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Evaluation of NForce-Fiber in Concrete Report

Submitted to:

CANADIAN GREENFIELD TECHNOLOGIES CORP.

Submitted by:

LZhang Consulting & Testing Ltd

Vancouver, BC

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LZhang File: 11VA062 -Phase 100

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1.0 INTRODUCTION

LZhang Consulting & Testing Ltd (LZhang) was contracted by Canadian Greenfield Technologies Corp (CGT) to conduct a product evaluation for NForce-Fiber in concrete and shotcrete. The Phase I study, i.e., *"Product Study and Due Diligence Phase"* involves evaluation of the behaviour and performance of concretes made with NForce-Fiber compared to plain concrete mixes with no fiber addition and concrete mixes with microsynthetic fibre. The Phase I work was conducted at the LZhang Consulting & Testing Ltd. (LZhang) laboratory in Richmond and Vancouver, BC from Dec 21, 2015 up to the date when this report was prepared.

2.0 CONCRETE MIXTURE DESIGNS

The concrete mixes shown in Table 1 below were evaluated in this study.

Table 1. Concrete Mixtures

Mix Type	Cast Concrete Designation	Fiber Content	
		(kg/ m^3)	(% volume)
Plain	CP	0	0
NForce-Fiber	CNF (1.35)	1.35	0.10
NForce-Fiber	CNF (2.0)	2	0.15
MicroSynthetic Fiber	CSF	1.35	0.15

The concrete mixture designs for all the mixes meet the CSA A23.1/23.2-2014 Class C1 exposure requirements (Ref 1). i.e. *Structurally reinforced concrete exposed to chlorides with or without freezing and thawing conditions.* These mixes are required to have a maximum water/cementing materials ratio of 0.40, a minimum compressive strength of 35 MPa at 28 days and be suitably air entrained. The concrete mix designs contained 19% fly ash by mass of cementitious materials and were based on mixes used in a comprehensive study of transport properties of concrete and shotcrete (Ref 2). Detailed mix designs are attached in Appendix A.

3.0 LABORATORY PRODUCTION AND TESTING

3.1 Batching, mixing and supply

A pan mixer with rotating paddles was used to produce the concrete mixes. Aggregates, cement, fly ash, and water were added and the concrete was mixed for 3 minutes. The fibers were then added and mixed for a minimum of 5 minutes. Slump was tested and superplasticizer was added when needed to achieve the required slump. The air content was tested and when in conformance with the required 5-8%, concrete samples were cast. All concrete samples were cured in laboratory conditions of 23+/-2 ^{0}C, and 50% relative humidity, except the samples for plastic shrinkage tests which had special exposure conditions. Photos for laboratory mixing are included in Appendix B.

3.2 Plastic Concrete Tests

Concrete temperature, slump and air content were tested. Test results are reported in Appendix C and are summarized in Table 2 which follows.

Table 2. Concrete Plastic Properties

Mixture	Fiber Content		Slump (mm)	Air Content (%)	Concrete Temperature (^oC)	Superplasticizer Glenium 7100, (ml/m^3)	Air Entraining Agent (ml/m^3)
	(kg/m^3)	(% volume)					
CP	0	0	65	6.4	21	0	250
CNF (1.35)	1.35	0.10	50	6	18	0	200
CNF (2.0)	2	0.15	50	7.9	18	200	300
CSF	1.35	0.15	50	6	20	0	200

It should be noted that the mix CNF (2.0) has a higher, but still within the required limit, air content. This is because the superplasticizer, Glenium 7100, was added to increase the slump to meet the minimum 50 mm slump requirement, and the superplasticizer slightly increased the air content.

3.3 Plastic Shrinkage Cracking Testing

Plastic shrinkage cracking testing was conducted to *ASTM C1579 Standard Test Method for Evaluating Plastic Shrinkage Cracking of Restrained Fiber Reinforced Concrete (Using a Steel Form Insert)*[3]. Two panels were cast and tested for each mix. After casting and finishing, the samples were placed in environmental chambers which provided an environment of: temperature 36 +/- 3 ^{0}C; wind velocity 4.7 m/s; and relative humidity 30 +/-10%, as required by the test method.

