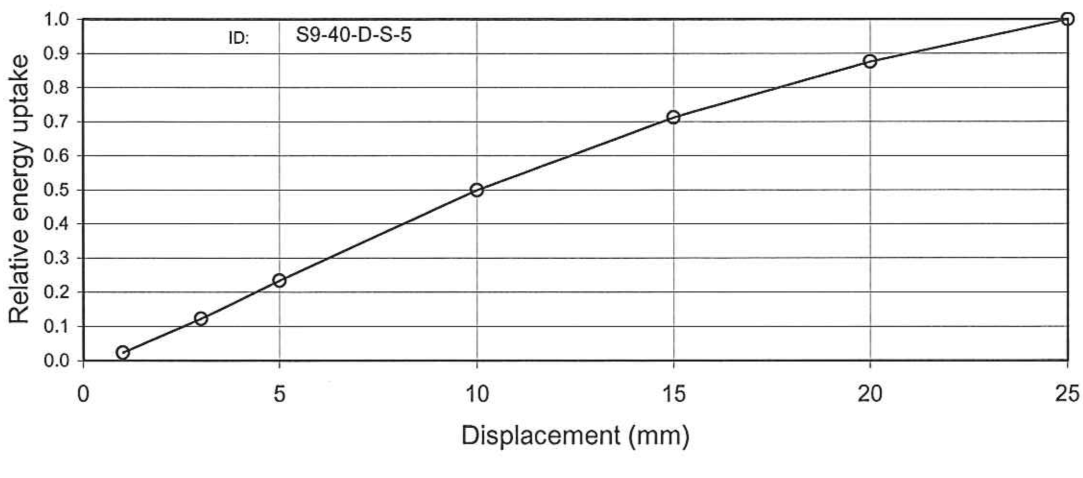
	Type yes/no			
Correct for thickness:	**yes**	Average plate thickness =	**100.3**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**600.0**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 0.997 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	**51**	**91**	**0.02**		
3.0	**272**	**119**	**0.12**		
5.0	**520**	**124**	**0.23**		
10.0	**1109**	**109**	**0.50**		
15.0	**1585**	**83**	**0.71**		
20.0	**1949**	**63**	**0.88**	Uncorr. Energy	Rel. uncorr/corr
25.0	**2227**	**49.1**	**1.00**	2237	100.5 %

Maximum load (corr) =	126.6	[kN]
Defl. at max. load =	4.1	[mm]





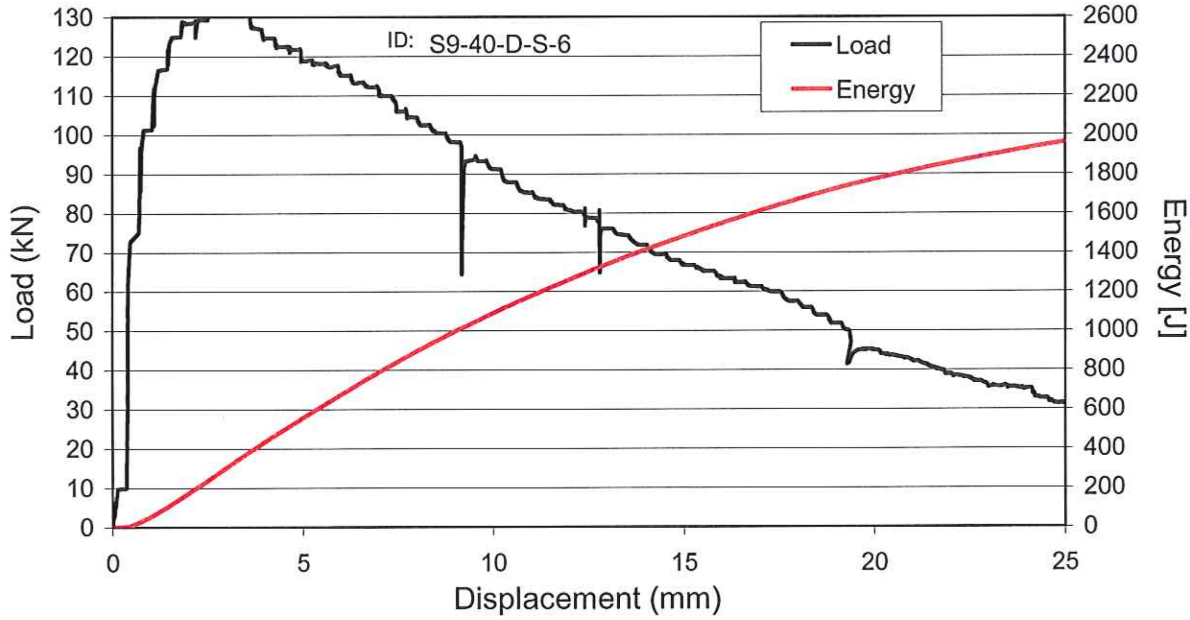
Project:	Series 9 Sprayed panels	**Panel production date:**	01.02.2010
Specimen ID:	S9-40-D-S-6		
Test date:	03.03.2010	**Fibre type:**	Dramix 65/35
Concrete test age (d):	30	**Nom. fibre dosage:**	40 kg
Comments:	Great shear failure, thickness not meas.	**Cast/sprayed:**	Sprayed

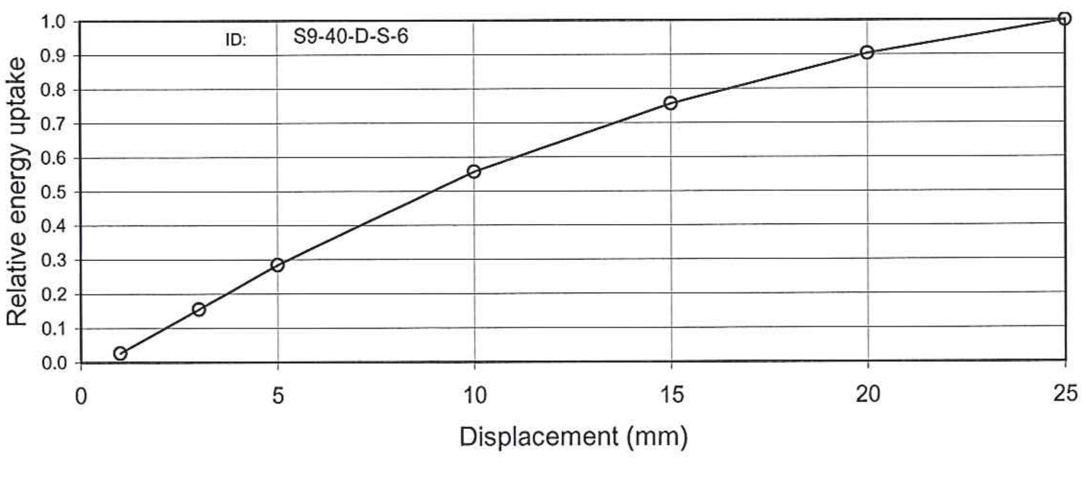
Type yes/no		Average plate thickness =	**100.0**	[mm]
Correct for thickness:	**yes**	Nominal plate thichness =	100.0	[mm]
Correct for diameter:	**no**			
Correct for early non-linearity:	**no**	Average plate diameter =	**600.0**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 1.000 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	54	101	0.03		
3.0	305	134	0.16		
5.0	559	119	0.28		
10.0	1091	91	0.56		
15.0	1484	67	0.76		
20.0	1772	45	0.90	Uncorr. Energy	Rel. uncorr/corr
25.0	1962	31.4	1.00	1962	100.0 %

Maximum load (corr) = 135.2 [kN]
Defl. at max. load = 3.2 [mm]





Project:	Series 9 Sprayed panels	**Panel production date:**	01.02.2010
Specimen ID:	S9-60-D-S-7		
Test date:	03.03.2010	**Fibre type:**	Dramix 65/35
Concrete test age (d):	30	**Nom. fibre dosage:**	60 kg
Comments:	Shear failure	**Cast/sprayed:**	Sprayed

Type yes/no

Correct for thickness: **yes**
Correct for diameter: **no**
Correct for early non-linearity: **no**

