1 July 2010

Committee C09 on Concrete
Subcommittee C09.42 on Fiber-Reinforced Concrete

Research Report C09-1036

Interlaboratory Study to Establish Precision Statements for ASTM C1550, Standard Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)

Technical contact:
Dr Erik S. Bernard,
Technologies in Structural Engineering P/L
Penrith, NSW 2750
Australia
+61-2-418407892
s.bernard@tse.net.au

Dr. Nicholas J. Carino
Consultant
107 Waverly Lane
Chagrin Falls, OH 44022
440 537-5134
ncarino@roadrunner.com

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

1. Introduction:

An Interlaboratory Study was conducted to establish a precision statement for ASTM Test Method C1550, Standard Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel).

2. Test Method:

The Test Method used for this ILS is ASTM C1550-05. To obtain a copy of C1550, go to ASTM's website, www.astm.org, or contact ASTM Customer Service by phone at 610-832-9585 (8:30 a.m. - 4:30 p.m. Eastern U.S. Standard Time, Monday through Friday) or by email at service@astm.org.

3. Participating Laboratories:

The ILS involved six testing machines and operators in five laboratories. The following laboratories participated in this interlaboratory study

1. TSE P/L
   28 Gordon Street
   Penrith, NSW 2750
   Australia
   Dr. Erik S. Bernard
   +61-2-47255801
   s.bernard@tse.net.au

2. University of Western
   Sydney, Civil Engineering
   Kingswood Campus
   Kingswood, NSW 2747
   Dr. Andrew Wheeler
   +61-2-47360000
   Andrew.wheeler@uws.edu.au

3. BASF Construction Chemicals
   LLC
   23700 Chagrin Blvd
   Cleveland, OH44122
   Ms. Heather See
   1-216-839-7007
   Heather.see@basf.com

4. University of Greenwich
   Old Royal Naval College
   Park Row
   Greenwich, United Kingdom
   SE10 9LS
   Mr. Tony Stevens
   +44-1634-883147
   T.D. Stevens@gre.ac.uk

5. University of Luleå Complab
   Luleå University of Technology
   Luleå, Sweden S-97187
   Claes Fahleson
   +46-920-492232
   Claes.Fahleson@ltu.se

4. Description of Specimens:

Round panel test specimens were produced from six mixtures with different target strengths and different dosages and types of fibers. Three mixtures were fiber reinforced shotcrete (FRS) and three mixtures were fiber reinforced concrete (FRC). Table 1 summarizes the six mixtures that were used for this study. The FRS specimens were made by spraying using a manual wet-mix process, and the FRC specimens were cast. Specimens were prepared and distributed by Erik Bernard of TSE P/L.

Table 1. FRC/FRS mixtures used in the ILS.

Set	Fiber dosage and type	Target strength
B1	6.4 kg/m^3 Kyodo 48 mm	40 MPa FRS
B2	8 kg/m^3 Enduro 50 mm	32 MPa FRS
B3	40 kg/m^3 Dramix RC 65/35	32 MPa FRS
B4	37.5 kg/m^3 Novotex 0730	20 MPa cast FRC
B5	5 kg/m^3 Shogun 48 mm	20 MPa cast FRC
B6	25 kg/m^3 Novotex 1050	25 MPa cast FRC

A total of 36 specimens were prepared from each mixture, for an overall total of 216 specimens. Each testing machine was used to test six replicates from each of the six mixtures; hence 36 specimens were tested in each machine.. The six mixtures that were used to make the specimens were proprietary mixtures supplied by Western Suburbs Concrete, Sydney and are not available for publication.