In addition, a water sample in a beaker was placed in the environmental chambers to monitor the evaporation rate. ASTM C1579 specifies a minimum rate of evaporation of 1.0 kg/m^2.h and this requirement was met. A setting time test sample was tested to determine the set time to ASTM C403. Once the concrete sample reached final set, samples were removed from the environmental chambers and placed in the laboratory for curing at 23+/-2 ^{0}C and 50% relative humidity, until 24 hours, as prescribed in the test method. Cracks were measured to determine shrinkage performance using the methodology provided in ASTM C1579. Test results and photos are included in Appendix D and summarized in Table 3 as follows:

Table 3. Plastic Shrinkage Testing Results for Concrete Mixtures

Mixture	Fiber Content		Crack Reduction Ratio (CRR), %
	(kg/m^3)	(% volume)	
CP	0	0	N/A
CNF (1.35)	1.35	0.10	60
CNF (2.0)	2	0.15	100
CSF	1.35	0.15	92

Table 3 shows that when NForce-Fiber was added at 1.35 kg/m^3, i.e., 0.10% by volume, the crack reduction ratio, as defined by ASTM C1579, is 60%. When NForce-Fiber was added at 2 kg/m^3, i.e., 0.15% by volume, the crack reduction ratio is 100%, which means no cracks occurred during the test (also shown in photos). When microsynthetic fiber was added at 1.35 kg/m^3, i.e., 0.15% by volume, the crack reduction ratio is 92%. This shows that when NForce-Fiber was added at

the same % by volume as the microsynthetic fiber, it is more efficient in mitigating, or in this case eliminating, plastic shrinkage cracking.

3.4 Finishability

After samples were cast, no evidence of sedimentation, segregation or bleeding was observed in any of the mixes. Concrete was cast into 355x550x100 mm plywood boxes and finished using different hand-held finishing tools to evaluate the finishability of the different mixes. The finishing tools used (in sequence from smoothest to most textured finish) are shown in Fig. E-1 in Appendix E and were: steel trowel, magnesium trowel, wood float, hard rubber float, textured rubber float, and sponge float. Photographs of the finished surface texture with each of these finishing tools, for the different mixes with fibers, are provided in Appendix E.

The plain concrete mix was relatively easy to finish with all of the selected finishing tools, showing the expected sequence of smooth to greatest surface texture for the different tools, as described above. The mix with microsynthetic fiber (Mix CSF), proved to be the most difficult to finish, with the finishing tools which provided greater surface texture (e.g. rubber float finish and sponge float finish) pulling more fibers to the surface and creating a quite rough finished surface texture with lots of protruding fibers, as is evident in photos E8 to E13 in Appendix E.

By contrast, the two mixes with NForce-Fiber (CNF (1.35) and CNF (2.0)) displayed superior finishing characteristics to both the plain concrete (CP) and microsynthetic fiber concrete (CSF) mixes. The NForce-Fiber appeared to act as a “finishing aid”, providing the mixes with a greater cohesiveness, which resulted in relatively smoother textured surface finishes for all of the finishing tools used, particularly when compared to the CSF mix. Virtually no fibers were evident in the finished surface of the CNF (1.35) and CNF (2.0) mixes finished with steel and magnesium trowels. Very few fibers were drawn to the finished surface with the wood, rubber or sponge floats. Interestingly the mix CNF (2.0) with the higher NForce-Fiber content appeared to be the easiest to finish of all the mixes. This is well illustrated in the photos in Appendix E.

4 HARDENED CONCRETE TESTS

4.1 Compressive Strength

For each mix, three cylinders (100mm dia x 200mm) were cast and tested for compressive strength at 7 and 28 days to ASTM C39. The compressive strength results are included in Appendix F and are summarized in Table 4 as follows:

Table 4. Compressive Strength for All Mixtures

Mixture	Fiber Content		7 Days Compressive Strength (MPa)	28 Days Compressive Strength (MPa)
	(kg/m^3)	(% volume)		
CP	0	0	34.7	41.5
CNF (1.35)	1.35	0.1	35.4	41.1
CNF (2.0)	2	0.15	33.4	40.7
CSF	1.35	0.15	35.4	42.8

The minimum concrete compressive strength, as required by CSA A23.1/23.2 for a C1 Exposure class, is 35 MPa at 28 days. All mixes meet the specified strength requirement.