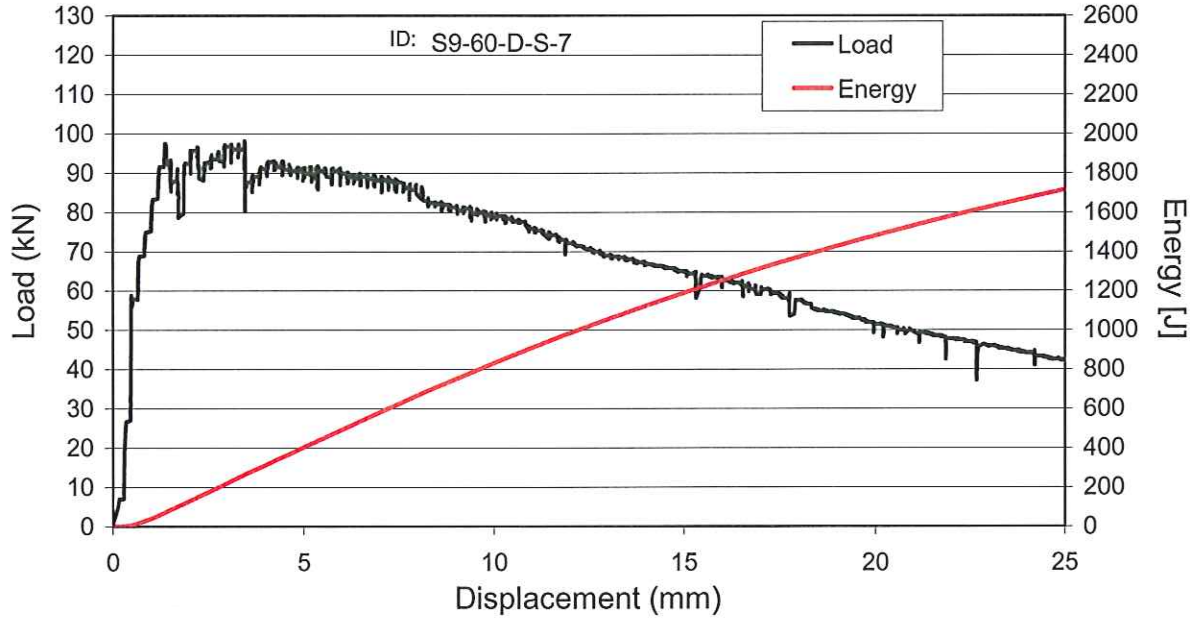
Average plate thickness = **102.4** [mm]
Nominal plate thichness = 100.0 [mm]

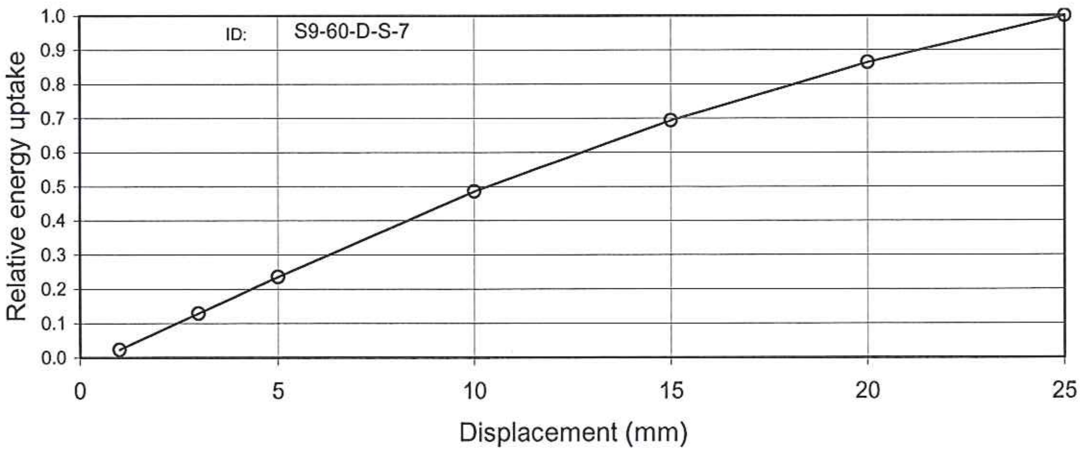
Average plate diameter = **601.7** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.977 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	41	75	0.02		
3.0	221	97	0.13		
5.0	405	91	0.24		
10.0	833	79	0.49		
15.0	1189	65	0.69		
20.0	1481	51	0.86	Uncorr. Energy	Rel. uncorr/corr
25.0	1715	42.4	1.00	1782	103.9 %

Maximum load (corr) = 98.0 [kN]
Defl. at max. load = 3.5 [mm]





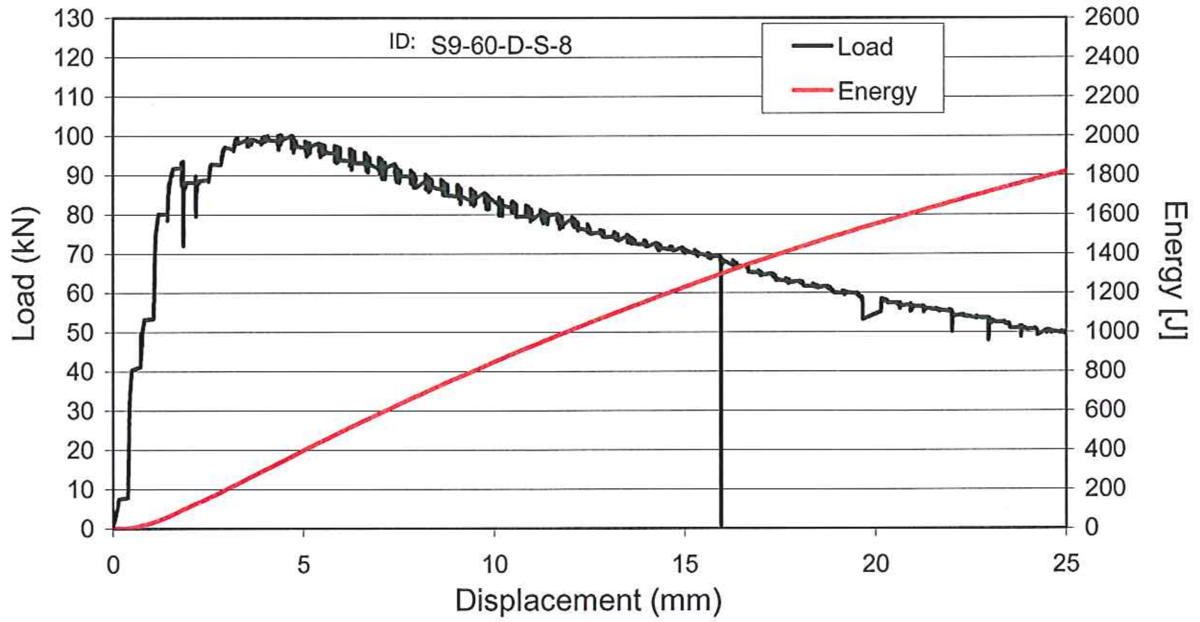
Project: Series 9 Sprayed panels		**Panel production date:** 01.02.2010	
Specimen ID: S9-60-D-S-8			
Test date: 03.03.2010		**Fibre type:** Dramix 65/35	
Concrete test age (d): 30		**Nom. fibre dosage:** 60 kg	
Comments:		**Cast/sprayed:** Sprayed	

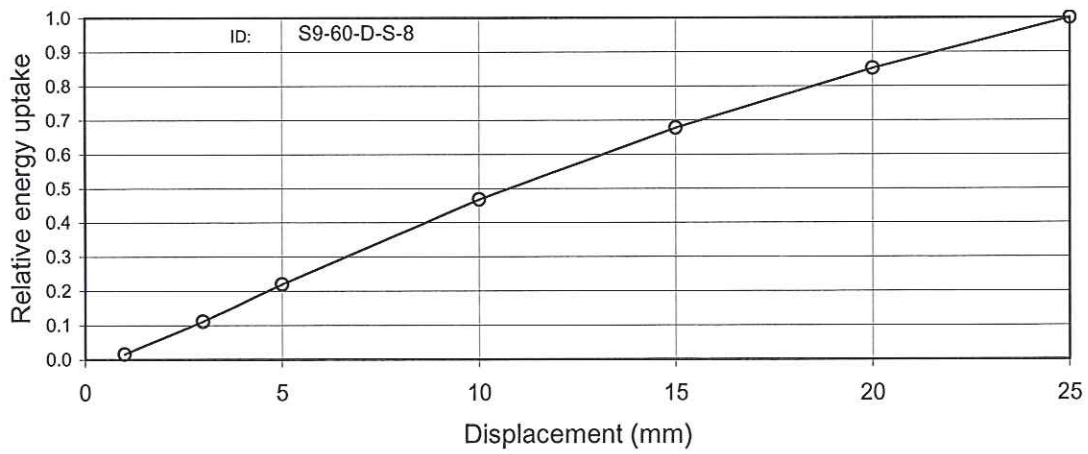
Type yes/no				
Correct for thickness:	**yes**	Average plate thickness =	**99.6**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**600.7**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 1.004 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	29	53	0.02		
3.0	202	97	0.11		
5.0	399	97	0.22		
10.0	850	83	0.47		
15.0	1232	70	0.68		
20.0	1551	55	0.85		
25.0	1819	49.6	1.00	1807	99.3 %

