

GUIDELINES FOR TESTING FRESH SELF-COMPACTING CONCRETE

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**MEASUREMENT OF PROPERTIES OF FRESH
SELF-COMPACTING CONCRETE**

Acronym:

TESTING-SCC

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1. Introduction

The guidelines for testing fresh self-compacting concrete contained in this document are the result of the European research project 'Measurement of properties of fresh self-compacting concrete' (acronym TESTING-SCC). This was carried out by a consortium of 12 partners from eight European countries between November 2001 and November 2004. The project has been fully documented in a final report which is supported by both summary and detailed reports from each of the project stages¹.

The objectives of the project were;

- principally, to find tests which identify the three key fresh properties of SCC - filling ability, passing ability and resistance to segregation - for mix design purposes in the lab and for compliance purposes on site;
- to recommend a range of results for the chosen tests to identify suitable SCC;
- to confirm the scientific basis of these tests by fundamental rheological measurements;
- to assess the use of these tests in real construction;
- to avoid duplication of work in different European countries and to establish agreed guidelines for draft standards for the test methods;
- to encourage the use of self-compacting concrete in general construction and to realise the potential economic and environmental benefits of this technology.

From the project:

Four tests are recommended for European standardisation as reference methods:

- **Slump flow test (total spread and T50 time):** primarily to assess filling ability, suitable for laboratory and site use
- **L-box test:** primarily to assess passing ability, suitable for laboratory use
- **J-ring test:** primarily to assess passing ability, suitable for laboratory and site use
- **Sieve stability test:** to assess segregation resistance, suitable for laboratory and site use

Three other tests are recommended for standardization as alternative methods.

- **V-funnel test:** partially indicates filling ability and blocking, suitable for laboratory and site use
- **Orimet test:** partially indicates filling ability and blocking, suitable for laboratory and site use
- **Penetration test:** to assess segregation, possibly used in combination with the sieve stability test

The document describes each of these tests, the detailed procedures for carrying them out and their precision (repeatability and reproducibility). The procedures resulted from a large and extremely rigorous amount of work, and were as used in the final stage of the project which was a systematic pan-European inter-laboratory 'round-robin' evaluation, in which 23 major companies, research institutes and universities from 12 countries participated. The precision data were obtained from this.

¹ The final report and the stage summary reports can be found at <http://www.civeng.ucl.ac.uk/research/concrete/Testing-SCC/>

2. Comments on the selected test methods

The final selection of recommended test methods was based mainly on their relation to one or more of the key properties of self-compacting concrete (filling ability, passing ability, and resistance to segregation) as well as on reproducibility and repeatability. The selection process involved consideration of the outcome of an extensive experimental programme in laboratory conditions and on site together with the general advantages and disadvantages of each method (cost, portability, simplicity of operation and other practical aspects).

The key rheological parameters ‘plastic viscosity’ and ‘yield value’ mainly determine the filling ability of self-compacting concrete; the slump flow and T50 tests demonstrate the best correlation with these, as well as having acceptable to good repeatability and reproducibility. Furthermore, the slump flow equipment is currently widely used in concrete practice, and the method is very simple and straightforward. Thus the slump flow combined with T50 was selected as the first priority test method for the filling ability of SCC. The V-funnel or Orimet tests are recommended as second priority alternatives to the T50 measurement.

The passing ability of fresh SCC can be tested by L-box or J-ring. There is some, but not very good, correlation between their results. The repeatability and reproducibility are acceptable to good for both tests. For the L-box a long practical experience was available, which led to a well-documented blocking criterion, and correlation with the behaviour in real construction elements was shown to be good. For the J-ring, no clear information is available on the blocking criterion, but it could be a potential method for combining the measurement of the different properties of filling and passing ability. After detailed evaluation, the consortium selected both L-box and J-ring as the test methods for passing ability with equal priority.

The sieve stability test was selected as the first priority test method for segregation resistance. This was preferred because of its better repeatability and reproducibility, because of its good correlation with full-scale behaviour, and principally because it is a very simple method. The penetration test was selected as the second priority. The settlement column test is more complicated, did not give better repeatability and reproducibility, and the correlation with full-scale behaviour was also no better. It was therefore not selected as a method for standardisation.

For the selected test methods the detailed test procedures and repeatability and reproducibility are given in a standardised format.

It is important to note that recommendations only go as far as proposals for the test methods for standardisation. No acceptance criteria were formulated in this project, but these have subsequently been considered by a European group of organisations representing concrete producers and users², in which several of the project consortium participated.

These guidelines also do not give any specific recommendations on which methods should be used on site and which in the laboratory. However, from practical considerations, it seems logical that the acceptance testing on-site could be based on the slump test solely (possibly combined with T50), while for initial type testing all test methods listed in first priority could be used. For particular purposes, the reference test methods could be extended or replaced by one or more of the alternative methods.

²BIBM, CEMBUREAU, ERMCO, EFCA and EFNARC, *The European Guidelines for Self-Compact Concrete - Specification, Production and Use*, available on websites: www.efca.info or www.efnarc.org, 5/2005, 68pp

3. Slump flow + T50 (Reference method for filling ability)

3.1 Principle

The slump flow test aims at investigating the filling ability of SCC. It measures two parameters: flow spread and flow time T50 (optional). The former indicates the free, unrestricted deformability and the latter indicates the rate of deformation within a defined flow distance.