It should be noted that the compressive strength for CNF (2.0), i.e., concrete mixture with 2.0 kg/m^3 NForce-Fiber, is a slightly lower than for all the other mixtures. This is due to the higher air content in this mix of 7.9%, which slightly reduces compressive strength. The higher air content will, however, not adversely affect the performance of the mix with respect to boiled absorption and volume of permeable voids and rapid chloride penetration [Ref 2].

4.2 Boiled Absorption and Volume of Permeable Voids

For each mix, three samples were prepared and tested at 28 days for Boiled Absorption (BA) and Volume of Permeable Voids (VPV) to ASTM C642. Test results are included in Appendix G and are summarized as follows:

Table 4. Boiled Absorption and Volume of Permeable Voids

Mixture	Fiber Content		Boiled Absorption (%)	Volume of Permeable Voids (%)
	(kg/m^3)	(% volume)		
CP	0	0	5.2	11.6
CNF (1.35)	1.35	0.1	5.6	12.6
CNF (2.0)	2	0.15	5.6	12.5
CSF	1.35	0.15	5.6	12.6

Results for boiled absorption and volume of permeable voids, as listed in Table 4, show that addition of NForce-Fiber will not adversely affect the BA and VPV values. This shows that the permeability of concrete will not be adversely affected by addition of these fibers.

4.3 Rapid Chloride Penetration Test (RCP)

For each mix, three samples were prepared for testing at 91 days to ASTM C1202 for Rapid Chloride Penetrability (RCP). Test results are included in Appendix H and are summarized in Table 5 as follows:

Table 5. Rapid Chloride Peneration Resistance

Mixture	Fiber Content		RCP Results at 91 Days (Coulombs)
	(kg/m^3)	(% volume)	
CP	0	0	1076
CNF (1.35)	1.35	0.1	1176
CNF (2.0)	2	0.15	1241
CSF	1.35	0.15	1085

These test results show that all the mixtures have RCP results at 91 days of between 1076 and 1241 Coulombs, which is considered as “low” by both ASTM C1202 and CSA A23.1/23.2-2014. These results also satisfy the CSA A23.1/23.2-2014 requirements for a Class C-1 Exposure of not more than 1500 Coulombs at 91 days. This shows that addition of the NForce-Fibers and microsynthetic fibers does not aversely affect the RCP test results.

4.4 Residual Flexural Strength to ASTM C1399 and Flexural Strength and Flexural Toughness to ASTM C1609

For each mix, three beams, with dimensions of 100 x100 x350 mm, were cast and cured and tested at 28 days for flexural strength and flexural toughness to ASTM C1609. Also for each mix,

three beams, with dimensions of 100 x100 x350 mm, were prepared and tested at 28 days for residual flexural strength to ASTM C1399. Detailed test results are included in Appendix I and are summarized in Table 6 as follows:

Table 6 shows that addition of both NForce-Fiber and microsyntehtic fibers slightly increase the flexural strength, when tested to ASTM C1609. The flexural strengths for NForce-Fiber at 1.35 kg/ m^3 and 2.0 kg/ m^3 are similar to the flexural strength for microsynthetic fiber at 1.35 kg/ m^3.

The flexural toughness for NForce-Fiber reinforced concrete in the ASTM C1609 test is zero. This is due to the fact that the beams fracture into two components at the peak load. The microsynthetic fiber reinforced concrete displays a small flexural toughness value, i.e., $T_{100,\,2.0}$ of 8.57 Joules. The residual flexural strength, when tested to ASTM C1399 for NForce-Fiber, is 0.07 MPa at an addition rate of 1.35 kg/ m^3, and 0.11 MPa at an addition rate of 2.00 kg/ m^3. The residual flexural strength for the microsynthetic fiber reinforced concrete is 0.51 MPa. This shows that although the residual strength for NForce-Fiber increases from 1.35 kg/ m^3 to 2.0 kg/ m^3, it is lower than for the microsynthetic fiber reinforced concrete at 1.35 kg/ m^3, which is the same fiber addition rate by % volume.