Maximum load (corr) =	100.2	[kN]
Defl. at max. load =	4.4	[mm]





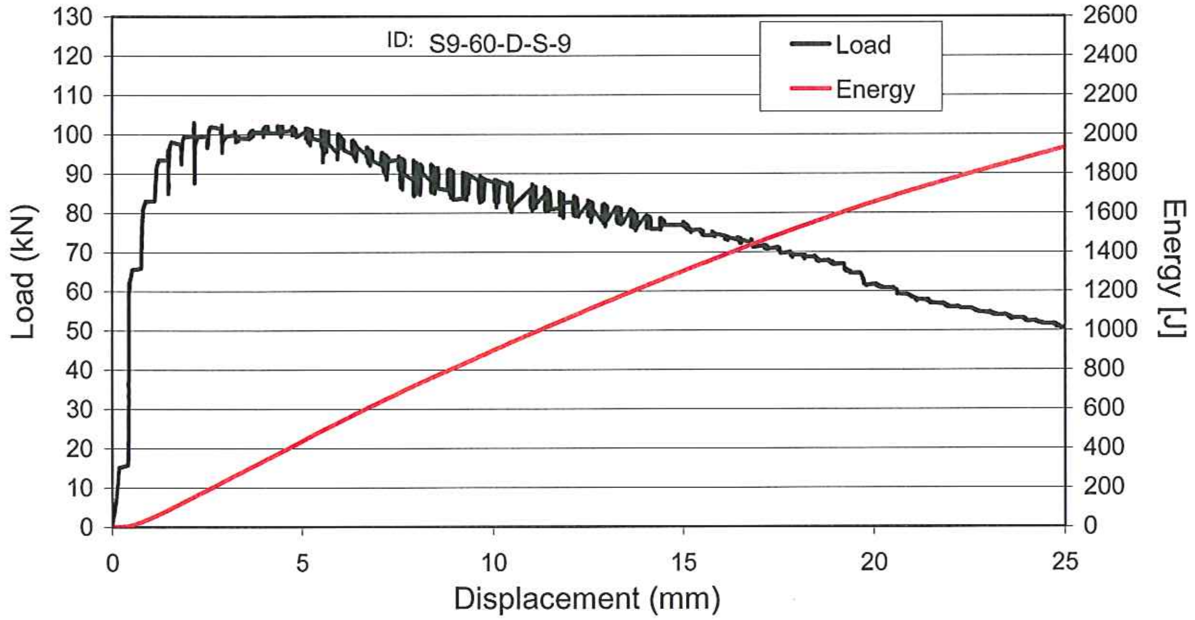
Project:	Series 9 Sprayed panels	**Panel production date:**	01.02.2010
Specimen ID:	S9-60-D-S-9		
Test date:	03.03.2010	**Fibre type:**	Dramix 65/35
Concrete test age (d):	30	**Nom. fibre dosage:**	60 kg
Comments:	Great shear failure	**Cast/sprayed:**	Sprayed

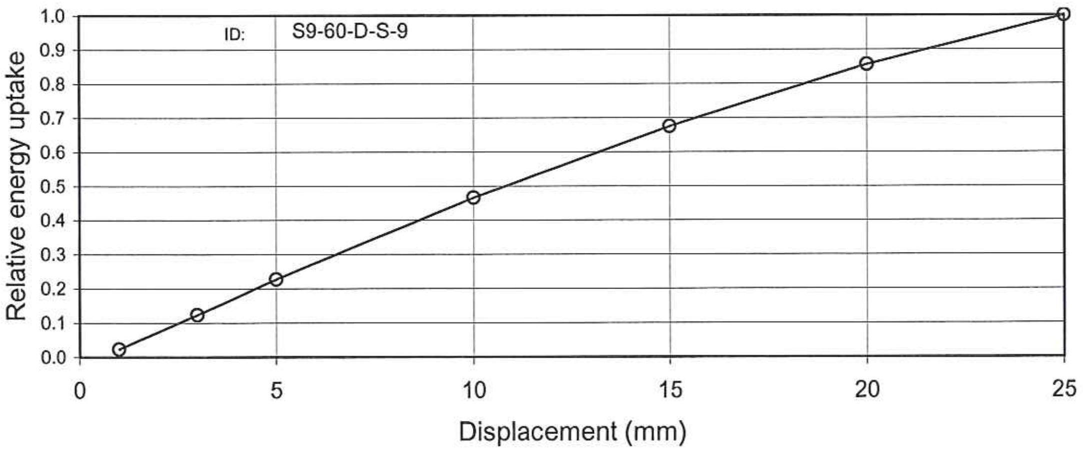
	Type yes/no			
Correct for thickness:	**yes**	Average plate thickness =	**101.6**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**599.3**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 0.984 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	45	83	0.02		
3.0	239	99	0.12		
5.0	439	100	0.23		
10.0	900	88	0.47		
15.0	1303	77	0.67		
20.0	1654	62	0.86		
25.0	1932	50.9	1.00	1984	102.7 %

Maximum load (corr) =	102.9	[kN]
Defl. at max. load =	2.2	[mm]





Project:	Series 9 Sprayed panels	**Panel production date:**	01.02.2010
Specimen ID:	S9-5-BK-S-10		
Test date:	03.03.2010	**Fibre type:**	BarChip Kyodo
Concrete test age (d):	30	**Nom. fibre dosage:**	5 kg
Comments:	Shear failure	**Cast/sprayed:**	Sprayed

	Type yes/no
Correct for thickness:	**yes**
Correct for diameter:	**no**
Correct for early non-linearity:	**no**

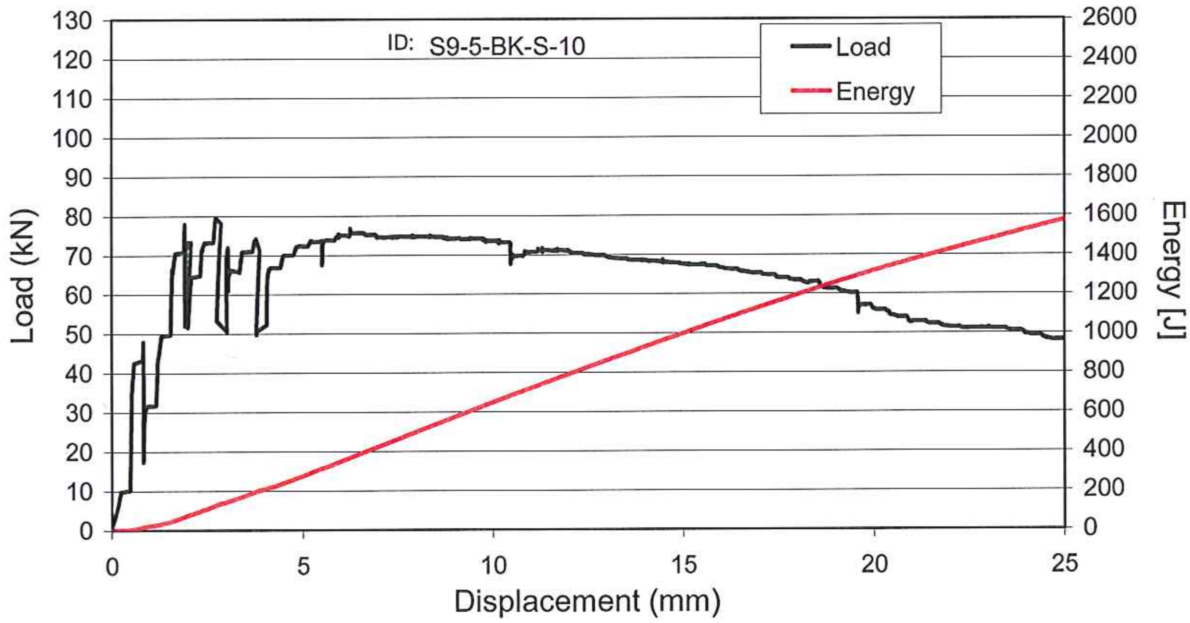
Average plate thickness = **100.6** [mm]
Nominal plate thichness = 100.0 [mm]