3.2 Equipment

3.2.1 Base plate of size at least 900 × 900 mm, made of impermeable and rigid material (steel or plywood) with smooth and plane test surface (deviation of the flatness not exceed 3 mm), and clearly marked with circles of Ø200mm and Ø500mm at the centre, as shown in Figure 2.

NOTE The deviation of the flatness of the test surface is defined as the greatest difference in height between the highest and the lowest points on that surface, while disregarding any small single cavities in the surface.

3.2.2 Abrams cone with the internal upper/lower diameter equal to 100/200 mm and the height of 300 mm, as shown in Figure 1.

3.2.3 Weight ring (>9 kg) for keeping Abrams cone in place during sample filling. An example of its dimensions is given in Figure 2. Alternatively, a cast iron cone may be used as long as the weight of the cone exceeds 10 kg. As a second alternative the cone may be kept in position by human force.

3.2.4 Stopwatch with the accuracy of 0.1 second for recording the flow time T50.

3.2.5 Ruler (graduated in mm) for measuring the diameters of the flow spread.

3.2.6 Bucket with a capacity of larger than 6 litres for sampling fresh concrete.

3.2.7 Moist sponge or towel for wetting the inner surface of the cone and the test surface of the base plate.

3.2.8 Rag for cleaning spilled concrete if any.

3.3 Test procedure

3.3.1 Place the cleaned base plate in a stable and level position.

3.3.2 Fill the bucket with 6~7 litres of representative fresh SCC and let the sample stand still for about 1 minute (± 10 seconds).

3.3.3 During the 1 minute waiting period pre-wet the inner surface of the cone and the test surface of the base plate using the moist sponge or towel, and place the cone in the centre on the 200 mm circle of the base plate and put the weight ring on the top of the cone to keep it in place. (If a heavy cone is used, or the cone is kept in position by hand no weight ring is needed).

3.3.4 Fill the cone with the sample from the bucket without any external compacting action such as rodding or vibrating. The surplus concrete above the top of the cone should be struck off, and any concrete remaining on the base plate should be removed.

3.3.5 Check and make sure that the test surface is neither too wet nor too dry. No dry area on the base plate is allowed and any surplus of the water should be removed – the moisture state of the plate has to be ‘just wet’.

3.3.6 After a short rest (no more than 30 seconds for cleaning and checking the moist state of the test surface), lift the cone perpendicular to the base plate in a single movement, in such a manner that the concrete is allowed to flow out freely without obstruction from the cone, and start the stopwatch the moment the cone loses contact with the base plate.

3.3.7 Stop the stopwatch when the front of the concrete first touches the circle of diameter 500 mm. The stopwatch reading is recorded as the T50 value. The test is completed when the concrete flow has ceased.

NOTE Do not touch the base plate or otherwise disturb the concrete until the measurement described below is completed.

3.3.8 Measure the largest diameter of the flow spread, d_{\max} , and the one perpendicular to it, d_{perp} , using the ruler (reading to nearest 5 mm). Care should be taken to prevent the ruler from bending.

3.3.9 Clean the base plate and the cone after testing.

3.4 Expression of results

3.4.1 The slump flow spread S is the average of diameters d_{\max} and d_{perp} , as shown in Equation (1). S is expressed in mm to the nearest 5 mm.

$$S = \frac{(d_{\max} + d_{\text{perp}})}{2} \quad (1)$$

3.4.2 The slump flow time T50 is the period between the moment the cone leaves the base plate and SCC first touches the circle of diameter 500 mm. T50 is expressed in seconds to the nearest 1/10 seconds.

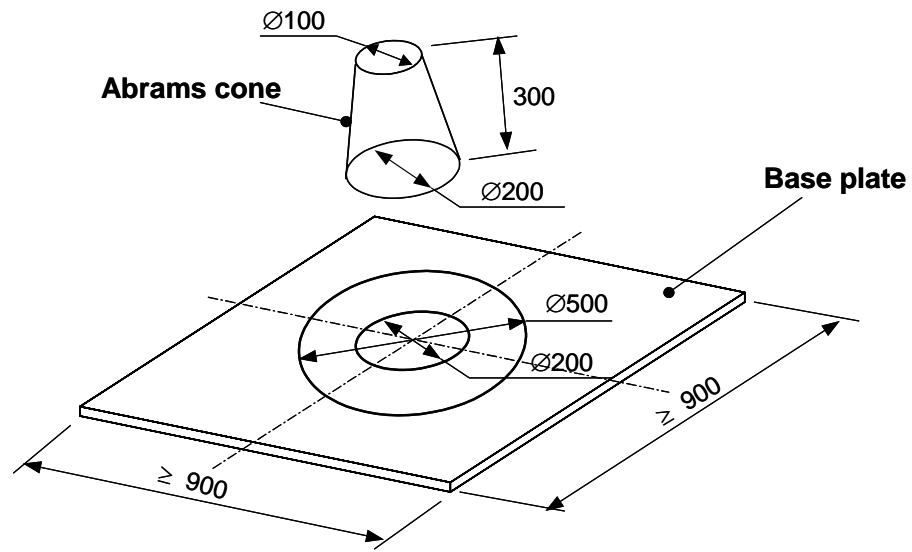
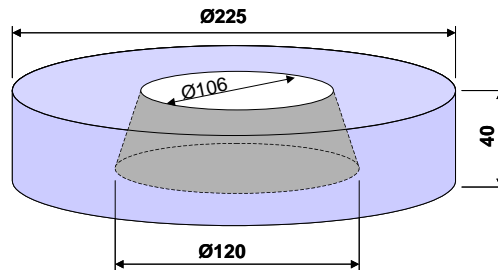