Table 6. Flexural Strength, Flexural Toughness and Residual Flexural Strength

Mixture	Fiber Content		Flexural Strength to ASTM C1609 (MPa)	Flexural Toughness to ASTM C1609, $T_{100,\,2.0}$ (Joule)	Residual Flexural Strength to ASTM C1399 (MPa)
	(kg/m^3)	(% volume)			
CP	0	0	5.87	0	0
CNF (1.35)*	1.35	0.1	6.06	0	0.07
CNF (2.0)	2	0.15	6.08	0	0.11
CSF	1.35	0.15	6.03	8.57	0.51

*CNF beams fractured into two parts with no residual load carry capacity when tested to ASTM C1609.

5 CONCLUSIONS

The following conclusions are reached with respect to the performance of NForce-Fiber in cast concrete compared to a Plain Concrete without fiber addition, and a concrete with Microsynthetic fiber addition, in this Phase I *"Product Study and Due Diligence Phase"*.

1. Both the NForce-Fiber and Microsynthetic fiber could be readily batched and mixed in a pan mixer with counter-rotating paddles, with uniform dispersion of the fibers throughout the mix, with no evidence of fiber balling or segregation. Such mixers are commonly used in the precast concrete industry.
2. The NForce-Fiber mix with 0.10% fiber volume addition (1.35 kg/m^3) and Microsynthetic fiber mix with 0.15% fiber volume addition (1.35 kg/m^3) had essentially identical mixture designs as the Plain Concrete mix prior to fiber addition. The NForce-Fiber mix with 0.15% fiber volume addition (2.0 kg/m^3) required a modest addition of 200 ml/m^3 of Glenium 7100 High Range Water Reducer (Superplasticizer) to produce a mix with similar slump to the other mixes.
3. Other than for a slightly higher air content in the NForce-Fiber mix with Superplasticizer addition, the slumps and air contents of all the mixes were very similar.

4. All mixes satisfied the CSA A23.1/23.2-2014 requirements for a Class C1 Exposure. i.e. *Structurally reinforced concrete exposed to chlorides with or without freezing and thawing*.

5. In Plastic Shrinkage Testing to ASTM C1579 the Plain Concrete without fibers developed average crack widths of 0.63mm. The Microsynthetic fiber mix with 0.15% fiber volume addition developed an average crack width of 0.05mm. By contrast the NForce-Fiber mix with 0.15% fiber volume addition developed no cracks. The NForce-Fiber mix with 0.10% fiber volume addition developed average crack widths of 0.25mm.

6. Analysis of the ASTM C1579 Plastic Shrinkage cracking test results noted in 5. above shows that addition of the Microsynthetic fiber at 0.15% volume results in a 92% *Crack Reduction Ratio.* The addition of NForce-Fiber at 0.15% volume results in a 100% *Crack reduction Ratio.* i.e. there was no cracking. The addition of NForce-Fiber at 0.10% volume resulted in a 60% *Crack Reduction Ratio.* This demonstrates that at equal % volume fibre addition rates the NForce-Fiber is more effective in mitigating cracking in freshly placed concrete than Microsynthetic Fiber.

7. Finishing tests were conducted on cast concrete slabs using the following finishing tools (sequenced from smoothest to roughest finishing texture): steel trowel, magnesium trowel, wood float, hard rubber float, textured rubber float and sponge float. The mixes with NForce-Fiber were the easiest to finish and resulted in the least rough and most uniform surface texture appearances. The fibers appeared to act as a *finishing aid.* Virtually no fibers were visible in the slabs finished with the steel and magnesium trowels and very few fibers were drawn to the surface by the wood, rubber or sponge floats. This is in marked contrast to the cast concrete slabs with Microsynthetic fibers where some fibers were visible in the surface of the steel and magnesium troweled slabs and progressively more fibers (with rougher textured finishes) were visible in the slabs finished with the rubber and sponge floats. In summary, mixes made with NForce-Fibers display markedly superior finishing characteristics compared to the mix with Microsynthetic fiber. This is possibly attributable in part to the *hydrophilic* characteristics of the NForce-Fiber compared to the *hydrophobic* characteristics of the Microsynthetic fiber.