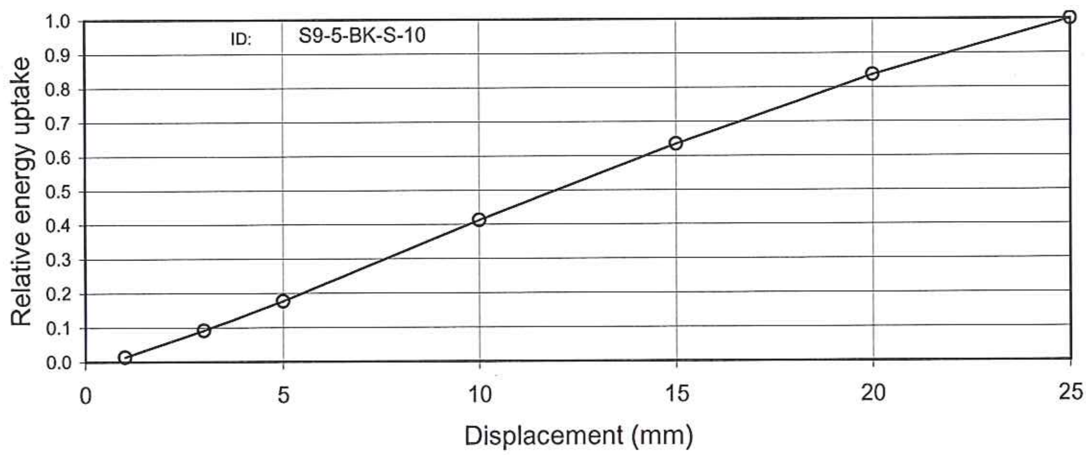
Average plate diameter = **600.0** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.994 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	23	32	0.01		
3.0	144	51	0.09		
5.0	278	72	0.18		
10.0	650	74	0.41		
15.0	1000	67	0.63		
20.0	1318	56	0.84		
25.0	1576	48.1	1.00	1593	101.1 %

Maximum load (corr) = 79.4 [kN]
Defl. at max. load = 2.7 [mm]





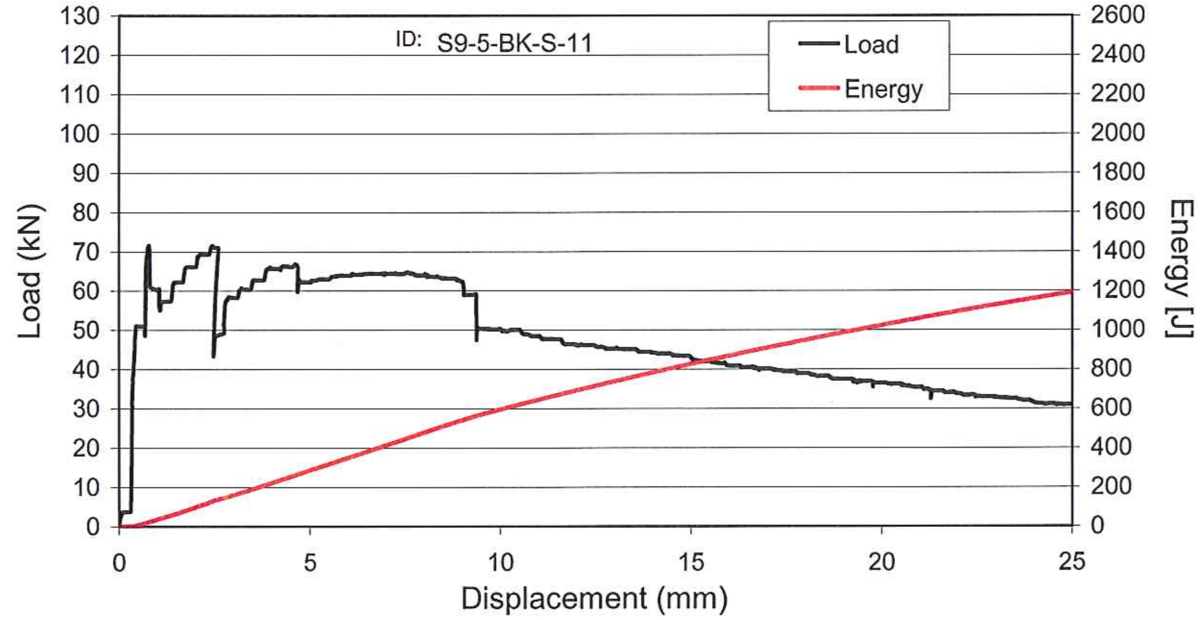
Project: Series 9 Sprayed panels		**Panel production date:** 01.02.2010	
Specimen ID: S9-5-BK-S-11			
Test date: 03.03.2010		**Fibre type:** BarChip Kyodo	
Concrete test age (d): 30		**Nom. fibre dosage:** 5 kg	
Comments: Great shear failure		**Cast/sprayed:** Sprayed	

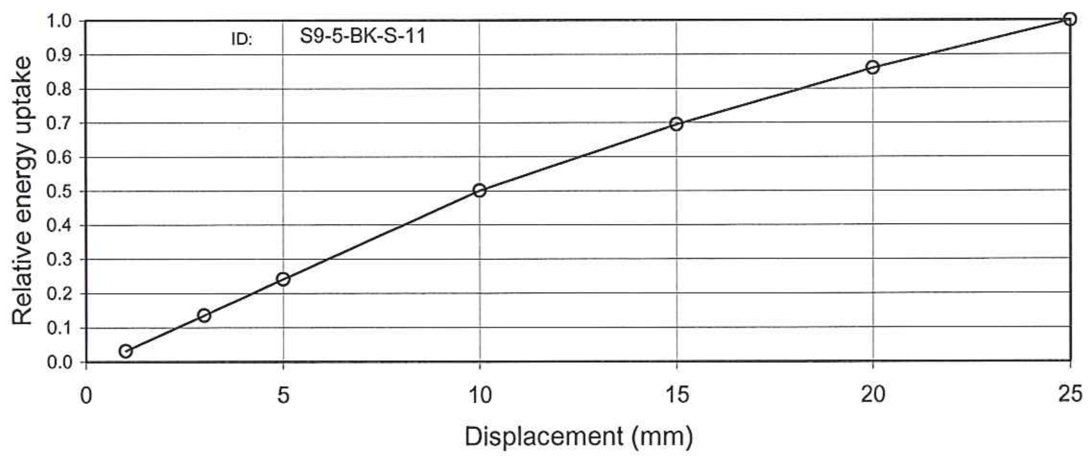
Type yes/no				
Correct for thickness:	**yes**	Average plate thickness =	**99.5**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**600.7**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 1.005 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	38	60	0.03		
3.0	162	58	0.14		
5.0	288	62	0.24		
10.0	597	50	0.50		
15.0	828	43	0.69		
20.0	1025	37	0.86		
25.0	1192	31.1	1.00	1182	99.2 %

Maximum load (corr) =	71.5	[kN]
Defl. at max. load =	0.8	[mm]





Project: Series 9 Sprayed panels
Panel production date: 01.02.2010
Specimen ID: S9-5-BK-S-12
Test date: 03.03.2010
Fibre type: BarChip Kyodo
Concrete test age (d): 30
Nom. fibre dosage: 5 kg
Comments: Shear failure
Cast/sprayed: Sprayed

Type yes/no
Correct for thickness: **yes**
Correct for diameter: **no**
Correct for early non-linearity: **no**

