

STRUX® 90/40 ASTM C1399 vs. ASTM C1609 Technical Bulletin

How are fibers tested and evaluated in concrete?

There are two ASTM flexural test procedures used to evaluate the performance of “macro” synthetic fibers, ASTM C1399 and ASTM C1609. Both are commonly used but there are some major differences between them and where they should be specified. ASTM C1399 is the more commonly used and specified, but this test has certain limitations as compared to ASTM C1609.

What is ASTM C1399?

This test method covers the determination of the average residual strength (ARS) of a fiber-reinforced concrete test beam supported by a steel plate underneath the entire length. The flexural beam is initially cracked from an applied load up to a deflection of 0.008 in. (0.2 mm). The steel plate is then removed and the post-crack deflections and loads are measured and recorded during the test up to a final deflection of 0.05 in. (1.25 mm). The ARS is computed using loads at specified beam deflections that are obtained during the test. This test provides the data needed to obtain the portion of the load-deflection curve beyond which a significant amount of cracking damage has occurred. It also provides an average measure of post-cracking or residual strength obtained by the use of fiber-reinforcement.

What applications should ASTM C1399 be specified for and why?

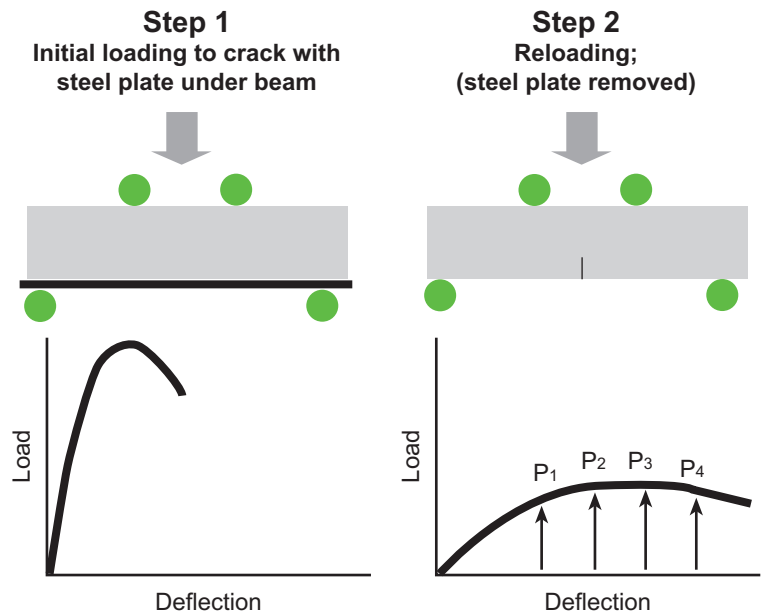
Since ASTM C1399 only allows the use of 4 in. x 4 in. x 14 in. (100 mm x 100 mm x 350 mm) beams, Grace recommends it to be used for concrete applications of 4 inches thickness or less if the fiber length is less than

or equal to 1.5 in. (40 mm). Therefore applications such as precast, thin overlays, whitetoppings, and slab-on-ground with thicknesses 4 inches or less be specified by ASTM C1399.

Why?

- 1) Testing in our labs, pre-cast production, and thin overlays have shown there is a tendency for fibers to have preferential alignment providing good results. However this cannot be related to concrete members with a thickness greater than 4 inches.
- 2) ASTM C1399 recommends that for tests of fiber-reinforced concrete containing relatively rigid or stiff fibers of length greater than 1.5 in. (40 mm), the use of sawed beams cut from samples with an initial width and depth of at least 3 times the length of the fiber is recommended to minimize effects of fiber orientation.

This requires special cutting equipment with a diamond saw and creates another procedural step for the concrete lab and is rarely performed.



3) With ASTM C1399 the flexural strength of the fiber-reinforced concrete cannot be obtained. In order to determine the flexural strength an additional test such as ASTM C78 needs to be performed.

4) The fracture behavior of fiber reinforced concrete at small crack openings cannot be determined using ASTM C1399 since the ARS value is only an average load value taken at deflections equal and greater than 0.02 in. (0.5 mm) of deflection.

What is ASTM C1609?