8. Relative to the Plain Concrete with no fibers, the addition of either NForce-Fiber or Microsynthetic fiber had no adverse effect on the compressive strength of the concrete at 7 and 28 days. Similarly, these fibers had no adverse effect on the flexural strength of the concrete at 28 days. Compressive strength test results readily satisfied the CSA A23.1/23.2 requirements of minimum 35 MPa at 28 days for a Class C1 exposure.

9. Relative to the Plain Concrete the addition of fibers had no adverse effect on the ASTM C642 values for Boiled Absorption (BA) and Volume of Permeable Voids (VPV). BA and VPV values were well below maximum permissible values permitted by various specifying authorities.

10. Relative to the Plain Concrete the addition of fibers had no adverse effect on the ASTM C1202 Rapid Chloride Permeability (RCP) test results. All the mixes tested had “Low” RCP values.

11. When tested to the ASTM C1609 Flexural Toughness test method the mixes with NForce-Fibers showed no toughness (there was no residual load carrying capacity). By contrast the mix with Microsynthetic fiber showed a small toughness value of 8.57 Joules.

12. When tested to the ASTM C1399 Residual Flexural Strength Method all three fiber reinforced mixes displayed small residual flexural strength values, but with the Microsynthetic fiber mix displaying the highest value.

In summary, the main reasons for adding NForce-Fiber to concrete are for:

a) the marked improvement it provides to the early age crack resistance of the concrete, compared to Plain Concrete and Microsynthetic fiber concrete, and
b) the substantial improvement it provides to the concrete finishing operations, compared to concrete with Microsynthetic fiber.

6 RECOMMENDATIONS

It is recommended that concrete conforming to CSA A23.1/23.2-2014 Class C1 exposure requirements made with NForce-Fiber now be evaluated in full-scale production of concrete slabs on grade, using ready mix concrete batching, mixing and supply. The performance of the fiber reinforced concrete with respect to plastic properties such as: slump, air content and placing and finishing characteristics, and hardened properties such as: resistance to cracking and compressive strength at 7 and 28 days should be determined. It is suggested that concretes be produced with both 0.10% volume (1.35 kg/m^3) and 0.15%volume (2.0 kg/m^3) of NForce-Fiber addition.

LZhang Consulting & Testing Ltd would, on request, be pleased to monitor such concrete production, provide the recommended concrete quality control tests, and provide a report with findings.

Respectfully submitted,

by LZhang Consulting & Testing Ltd

Reviewed by

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2. L. Zhang., D.R. Morgan., S. Mindess "Comparative Evaluation of the Transport Properties of Shotcrete Compared to Cast-in-Place Concrete", ACI Materials Journal, (accepted for publication)
3. ASTM C1579-2009 Standard Test Method for Evaluating Plastic Shrinkage Cracking of Restrained Fiber reinforced Concrete (Using a Steel Form Insert).

Appendix A: CONCRETE MIX DESIGN Mix CP (Plain Concrete)

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LZhang File No: 11VA062
Date: 04-Dec-15

PROJECT: NForce-Fiber Reinforced Concrete Evaluation
SUBJECT: Mix CP (Plain Concrete)

Material	Mass per m^3 SSD Agg [kg]	Density [kg/m^3]	Volume [m^3]
Cement Type GU (ASTM Type I)	340	3150	0.1079
Flyash	80	2550	0.0314
Coarse Aggregate (10-5 mm, SSD)	1135	2730	0.4158
Fine Aggregate (SSD)	770	2673	0.2881
Estimated Water, L	168	1000	0.1680
Water Reducing Admixture, Glenium 7100, L	0.000	1010	0.0000
NForce Fiber	0.000	1480	0.0000
Air-Entraining Admixture (BASF MBAE 90), L	0.250	1010	0.0002
Air Content: +/- 1.5%	7.5%	-	0.0750
Total	2493	Yield (m^3)=	1.0114