As noted, the round panel specimens were produced either by casting or spraying. Concrete was supplied from a dry-batch ready-mixed plant and delivered as a 3.0 m^3 batch in a 5.6 m^3 truck-mounted mixer. Fibers were added on top of the concrete and mixed in for 15 minutes at high-speed rotation of the drum. For the cast specimens, round molds were placed horizontally on the ground and the fiber-reinforced concrete was dispensed directly into the molds using the truck chute. The concrete was vibrated using an internal vibrator, then screeded and floated using the procedure described in the Appendix of Test Method C1550. The sprayed specimens were produced by placing the molds against a rack at approximately 45° to the horizontal and manually spraying the fiber-reinforced shotcrete into the forms starting at the bottom. Set accelerator was used at a dosage rate of approximately 5% by mass of cement. The inclined specimens were screeded and floated in the inclined position before being placed in the horizontal position and finished with a steel float.

After finishing, all specimens were covered with plastic sheeting and allowed to harden for two days before stripping and transfer to lime-saturated water-filled tanks. Immersion curing in water continued for 6 months after which the specimens were stored in an external shaded environment for 18 months, during which the specimens were allowed to air dry. The specimens were then placed in crates and shipped to the various laboratories involved in the ILS. The extended conditioning period was used to minimize any effects of testing age among the laboratories. All the specimens were tested within a period of approximately 4 weeks and at an age of approximately two and a half years.

Specimens were numbered sequentially as they were produced. The specimens to be tested on each of the six testing machines were selected successively from the 36 specimens produced for each mixture. Thus, every sixth specimen was tested by same machine (e.g., specimens 1, 7, 13, 19, 25, and 31 were testing by one machine.). This ensured that the six specimens from each mixture to be tested by each machine represented material from throughout the entire load of concrete used to make the specimens.

5. Interlaboratory Study Instructions

Laboratory participants were emailed the test program instructions. Participants were instructed to test six replicate specimens from each of the six mixtures, and to report test results as they would normally be reported to a customer. The results of this ILS

comprised peak load and energy absorption at four values of panel deflection (5, 10, 20, and 40 mm). Reporting of peak load is not required by Test methods C1550-05, but a revision to the standard will include measuring and reporting peak load.

6. Description of Equipment/Apparatus[1]:

As noted in Section 2, the ILS involved five facilities and six testing machines. The University of Western Sidney used two different testing machines, and the results for each machine were treated as a different "laboratory". Table 2 provides descriptions of the testing machines. The load train stiffness for the machine at BASF was unknown.

.Table 2. Testing machines used in the ILS.

Facility	Machine	*k* (N/mm)
UWS	3000 kN Instron 8506	72300
UWS	1000 kN Instron 8804	72400
TSE	100 kN MTS 244.21	53100
BASF	Instron 300BTE 1300 kN	-
Greenwich	DARTEC 500 kN	120900
Luleå	Eland 1000 kN	157000

7. Data Report Forms:

Each laboratory was instructed to report the mean diameter and mean thickness of each specimen, plus the peak load sustained, and computed energy absorption at 5, 10, 20, and 40 mm central deflection. Test results were corrected for panel dimensions in accordance with Test Method C1550-05. An individual test certificate was issued for each specimen tested. The results used for this analysis are given in Annex A.

Please note: The laboratories have been randomly coded and cannot be identified herein.

8. Statistical Data Summary:

Analysis of this data was complicated by the incidence of invalid tests involving the formation of a single dimetral crack rather than the required three radial cracks. Therefore, several specimen results had to be discarded and the number of replicates in each cell (laboratory-material combination) was not equal. Thus the usual procedures in ASTM Practice C802 or Practice E691 were not applicable. Dr. Nicholas J. Carino provided a report on the data analysis, which is included as Annex A.

9. Precision and Bias Statement:

X. Precision and Bias

X.1 *Precision*

X.1.1 *Interlaboratory Test Program*—An interlaboratory study of Test Method C1550 was run in 2008. Six testing machines and operators were used to test six replicate panel specimens for each of six fiber reinforced concretes mixtures designed to provide different levels of peak load and energy absorption. The average peak loads for the six mixtures varied from 26.9 kN to 36.3 kN and the ranges of average energy absorption are

[1] The equipment listed was used to develop a precision statement for ASTM C1550-05. This listing is not an endorsement or certification by ASTM International.