Figure 1 — Base plate and Abrams cone



Material density: 7.8~7.9 g/cm³

Figure 2 — Example of dimensions of a weight ring

3.5 Precision

3.5.1 In accordance with ISO 5725, the repeatability r is defined as the difference between two consecutive test values by the same operator with the same apparatus that should be exceeded only once in 20 times, and reproducibility R is defined as the difference between two consecutive test values by different operators with different apparatus that should be exceeded only once in 20 times.

3.5.2 Based on the inter-laboratory test organised in the EU-project “Testing-SCC” (GRD2-2000-30024/G6RD-CT-2001-00580) with 2 replicates and 16 operators from 8 laboratories, the values of repeatability and reproducibility of the slump flow spread and flow time T50 are listed in Table 1.

Table 1 — Precisions of the slump flow spread and flow time T50

| Slump flow spread S [mm] | < 600 | 600 ~ 750 | > 750 |
|--|------------------------------|------------------|-----------------|
| Repeatability r [mm] | N.A. | 42 | 22 |
| Reproducibility R [mm] | N.A. | 43 | 28 |
| Slump flow time T50 [sec] | ≤ 3.5 | 3.5 ~ 6 | > 6 |
| Repeatability r [sec] | 0.66 | 1.18 | N.A. |
| Reproducibility R [sec] | 0.88 | 1.18 | N.A. |

4. L-box (Reference method for passing ability)

4.1 Principle

The method aims at investigating the passing ability of SCC. It measures the reached height of fresh SCC after passing through the specified gaps of steel bars and flowing within a defined flow distance. With this reached height, the passing or blocking behaviour of SCC can be estimated.

4.2 Equipment

4.2.1 L- box, as shown in Figures 3 and 4. Two types of gates can be used, one with 3 smooth bars and one with 2 smooth bars. The gaps are 41 and 59 mm, respectively.