PROJECT REQUIREMENTS

Minimum Compressive Strength	35 MPa at 28 days
Slump	70+/-20 mm
Maximum W/CM Ratio	0.40
Rapid Chloride Permeability (ASTM C1202)	<1500 Coulombs at 91 days
Maximum Boiled Absorption (ASTM C642)	8%
Maximum Volume of Permeable Voids (ASTM C642)	17%

CALCULATED MIX DESIGN PARAMETERS

Fine Aggregate Content	40%
Water:Cementitious Ratio	0.40
Plastic Density (kg/m^3)	2465
Fly Ash Content (% by mass of cement+fly ash)	19.0%

Per: Lihe (John) Zhang, Ph.D., P.Eng
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Appendix A: CONCRETE MIX DESIGN Mix CNF (1.35) (NForce-Fiber)

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Date: 04-Dec-15

PROJECT: Nforce-Fiber Reinforced Concrete Evaluation
SUBJECT: Mix CNF (1.35) (NForce-Fiber)

Material	Mass per m^3 SSD Agg [kg]	Density [kg/m^3]	Volume [m^3]
Cement Type GU (ASTM Type I)	340	3150	0.1079
Flyash	80	2550	0.0314
Coarse Aggregate (10-5 mm, SSD)	1135	2730	0.4158
Fine Aggregate (SSD)	770	2673	0.2881
Estimated Water, L	168	1000	0.1680
Water Reducing Admixture, Glenium 7100, L	0.000	1010	0.0000
NForce Fiber	1.350	1480	0.0009
Air-Entraining Admixture (BASF MBAE 90), L	0.200	1010	0.0002
Air Content: +/- 1.5%	7.5	-	0.0750
Total	2495	Yield (m^3)=	1.0122

PROJECT REQUIREMENTS

Minimum Compressive Strength	35 MPa at 28 days
Slump	70+/-20 mm
Maximum W/CM Ratio	0.40
Rapid Chloride Permeability (ASTM C1202)	<1500 Coulombs at 91 days
Maximum Boiled Absorption (ASTM C642)	8%
Maximum Volume of Permeable Voids (ASTM C642)	17%

CALCULATED MIX DESIGN PARAMETERS

Fine Aggregate Content	40%
Water:Cementitious Ratio	0.40
Plastic Density (kg/m^3)	2464
Fly Ash Content (% by mass of cement+fly ash)	19.0%

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Appendix A: CONCRETE MIX DESIGN Mix CSF (Microsynthetic Fiber)

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LZhang File No: 11VA062
Date: 04-Dec-15

PROJECT: Nforce-Fiber Reinforced Concrete Evaluation
SUBJECT: Mix CSF (Microsynthetic Fiber)

Material	Mass per m^3 SSD Agg [kg]	Density [kg/m^3]	Volume [m^3]
Cement Type GU (ASTM Type I)	340	3150	0.1079
Flyash	80	2550	0.0314
Coarse Aggregate (10-5 mm, SSD)	1135	2730	0.4158
Fine Aggregate (SSD)	770	2673	0.2881
Estimated Water, L	168	1000	0.1680
Water Reducing Admixture, L	0.000	1010	0.0000
Interstar Microsynthetic Fiber	1.350	920	0.0015
Air-Entraining Admixture (BASF MBAE 90), L	0.200	1010	0.0002
Air Content: +/- 1.5%	7.5	-	0.0750
Total	2495	Yield (m^3)=	1.0128

PROJECT REQUIREMENTS

Minimum Compressive Strength	35 MPa at 28 days
Slump	70+/-20 mm
Maximum W/CM Ratio	0.40
Rapid Chloride Permeability (ASTM C1202)	<1500 Coulombs at 91 days
Maximum Boiled Absorption (ASTM C642)	8%
Maximum Volume of Permeable Voids (ASTM C642)	17%