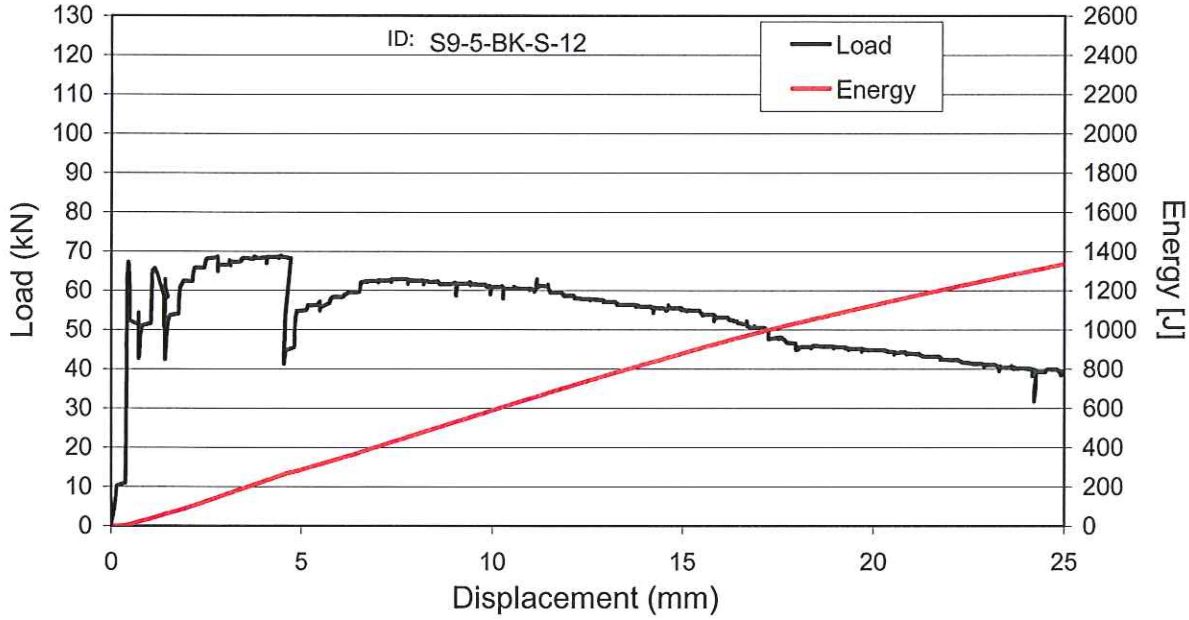
Average plate thickness = **99.2** [mm]
Nominal plate thichness = 100.0 [mm]

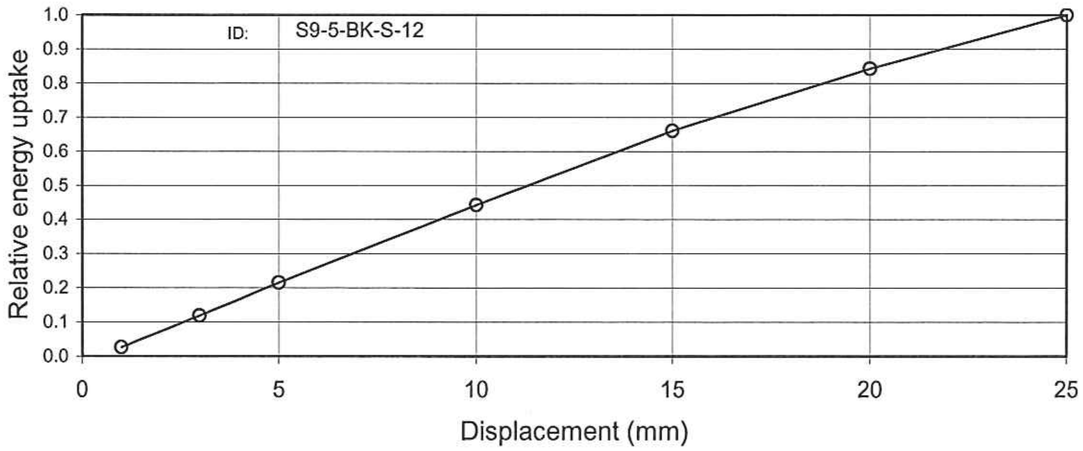
Average plate diameter = **601.7** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 1.008 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	35	52	0.03		
3.0	159	67	0.12		
5.0	288	55	0.22		
10.0	591	61	0.44		
15.0	882	55	0.66		
20.0	1127	45	0.84	Uncorr. Energy	Rel. uncorr/corr
25.0	1336	39.3	1.00	1318	98.6 %

Maximum load (corr) = 68.8 [kN]
Defl. at max. load = 4.4 [mm]





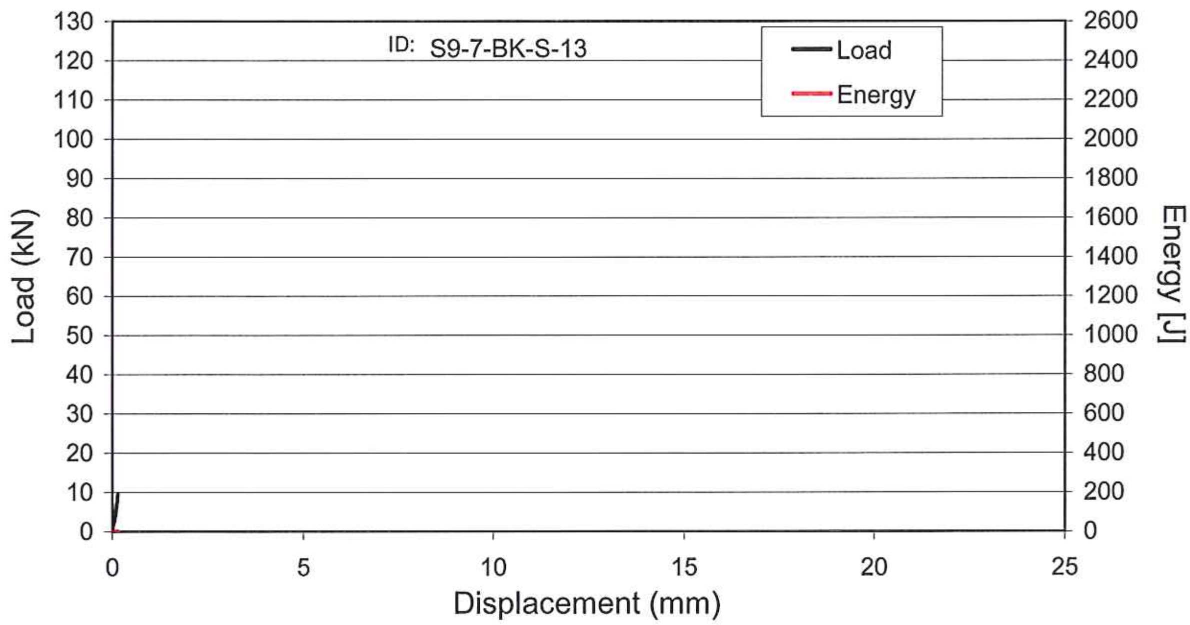
Project:	Series 9 Sprayed panels	**Panel production date:**	01.02.2010
Specimen ID:	S9-7-BK-S-13		
Test date:	03.03.2010	**Fibre type:**	BarChip Kyodo
Concrete test age (d):	30	**Nom. fibre dosage:**	7 kg
Comments:	**NO DATA!** Shear failure, casting defect	**Cast/sprayed:**	Sprayed

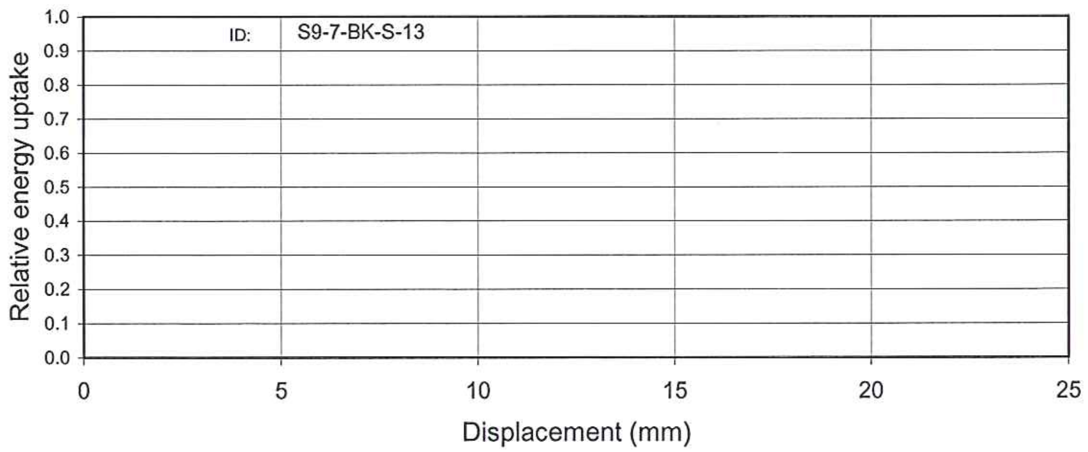
	Type yes/no			
Correct for thickness:	**yes**	Average plate thickness =	**101.4**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**600.7**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 0.986 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0					
2.0					
5.0					
10.0					
15.0					
20.0					
25.0				117	#DIV/0!