4.2.2 Suitable tool for ensuring that the box is level i.e. a spirit level.

4.2.3 Suitable buckets for taking concrete sample.

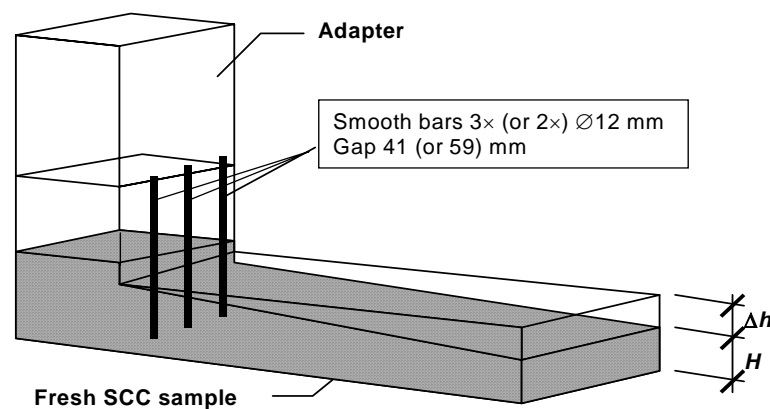


Figure 3 — Principle of the L-box test

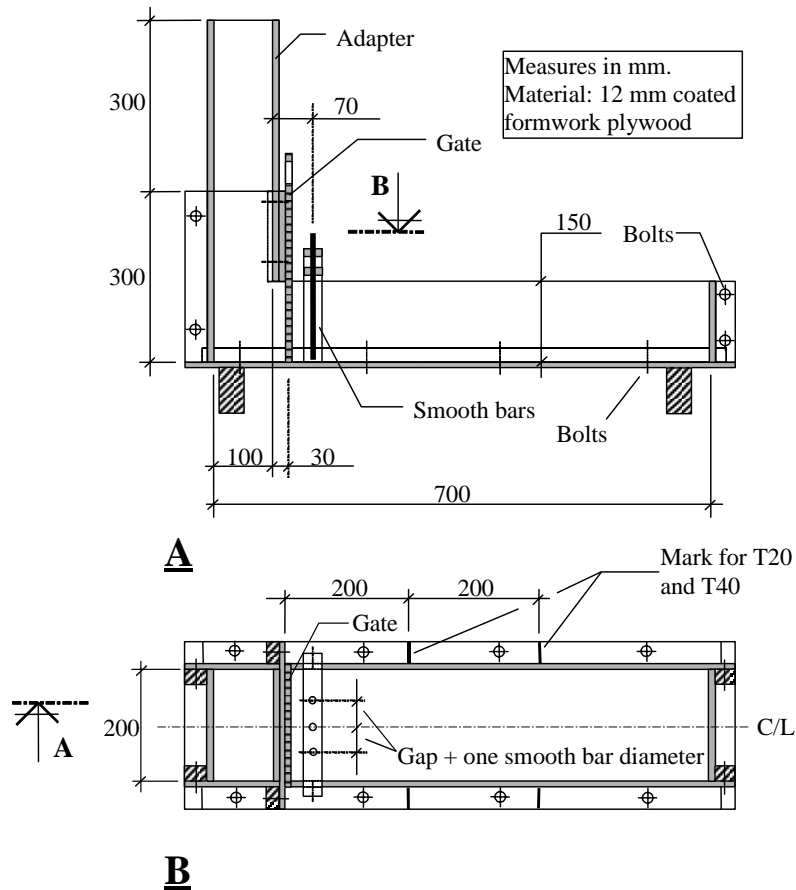


Figure 4 — Detailed dimensions of the L-box test

4.3 Test procedure

4.3.1 Place the L-box in a stable and level position.

4.3.2 Fill the vertical part of the L-box, with the extra adapter mounted, with 12.7 litres of representative fresh SCC.

4.3.3 Let the concrete rest in the vertical part for one minute (± 10 seconds). During this time the concrete will display whether it is stable or not (segregation).

4.3.4 Lift the sliding gate and let the concrete flow out of the vertical part into the horizontal part of the L-box.

4.3.5 When the concrete has stopped moving, measure the average distance, noted as Δh (see Figure 4), between the top edge of the box and the concrete that reached the end of the box, at three positions, one at the centre and two at each side.

4.4 Expression of results

The passing ratio P_L or blocking ratio B_L is calculated using equation (2) or (2'), and expressed in dimensionless to the nearest 0.01.

$$P_L = \frac{H}{H_{\max}} \quad (2)$$

or

$$B_L = 1 - \frac{H}{H_{\max}} \quad (2')$$

where $H_{\max} = 91$ mm and $H = 150 - \Delta h$

4.5 Precision

4.5.1 The definition of repeatability r and the reproducibility R is as in 3.5.1.

4.5.2 Based on the inter-laboratory test organised in the EU-project “Testing-SCC” (GRD2-2000-30024/G6RD-CT-2001-00580) with 2 replicates and 22 operators from 11 laboratories, the precision of the L-box passing or blocking ratio can be expressed by the following equations:

$$r = 0.474 - 0.463P_L, \text{ with } R^2 = 0.996, \text{ when } P_L \geq 0.65; \text{ and } r = 0.18 \text{ when } P_L < 0.65 \quad (3)$$

or

$$r = 0.463B_L - 0.011, \text{ with } R^2 = 0.996, \text{ when } B_L \leq 0.35; \text{ and } r = 0.18 \text{ when } B_L > 0.35 \quad (3')$$

and

$$R = 0.454 - 0.425P_L, \text{ with } R^2 = 0.989, \text{ when } P_L \geq 0.65; \text{ and } R = 0.18 \text{ when } P_L < 0.65 \quad (4)$$

or

$$R = 0.425B_L - 0.029, \text{ with } R^2 = 0.996, \text{ when } B_L \leq 0.35; \text{ and } R = 0.18 \text{ when } B_L > 0.35 \quad (4')$$

where R^2 is the square correlation coefficient.

Some values are listed in Table 2 for convenience of use.

Table 2 — Precisions of the L-box passing or blocking ratio

| | | | | | |
|--|----------|------------|------------|------------|------------------|
| Passing ratio P_L | 1 | 0.9 | 0.8 | 0.7 | < 0.65 |
| Blocking ratio B_L | 0 | 0.1 | 0.2 | 0.3 | > 0.35 |
| Repeatability r | 0.01 | 0.06 | 0.10 | 0.15 | 0.18 |
| Reproducibility R | 0.03 | 0.07 | 0.11 | 0.16 | 0.18 |

5. J-ring (Reference method for filling and/or passing ability)

5.1 Principle

The J-ring test aims at investigating both the filling ability and the passing ability of SCC. It can also be used to investigate the resistance of SCC to segregation by comparing test results from two different portions of sample. The J-ring test measures three parameters: flow spread, flow time T_{50j} (optional) and blocking step. The J-ring flow spread indicates the restricted deformability of SCC due to blocking effect of reinforcement bars and the flow time T_{50j} indicates the rate of deformation within a defined flow distance. The blocking step quantifies the effect of blocking.

5.2 Equipment

5.2.1 All those described in 5.2 shall be used in the J-ring test.

5.2.2 J-ring with the dimensions as shown in Figure 6, where the positions for the measurement of height differences are also given.

5.2.3 Straight rod for aligning the reference line in the measurement, with a length of about 400 mm and at least one flat side having the flexure less than 1 mm.

5.3 Test procedure

5.3.1 Place the cleaned base plate in a stable and level position.

5.3.2 Fill the bucket with 6~7 litres of representative fresh SCC and let the sample stand still for about 1 minute (± 10 seconds).

5.3.3 Under the 1 minute waiting period pre-wet the inner surface of the cone and the top surface of the base plate using the moist sponge or towel, and place the cone in the centre on the 200 mm circle of the base plate and put the weight ring on the top of the cone to keep it in place. (If a heavy cone is used, or the cone is kept in position by hand no weight ring is needed).

5.3.4 Place the J-ring on the base plate around the cone.

5.3.5 Fill the cone with the sample from the bucket without any external compacting action such as rodding or vibrating. The surplus concrete above the top of the cone should be struck off, and any concrete remaining on the base plate should be removed.