This test method evaluates the flexural performance of fiber-reinforced concrete using parameters derived from the load-deflection curve. This is obtained by testing a simply supported beam under third-point loading using a closed-loop, servo-controlled testing system. *Without this closed-loop control system, stable crack propagation after peak is very unlikely to be achieved.* (Unlike ASTM C1399, a steel plate is NOT used for achieving controlled cracking of concrete.)

This test method provides for the determination of first-peak and peak loads and the corresponding stresses calculated by inserting them in the formula for modulus of rupture. It also requires determination of residual loads at specified deflections, and the corresponding residual flexural strength (see Note 1). At the option of the specifier, it provides for determination of specimen toughness based on the area under the load-deflection curve up to a prescribed deflection (see Note 2).

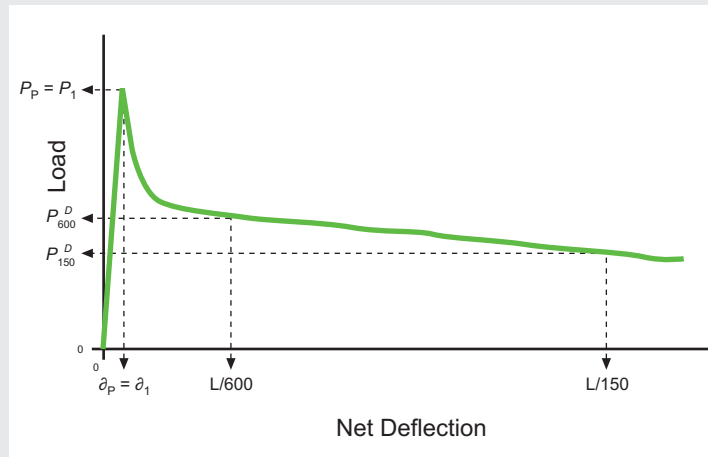
What applications should ASTM C1609 be specified for and why?

ASTM C1609 is a more controllable test and allows the use of small beams 4 in. x 4 in. x 14 in. (100 mm x 100 mm x 350 mm) and larger beams 6 in. x 6 in. x 20 in. (150 mm x 150 mm x 500 mm). Therefore for applications such as pre-cast and slab-on-ground greater than 4 inches (100 mm) thick, the larger beam is much more representative of “in-place” or “field” concrete.

Why?

1) The larger beam allows the use of macro fibers up to 2.5 in. (65 mm) in length. This will accommodate for the majority of macro fibers on the market that have lengths between 1.5 to 2.5 in. (38 to 65 mm).

Flexural Performance Evaluation—ASTM C1609-05



L = Span Length
 $P_p = P_1$ = Peak Load = First-Peak Load
 $\delta_p = \delta_1$ = Net Deflection at Peak and First-Peak Loads
 $f_p = f_1$ = Peak Strength and First-Peak Strength
 P_{600}^D = Residual Load at net deflection of $L/600$
 f_{600}^D = Residual Strength at net deflection of $L/600$
 P_{150}^D = Residual Load at net deflection of $L/150$
 f_{150}^D = Residual Strength at net deflection of $L/150$
 T_{150}^D = Area under the load vs. net deflection curve 0 to $L/150$

NOTE 1—Residual flexural strength is not a true stress but an engineering stress computed using simple engineering bending theory for linear elastic materials and gross (un-cracked) section properties.

NOTE 2—Specimen toughness expressed in terms of the area under the load-deflection curve is an indication of the energy absorption capability, which is direct proportional to the f_{e3} value.

2) The potential preferential alignment of fibers is now reduced and a more random distribution of fibers both horizontally, vertically and diagonally will occur similar to “real life” concrete with fibers.