Maximum load (corr) =	9.4	[kN]
Defl. at max. load =	0.1	[mm]





Project:	Series 9 Sprayed panels	**Panel production date:**	01.02.2010
Specimen ID:	S9-7-BK-S-14		
Test date:	03.03.2010	**Fibre type:**	BarChip Kyodo
Concrete test age (d):	30	**Nom. fibre dosage:**	7 kg
Comments:	Shear failure tendency	**Cast/sprayed:**	Sprayed

	Type yes/no
Correct for thickness:	**yes**
Correct for diameter:	**no**
Correct for early non-linearity:	**no**

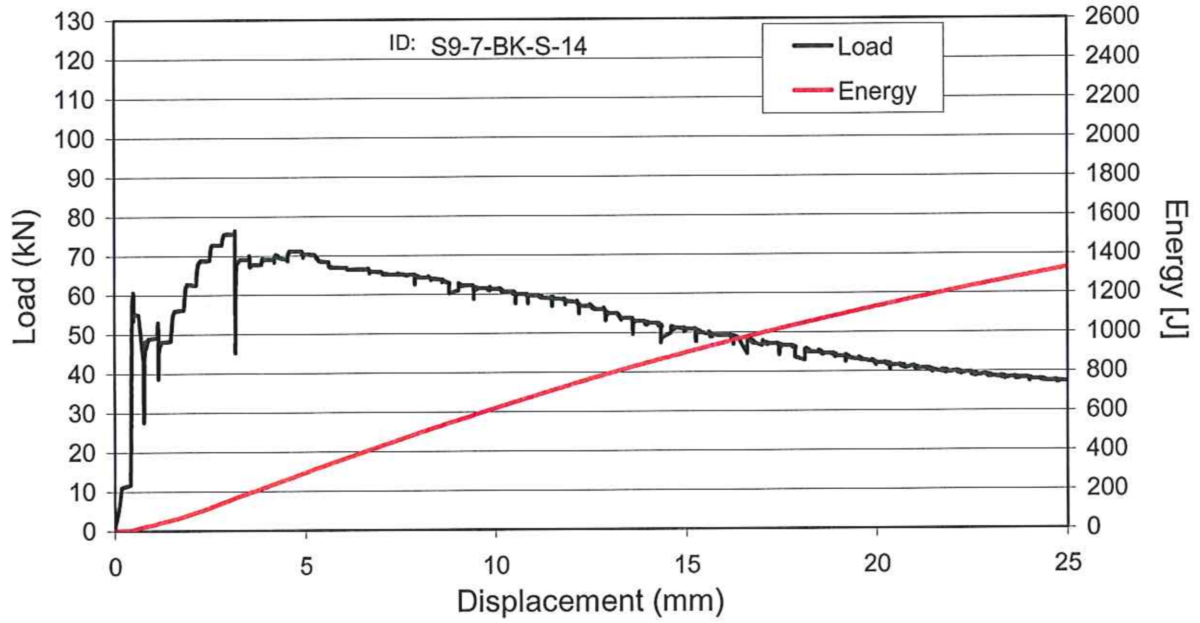
Average plate thickness = **100.4** [mm]
Nominal plate thichness = 100.0 [mm]

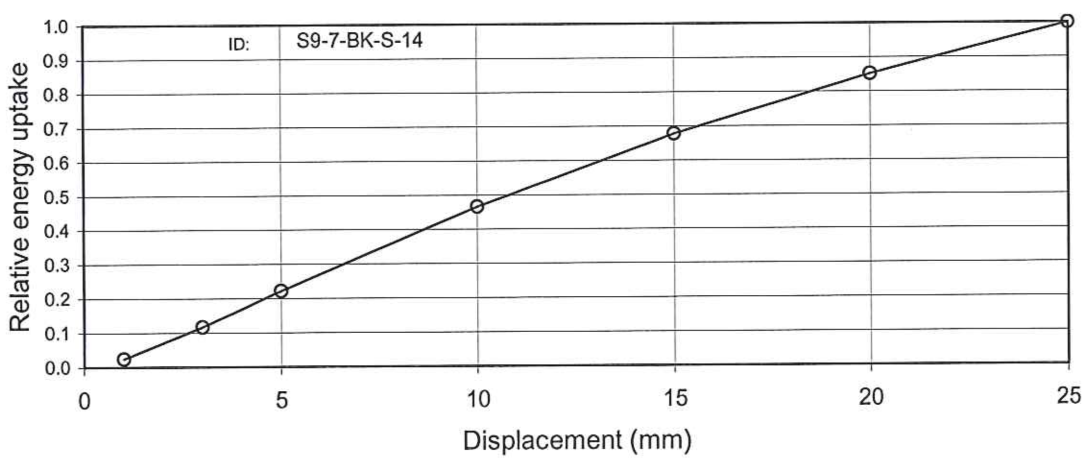
Average plate diameter = **600.7** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.996 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	32	49	0.02		
3.0	155	75	0.12		
5.0	295	70	0.22		
10.0	620	61	0.47		
15.0	900	51	0.68		
20.0	1132	42	0.85		
25.0	1329	37.3	1.00	1338	100.7 %

Maximum load (corr) = 76.3 [kN]
Defl. at max. load = 3.2 [mm]





Project:	Series 9 Sprayed panels	**Panel production date:**	01.02.2010
Specimen ID:	S9-7-BK-S-15		
Test date:	03.03.2010	**Fibre type:**	BarChip Kyodo
Concrete test age (d):	30	**Nom. fibre dosage:**	7 kg
Comments:	Shear failure tendency	**Cast/sprayed:**	Sprayed

	Type yes/no
Correct for thickness:	**yes**
Correct for diameter:	**no**
Correct for early non-linearity:	**no**

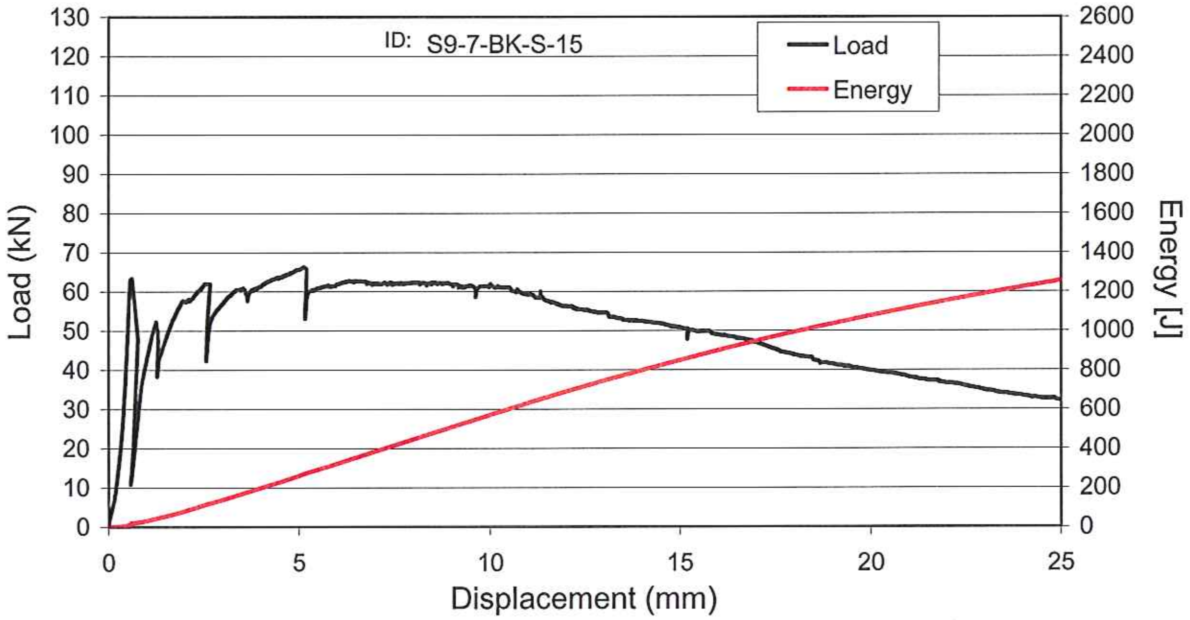
Average plate thickness = **99.9** [mm]
Nominal plate thichness = 100.0 [mm]