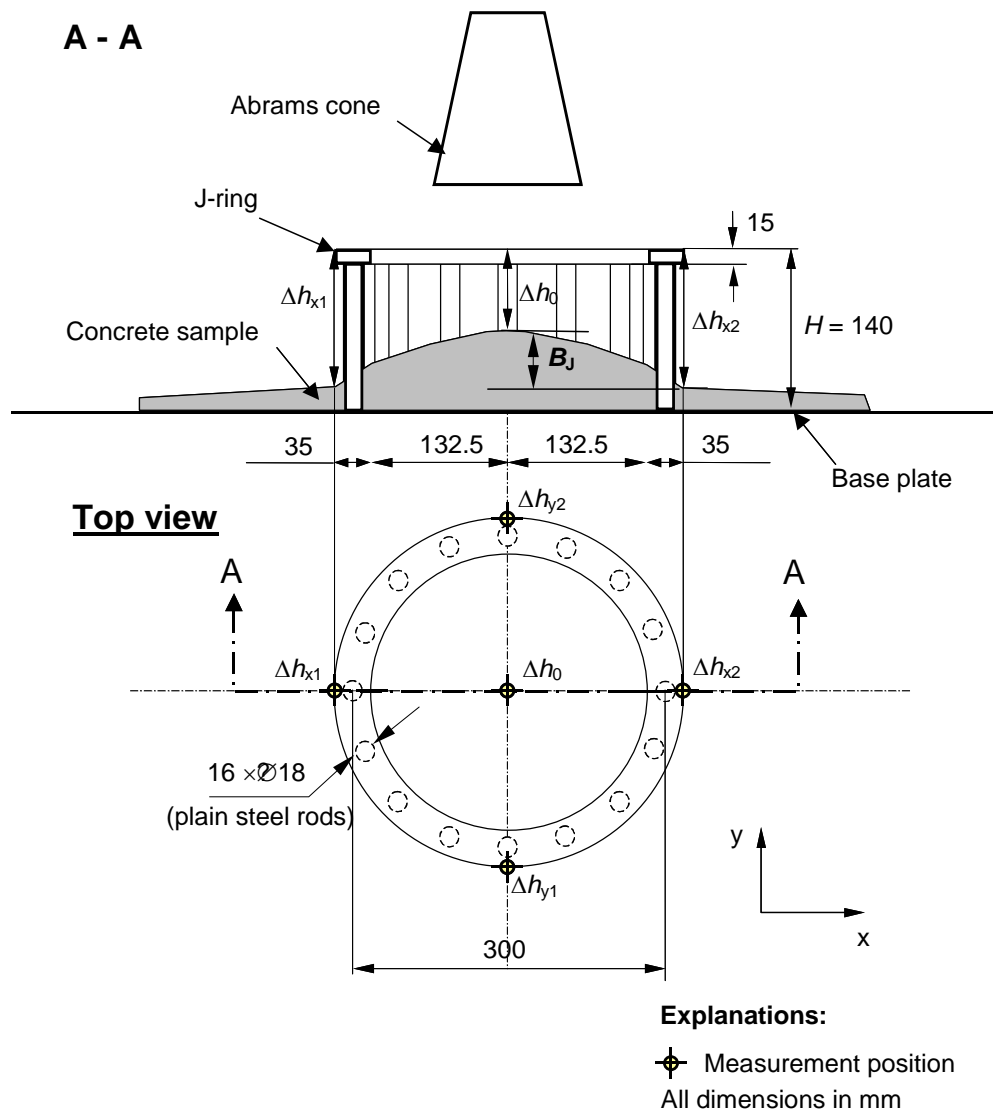


Figure 5 — Dimensions of the J-ring and positions for measurement of height differences

5.3.6 Check and make sure that the test surface is neither too wet nor too dry. No dry area on the base plate is allowed and any surplus of the water should be removed – the moisture state of the plate shall be ‘just wet’.

5.3.7 After a short rest (no more than 30 seconds for cleaning and checking the moist state of the test surface), lift the cone perpendicular to the base plate in a single movement, in such a manner that the concrete is allowed to flow out freely without obstruction from the cone, and start the stopwatch the moment the cone loses the contact with the base plate.

5.3.8 Stop the stopwatch when the front of the concrete first touches the circle of diameter 500 mm. The stopwatch reading is recorded as the T_{50J} value. The test is completed when the concrete flow has ceased.

NOTE Do not touch the base plate or otherwise disturb the concrete until the measurement described below is completed.

5.3.9 lay the straight rod with the flat side on the top side of the J-ring and measure the relative height differences between the lower edge of the straight rod and the concrete surface at the central position (Δh_0) and at the four positions outside the J-ring, two (Δh_{x1} , Δh_{x2}) in the x -direction and the other two (Δh_{y1} , Δh_{y2}) in the y -direction (perpendicular to x), as shown in Figure 6.

NOTE For non-circular concrete spreads the x -direction is that of the largest spread diameter.

5.3.10 Measure the largest diameter of the flow spread, d_{\max} , and the one perpendicular to it, d_{perp} , using the ruler (reading to nearest 5 mm). Care should be taken to prevent the ruler from bending.

5.3.11 Clean the base plate and the cone after testing.

5.4 Expression of results

5.4.1 The J-ring flow spread S_J is the average of diameters d_{\max} and d_{perp} , as shown in Equation (6). S_J is expressed in mm to the nearest 5 mm.

$$S_J = \frac{(d_{\max} + d_{\text{perp}})}{2} \quad (6)$$

5.4.2 The J-ring flow time $T50_J$ is the period between the moment the cone leaves the base plate and SCC first touches the circle of diameter 500 mm. $T50_J$ is expressed in seconds to the nearest 1/10 seconds.