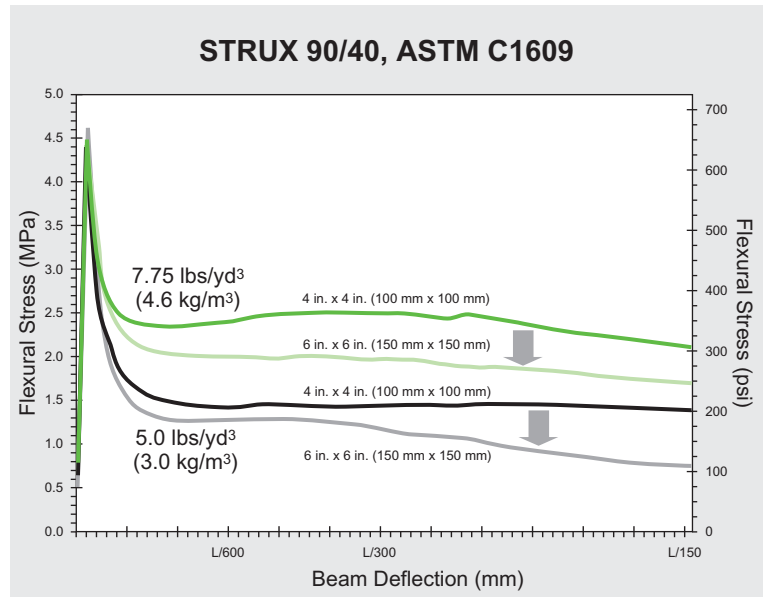
To summarize the differences between ASTM C1399 versus ASTM C1609 with respect to preferential fiber alignment of small versus large beams, Figure 1 represents STRUX® 90/40 cast from identical concrete placed in small and large beams and then tested.

Figure 2 and 3 represents the ARS values (ASTM C1399) and f_{e3} values (ASTM C1609, formerly ASTM C1018-97) for a variety of addition rates and concrete strengths. The values in the tables are a result from over 500 beam tests done in the Research & Development Laboratory at W. R. Grace & Co.

Conclusion: For basic slab-on-ground and pre-cast applications, refer to the recommendations for each ASTM test and tables when specifying ARS or f_{e3} values. In addition, W. R. Grace has developed a slab-on-ground design software (STRUX 90/40 SDS) that has the capability to assist with a variety of applied loading on slabs from wheel loads, post loads, racking systems, walls loads or uniform loading. It calculates an addition rate of STRUX 90/40 for edge, center, or free-edge loading cases obtained from details such as concrete strength (f'_c), modulus of sub-grade reaction (k-value), joint spacing, and the coefficient of friction. The analysis will provide a 25-page report showing the most cost-effective thickness of concrete and addition rate of STRUX 90/40 using the Yield Line theory backing up the calculations accepted by Chapter 10 of ACI 360.

Consult with a W. R. Grace Engineering Services Group representative for the SDS input sheet for your particular slab-on-ground project. Other STRUX 90/40 information such as Datasheet, Engineering Bulletin and sample specifications are available at www.graceconstruction.com/strux.

Figure 1



Residual flexural strength and toughness are lower when measured with the larger flexural beams!

Figure 2
ARS values measured according to ASTM C1399-07

STRUX 90/40	Cylinder Compressive Strength (psi)							
	lbs/yd ³	3,000	3,500	4,000	4,500	5,000	5,500	6,000
3.0	95	110						
3.5	125	140	150	160	175			
4.0	150	165	175	185	200	210	220	
4.5	175	185	195	210	220	230	245	
5.0	195	205	215	230	240	250	260	
5.5	215	225	235	245	255	270	280	
6.0	230	240	250	260	275	285	295	
6.5	245	255	265	275	285	300	310	320
7.0	260	270	280	290	300	310	320	335
7.5	270	280	295	305	315	325	335	

Figure 3
 f_{e3} values measured according to JSCE* (JCI-SF4)

STRUX 90/40	Cylinder Compressive Strength (psi)							
	lbs/yd ³	3,000	3,500	4,000	4,500	5,000	5,500	6,000
3.0	95	105						
3.5	105	115	125	135	140			
4.0	120	130	140	150	155	165	175	
4.5	135	145	155	165	170	180	190	
5.0	150	160	170	180	185	195	205	
5.5	165	175	185	195	200	210	220	
6.0	180	190	200	210	215	225	235	
6.5	195	205	215	225	235	240	250	
7.0	210	220	230	240	250	255	265	
7.5	225	235	245	255	265	270	280	

www.graceconstruction.com/strux

North American Customer Service: 1-877-4AD-MIX1 (1-877-423-6491)

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