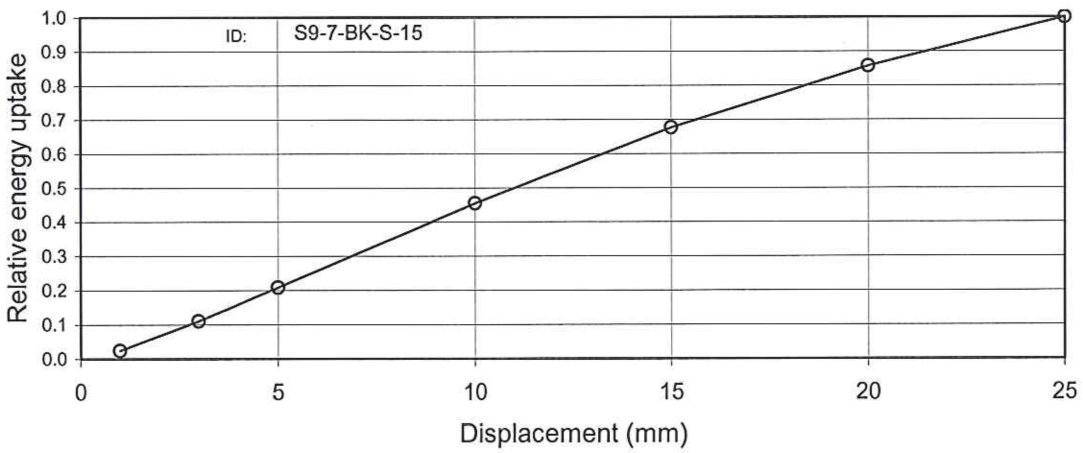
Average plate diameter = **599.7** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 1.001 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	31	42	0.02		
3.0	138	57	0.11		
5.0	262	66	0.21		
10.0	572	62	0.46		
15.0	850	51	0.68		
20.0	1077	40	0.86		
25.0	1256	32.3	1.00	1254	99.8 %

Maximum load (corr) = 66.2 [kN]
Defl. at max. load = 5.1 [mm]





Project:	Series 9 Sprayed panels	**Panel production date:**	01.02.2010
Specimen ID:	S9-8-BK-S-16		
Test date:	03.03.2010	**Fibre type:**	BarChip Kyodo
Concrete test age (d):	30	**Nom. fibre dosage:**	8 kg
Comments:	Shear failure tendency	**Cast/sprayed:**	Sprayed

Type yes/no

Correct for thickness: **yes**
Correct for diameter: **no**
Correct for early non-linearity: **no**

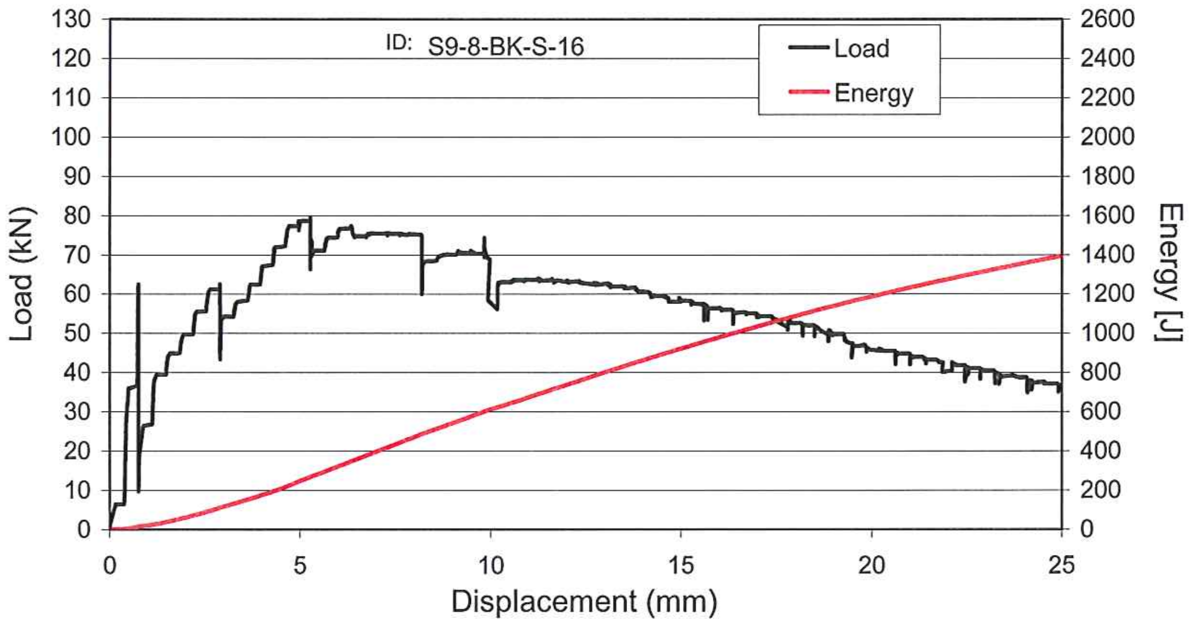
Average plate thickness = **102.3** [mm]
Nominal plate thichness = 100.0 [mm]

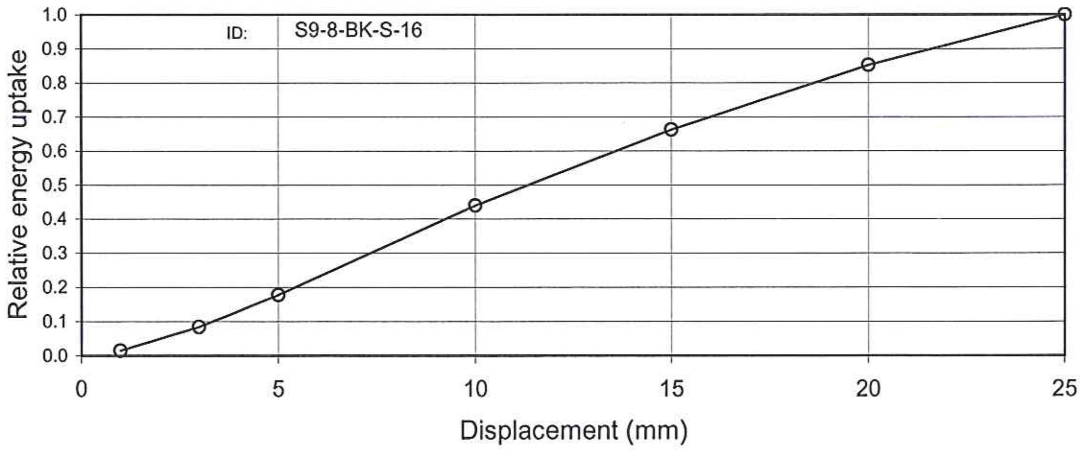
Average plate diameter = **601.7** [mm]
Nominal plate diameter = 600.0 [mm]

Corr. factor thickness, k_h = 0.978 [-]   Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]		
1.0	21	27	0.01		
3.0	117	54	0.08		
5.0	248	78	0.18		
10.0	613	58	0.44		
15.0	923	58	0.66		
20.0	1188	46	0.85	Uncorr. Energy	Rel. uncorr/corr
25.0	1394	36.6	1.00	1447	103.8 %

Maximum load (corr) = 79.5 [kN]
Defl. at max. load = 5.3 [mm]





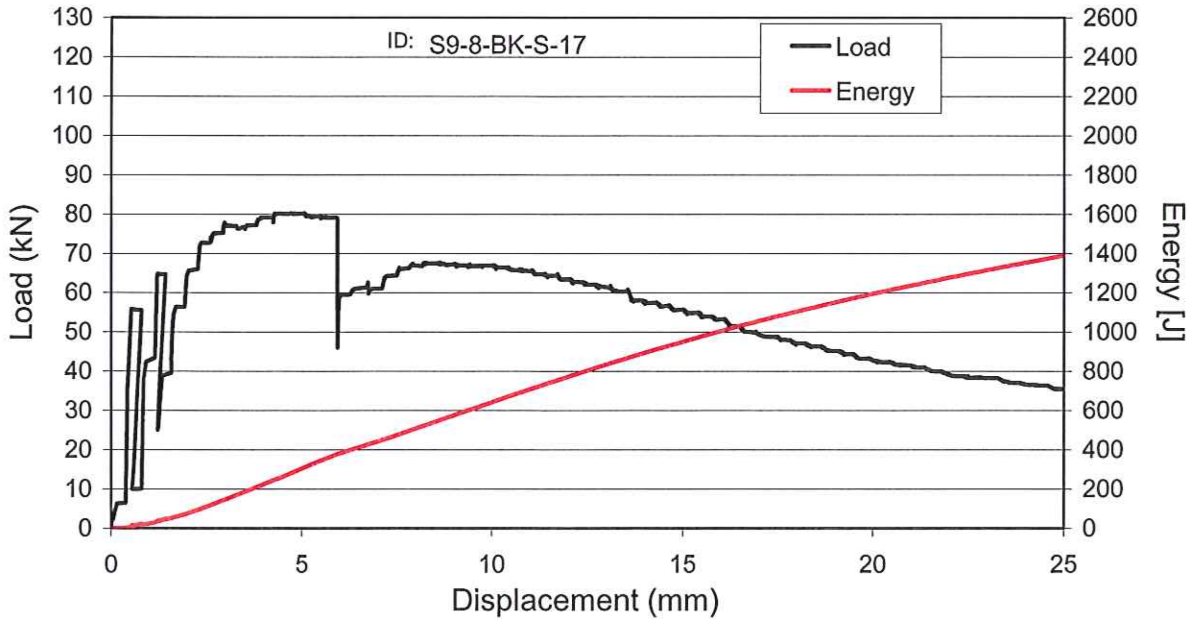
Project:	Series 9 Sprayed panels	**Panel production date:**	01.02.2010
Specimen ID:	S9-8-BK-S-17		
Test date:	03.03.2010	**Fibre type:**	BarChip Kyodo
Concrete test age (d):	30	**Nom. fibre dosage:**	8 kg
Comments:		**Cast/sprayed:**	Sprayed