5.4.3 The J-ring blocking step B_J is calculated using equation (7) and expressed in mm to the nearest 1 mm.

$$B_J = \frac{(\Delta h_{x1} + \Delta h_{x2} + \Delta h_{y1} + \Delta h_{y2})}{4} - \Delta h_0 \quad (7)$$

5.5 Precisions

5.5.1 The definition of repeatability r and the reproducibility R is as in 3.5.1.

5.5.2 Based on the inter-laboratory test organised in the EU-project “Testing-SCC” (GRD2-2000-30024/G6RD-CT-2001-00580) with 2 replicates and 16 operators from 8 laboratories, the values of repeatability and reproducibility of the J-ring flow spread and flow time $T50_J$ are listed in Table 6.

Table 3 — Precisions of the J-ring flow spread and flow time T_{50_J}

| J-ring flow spread S_J [mm] | < 600 | 600 ~ 750 | > 750 |
|---|------------------------------|------------------|-----------------|
| Repeatability r [mm] | 59 | 46 | 25 |
| Reproducibility R [mm] | 67 | 46 | 31 |
| J-ring flow time T_{50_J} [sec] | ≤ 3.5 | 3.5 ~ 6 | > 6 |
| Repeatability r [sec] | 0.70 | 1.23 | 4.34 |
| Reproducibility R [sec] | 0.90 | 1.32 | 4.34 |
| J-ring blocking step B_J [mm] | ≤ 20 | | > 20 |
| Repeatability r [mm] | 4.6 | | 7.8 |
| Reproducibility R [mm] | 4.9 | | 7.8 |

6. Sieve stability test (Reference method for resistance to segregation)

6.1 Principle

The test aims at investigating the resistance of SCC to segregation by measuring the portion of the fresh SCC sample passing through a 5 mm sieve. If the SCC has poor resistance to segregation, the paste or mortar can easily pass the sieve. Therefore the sieved portion indicates whether the SCC is stable or not.

6.2 Equipment

6.2.1 Perforated plate sieve with square holes of 5 mm, frame diameter 300 mm or 315 mm and height 40 mm or 75 mm (ISO 3310-2).

6.2.2 Pan with the shape and volume suitable to retain the materials passing through the sieve and easy for the operator to remove the sieve without forcing extra materials passing through.

6.2.3 Balance of a digital type with accuracy within ± 20 g and capacity about 10 kg, and can be zeroed.

6.2.4 Bucket, made of rigid plastic or metal with the maximal inner diameter of (300 ± 10) mm and capacity of 10~12 litres.

6.2.5 Lid suitable for covering the bucket so as to protect the fresh concrete from extensive evaporation.

6.3 Test procedure

6.3.1 Place the balance in a stable and level position and control its functions according to manufacturer's instructions.

6.3.2 Fill the bucket with (10 ± 0.5) litres of representative fresh SCC and cover the bucket with the lid.

6.3.3 Place the bucket in a stable and level position and let the sample stand still for (15 ± 0.5) minutes.

6.3.4 Under the waiting period weigh the pan alone, noted as W_p , and place the sieve on the pan without removing it from the balance.

6.3.5 15 min after filling of the bucket, inspect the surface of the bucket for clear bleed water and record it if there is any.

6.3.6 Zero the balance and pour (4.8 ± 0.2) kg sample onto the central part of the sieve from a height of (50 ± 5) cm.

6.3.7 Record the weight of the sample poured onto the sieve, noted as W_c .

6.3.8 Two minutes after pouring the sample gently remove the sieve from the pan without any shaking action that may force extra materials passing through the sieve.

6.3.9 Weigh the pan with the sieved materials, noted as W_{ps} .

6.3.10 Clean the sieve and the pan after testing.

6.4 Expression of results

The sieved portion π (the mass percentage of the sample passing through the sieve) is calculated using equation (5) and expressed in % to the nearest 1%.

$$\pi = \frac{W_{ps} - W_p}{W_c} \times 100 \quad (5)$$

6.5 Precisions

6.5.1 The definition of repeatability r and the reproducibility R is as in 3.5.1.

6.5.2 Based on the inter-laboratory test organised in the EU-project “Testing-SCC” (GRD2-2000-30024/G6RD-CT-2001-00580) with 2 replicates and 22 operators from 11 laboratories, the values of repeatability and reproducibility of the sieved portion are listed in Table 4.

Table 4 — Precisions of the sieved portion

| Sieved portion π [%] | ≤ 20 | > 20 |
|--|-----------------------------|-----------------------------|
| Repeatability r [%] | 3.7 | 10.9 |
| Reproducibility R [%] | 3.7 | 10.9 |

7. V-funnel (Alternative method to T50 for filling ability)

7.1 Principle

The V-funnel flow time is the period a defined volume of SCC needs to pass a narrow opening and gives an indication of the filling ability of SCC provided that blocking and/or segregation do not take place; the flow time of the V-funnel test is to some degree related to the plastic viscosity.

7.2 Equipment

7.2.1 V-funnel, as shown in Figure 7, made of steel, with a flat, horizontal top and placed on vertical supports, and with a momentary releasable, watertight opening gate.

7.2.2 Stopwatch with the accuracy of 0.1 second for recording the flow time.

7.2.3 Straightedge for levelling the concrete.

7.2.4 Buckets with a capacity of 12~14 litres for taking concrete sample.

7.2.5 Moist sponge or towel for wetting the inner surface of the V-funnel.

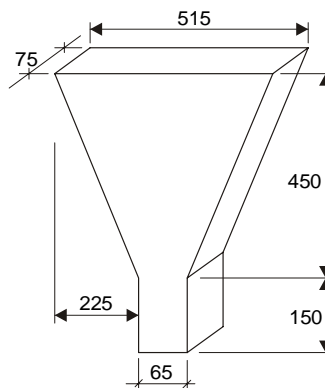


Figure 6 — Dimensions of the V-funnel

7.3 Test procedure

7.3.1 Place the cleaned V-funnel vertically on a stable and flat ground, with the top opening horizontally positioned.

7.3.2 Wet the interior of the funnel with the moist sponge or towel and remove the surplus of water, e.g. through the opening. The inner side of the funnel should be 'just wet'.

7.3.3 Close the gate and place a bucket under it in order to retain the concrete to be passed.

7.3.4 Fill the funnel completely with a representative sample of SCC without applying any compaction or rodding.

7.3.5 Remove any surplus of concrete from the top of the funnel using the straightedge.

7.3.6 Open the gate after a waiting period of (10 ± 2) seconds. Start the stopwatch at the same moment the gate opens.

7.3.7 Look inside the funnel and stop the time at the moment when clear space is visible through the opening of the funnel. The stopwatch reading is recorded as the V-funnel flow time, noted as t_V .

NOTE Do not touch or move the V-funnel until it is empty.

7.3.8 Clean the V-funnel after testing.

7.4 Expression of results

The V-funnel flow time t_V is the period from releasing the gate until first light enters the opening, expressed to the nearest 0.1 second.

7.5 Precision

7.5.1 The definition of repeatability r and the reproducibility R is as in 3.5.1.

7.5.2 Based on the inter-laboratory test organised in the EU-project “Testing-SCC” (GRD2-2000-30024/G6RD-CT-2001-00580) with 2 replicates and 20 operators from 10 laboratories, the precision of the V-funnel flow time can be expressed by the following equations:

$$r = 0.335 t_V - 0.62, \text{ with } R^2 = 0.823, \text{ when } 3 \leq t_V \leq 15; \text{ and } r = 4.4 \text{ when } t_V > 15 \quad (8)$$

and

$$R = 0.502 t_V - 0.943, \text{ with } R^2 = 0.984, \text{ when } 3 \leq t_V \leq 15; \text{ and } R = 6.6 \text{ when } t_V > 15 \quad (9)$$

where R^2 is the square correlation coefficient.

Some values are listed in Table 5 for convenience of use.

Table 5 — Precisions of the V-funnel flow time

| V-funnel flow time t_V [sec] | 3 | 5 | 8 | 12 | ≥ 15 |
|--------------------------------|-----|-----|-----|-----|-----------|
| Repeatability r [sec] | 0.4 | 1.1 | 2.1 | 3.4 | 4.4 |
| Reproducibility R [sec] | 0.6 | 1.6 | 3.1 | 5.1 | 6.6 |

8. Orimet (Alternative method to T50 for filling ability)

8.1 Principle

The Orimet flow time is the period a defined volume of SCC needs to pass a narrow opening (a tube narrowed by an orifice). The flow time of the Orimet test is to some degree related to the plastic viscosity.

8.2 Equipment

8.2.1 Orimet, made of steel, with the tube of a length of 600 mm and an inner diameter of 120 mm. The orifice, which narrows the opening of the tube and shears SCC, is interchangeable; its diameter can be chosen according to the mixture composition and the criteria on SCC. Figure 8 shows the filling of the Orimet with a bucket.

8.2.2 Stopwatch with the accuracy of 0.1 second for recording the flow time.

8.2.3 Straightedge for levelling the concrete.

8.2.4 Buckets with a capacity of 10~12 litres for taking concrete sample.

8.2.5 Moist sponge or towel for wetting the inner surface of the Orimet.



Figure 7 — Filling of the Orimet test

8.3 Test procedure

8.3.1 Place the cleaned Orimet vertically on a stable and flat ground, with the top opening horizontally positioned and check whether the tripod is completely extended.

8.3.2 Wet the interior of the Orimet with the moist sponge or towel and remove the surplus of water, e.g. through the opening. The inner side of the Orimet should be ‘just wet’.

- 8.3.3** Close the gate and place a bucket under it in order to retain the concrete to be passed.
- 8.3.4** Fill the Orimet completely with a representative sample of SCC without applying any compaction or rodding.
- 8.3.5** Remove any surplus of concrete from the top of the Orimet using the straightedge.
- 8.3.6** Open the gate after a waiting period of (10 ± 2) seconds. Start the stopwatch at the same moment the gate opens.
- 8.3.7** Look inside the Orimet and stop the time at the moment when clear space is visible through the opening of the Orimet. The stopwatch reading is recorded as the Orimet flow time, noted as t_O .

NOTE Do not touch or move the Orimet until it is empty.

- 8.3.8** Clean the Orimet after testing.