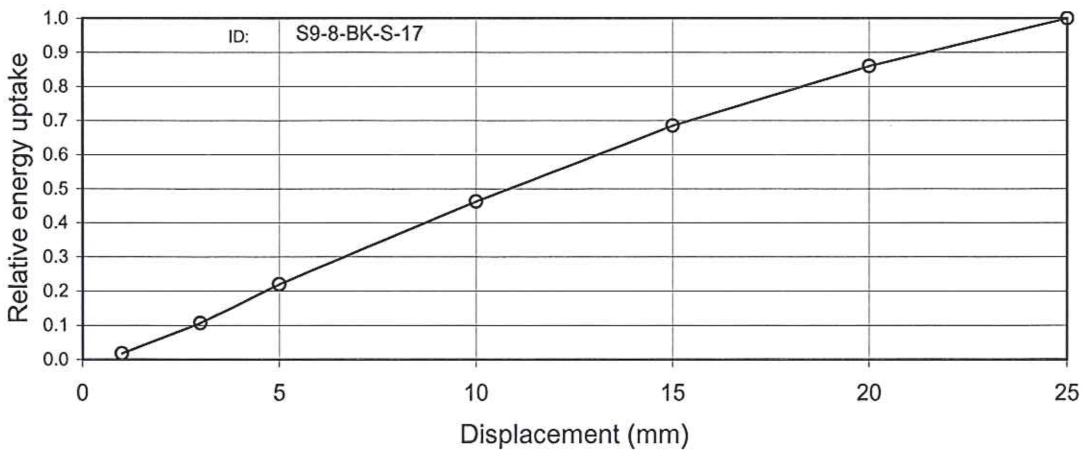
	Type yes/no			
Correct for thickness:	yes	Average plate thickness =	**100.1**	[mm]
Correct for diameter:	no	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	no	Average plate diameter =	**603.3**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 0.999 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	25	43	0.02		
3.0	148	77	0.11		
5.0	305	80	0.22		
10.0	642	67	0.46		
15.0	951	56	0.68		
20.0	1195	43	0.86		
25.0	1390	35.4	1.00	1392	100.2 %

Maximum load (corr) = 80.2 [kN]
Defl. at max. load = 4.7 [mm]





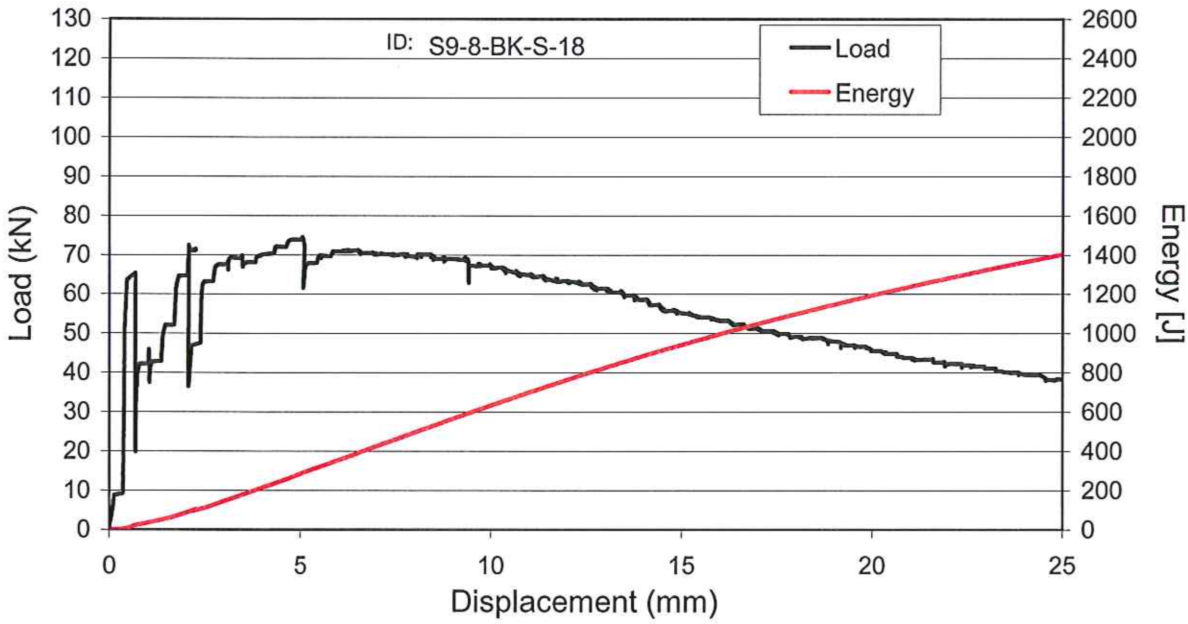
Project:	Series 9 Sprayed panels	**Panel production date:**	01.02.2010
Specimen ID:	S9-8-BK-S-18		
Test date:	03.03.2010	**Fibre type:**	BarChip Kyodo
Concrete test age (d):	30	**Nom. fibre dosage:**	8 kg
Comments:		**Cast/sprayed:**	Sprayed

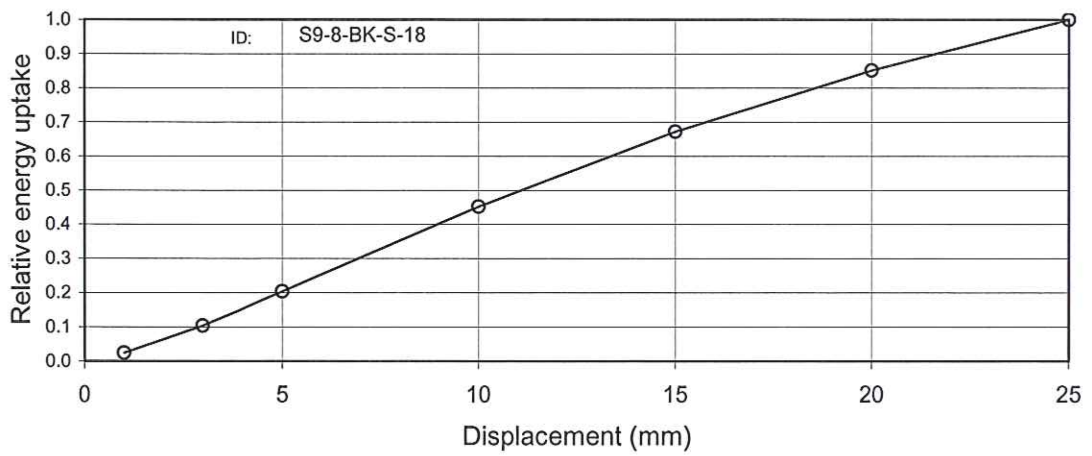
	Type yes/no			
Correct for thickness:	**yes**	Average plate thickness =	**97.6**	[mm]
Correct for diameter:	**no**	Nominal plate thichness =	100.0	[mm]
Correct for early non-linearity:	**no**	Average plate diameter =	**599.7**	[mm]
		Nominal plate diameter =	600.0	[mm]

Corr. factor thickness, k_h = 1.025 [-] Corr. factor diameter, k_D = 1.000 [-]

Displacement [mm]	(corrected) Energy uptake [J]	(corrected) Load [kN]	Relative Energy uptake [J]	Uncorr. Energy	Rel. uncorr/corr
1.0	35	42	0.02		
3.0	145	68	0.10		
5.0	286	74	0.20		
10.0	633	67	0.45		
15.0	942	55	0.67		
20.0	1194	46	0.85		
25.0	1403	38.3	1.00	1347	96.0 %

Maximum load (corr) = 74.4 [kN]
Defl. at max. load = 5.0 [mm]





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