8.4 Expression of results

The Orimet flow time t_O is the period from releasing the gate until first light enters the opening, expressed to the nearest 0.1 second.

8.5 Precisions

- 8.5.1** The definition of repeatability r and the reproducibility R is as in 3.5.1.

8.5.2 Based on the inter-laboratory test organised in the EU-project “Testing-SCC” (GRD2-2000-30024/G6RD-CT-2001-00580) with 2 replicates and 20 operators from 10 laboratories, the precision of the Orimet flow time (with the orifice 70 mm) can be expressed by the following equations:

$$r = 0.433 t_O - 0.594, \text{ with } R^2 = 0.996, \text{ when } 3 \leq t_O \leq 15; \text{ and } r = 6.6 \text{ when } t_O > 15 \quad (10)$$

and

$$R = 0.472 t_O - 0.28, \text{ with } R^2 = 0.947, \text{ when } 3 \leq t_O \leq 15; \text{ and } R = 6.8 \text{ when } t_O > 15 \quad (11)$$

where R^2 is the square correlation coefficient.

Some values are listed in Table 6 for convenience of use.

Table 6 — Precisions of the Orimet flow time (with the orifice 70 mm)

| Orimet flow time t_O [sec] | 3 | 5 | 8 | 12 | > 15 |
|------------------------------|-----|-----|-----|-----|------|
| Repeatability r [sec] | 0.7 | 1.6 | 2.9 | 4.6 | 6.6 |
| Reproducibility R [sec] | 1.1 | 2.1 | 3.5 | 5.4 | 6.8 |

9. Penetration test (Alternative method for resistance to segregation)

9.1 Principle

The test aims at investigating the resistance of SCC to segregation by penetrating a cylinder with a given weight into the fresh SCC sample. If the SCC has poor resistance to segregation, the cylinder will penetrate deeper due to the less amount of aggregate in the upper layer of the sample. Therefore the penetration depth indicates whether the SCC is stable or not.

9.2 Equipment

9.2.1 Penetration apparatus, as illustrated in Figure 9, consisting of a frame, slot and screw, reading scale and penetration head. The penetration head is assembled with an aluminium cylinder and rod. The rod should be able to move inside slot, as freely as possible. The inner diameter, height and thickness of the cylinder are 75 mm, 50 mm and 1 mm, respectively. The total weight of the penetration head is 54 g.

9.2.2 Bucket with a capacity of 10~12 litres.



Figure 9 — Illustration of the penetration test

9.3 Test procedure

9.3.1 Place the bucket in a stable and level position.

9.3.2 Fill the bucket with (10 ± 0.5) litres of representative fresh SCC and let the sample stand still for $2 \text{ minutes} \pm 10 \text{ seconds}$.

NOTE Care must be taken to avoid segregation caused by external impacts.

9.3.3 2 minutes after filling of the bucket, locate the penetration apparatus on the top of the bucket, adjust the penetration cylinder until it just touches the upper surface of the concrete, and then let the cylinder penetrate freely into concrete.

9.3.4 After the stabilisation of the cylinder (generally < 15~20 sec), the penetration depth of the cylinder head is recorded from the scale. Measure the penetration depths at the centre (noted as P_1) and two sides (noted as P_2 and P_3) of the width of the bucket.

NOTE The duration of the three measurements should be less than 3 minutes

9.3.5 Cleaning the apparatus after testing.

9.4 Expression of results

The penetration depth P is the average value of the three measurements, rounded to 1 mm.

9.5 Precisions

9.5.1 The definition of repeatability r and the reproducibility R is as in 3.5.1.

9.5.2 Based on the inter-laboratory test organised in the EU-project “Testing-SCC” (GRD2-2000-30024/G6RD-CT-2001-00580) with 2 replicates and 22 operators from 11 laboratories, the precision of the penetration depth can be expressed by the following equation:

$$r = R = 0.59 P + 1.7, \text{ with } R^2 = 1, \text{ when } P \leq 17; \text{ and } r = R = 12 \text{ when } t_0 > 17 \quad (12)$$

where R^2 is the square correlation coefficient.

Some values are listed in Table 7 for convenience of use.

Table 7 — Precisions of the penetration depth

| Penetration depth P [mm] | 5 | 10 | 15 | > 17 |
|-------------------------------|---|----|----|------|
| Repeatability r [mm] | 5 | 8 | 11 | 12 |
| Reproducibility R [mm] | 5 | 8 | 11 | 12 |

10. Conclusions

Based on the scientific evaluation of results from laboratory and site testing within the European research project 'TESTING-SCC', the slump flow + T50, L-box, and sieve stability tests have been selected as first priority test methods for fresh self-compacting concrete. These tests are therefore proposed for European standardisation as reference methods. Four other tests have been selected as second priority : J-ring, Orimet, V-funnel and Penetration tests. These test are therefore proposed for standardisation as alternative methods. This is summarised as Table 8

Table 8 Recommended test methods

| FIRST PRIORITY | SECOND PRIORITY |
|--|--|
| These tests are proposed for European standardisation as reference methods | These tests are proposed for European standardisation as alternative methods |
| Slump flow + T50 L-box Sieve stability test | J-ring Orimet V-funnel Penetration test |

For each of above test methods, detailed test procedures have been given in sections 3-9 of this document, together with information regarding repeatability and reproducibility in a standardised format.