CALCULATED MIX DESIGN PARAMETERS

Fine Aggregate Content	40%
Water:Cementitious Ratio	0.40
Plastic Density (kg/m^3)	2463
Fly Ash Content (% by mass of cement+fly ash)	19.0%

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Appendix A: CONCRETE MIX DESIGN Mix CNF (2.0) (NForce-Fiber)

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Date: 08-Jan-16

PROJECT: Nforce-Fiber Reinforced Concrete Evaluation
SUBJECT: Mix CNF (2.0) (NForce-Fiber)

Material	Mass per m^3 SSD Agg [kg]	Density [kg/m^3]	Volume [m^3]
Cement Type GU (ASTM Type I)	340	3150	0.1079
Flyash	80	2550	0.0314
Coarse Aggregate (10-5 mm, SSD)	1135	2730	0.4158
Fine Aggregate (SSD)	770	2673	0.2881
Estimated Water, L	168	1000	0.1680
Water Reducing Admixture, Glenium 7100, L	0.200	1010	0.0002
NForce Fiber	2.0	1480	0.0014
Air-Entraining Admixture (BASF MBAE 90), L	0.300	1010	0.0003
Air Content: +/- 1.5%	7.5	-	0.0750
Total	2496	Yield (m^3)=	1.0130

PROJECT REQUIREMENTS

Minimum Compressive Strength	35 MPa at 28 days
Slump	70+/-20 mm
Maximum W/CM Ratio	0.40
Rapid Chloride Permeability (ASTM C1202)	<1500 Coulombs at 91 days
Maximum Boiled Absorption (ASTM C642)	8%
Maximum Volume of Permeable Voids (ASTM C642)	17%

CALCULATED MIX DESIGN PARAMETERS

Fine Aggregate Content	40%
Water:Cementitious Ratio	0.40
Plastic Density (kg/m^3)	2464
Fly Ash Content (% by mass of cement+fly ash)	19.0%

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APPENDIX B Laboratory trial batch with NForce-Fiber

Figure B-1:1.35 kg/m^3 NForce-Fiber and 1.35 kg/m^3 microsynthetic fiber

Figure B-2: Laboratory trial batch mixer, beam moulds, shrinkage moulds

Figure B-3: 1.35 kg/m^3 NForce-Fiber mix

Figure B-4: 1.35 kg/m^3 NForce-Fiber mix: close look at fibers

Figure B-5: 1.35 kg/m^3 NForce-Fiber mix: 50 mm slump

Figure B-6: 1.35 kg/m^3 microsynthetic fiber

Figure B-7: 1.35 kg/m^3 microsynthetic fiber mix: close look at fiber distribution

Figure B-8: 2.0 kg/m^3 NForce-Fiber

Figure B-9: 2 kg/m^3 NForce-Fiber added to the concrete mix

Figure B-10: 2 kg/m^3 NForce-Fiber mix

Figure B-11: 2 kg/m^3 NForce-Fiber mix: close look at fiber distribution

Figure B-12: 2 kg/m^3 NForce-Fiber at 50 mm slump

Appendix C: Plastic Properties

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PROJECT: NForce-Fiber Reinforced Concrete Evaluation

SUBJECT: Plastic Properties for Laboratory Trial Batch

Date Cast: 21-Dec-15

Mixture	Fiber Content		Slump (mm)	Air Content (%)	Concrete Temperature (^oC)	Superplasticizer, Glenium 7100, (ml/m^3)	Air Entraining Agent (ml/m^3)	Evaporation Rate (kg/m^2.h) in ASTM C1579 Test
	(kg/m^3)	(% volume)						
CP*	0	0	150	7.0	16.0	620	200	1.50
CNF (1.35)	1.35	0.10	50	6.0	18.0	0	200	1.50
CSF	1.35	0.15	50	6.0	20.0	0	200	1.50

*This mix was discarded and repeated on Jan 12, 2016

Date Cast: 05-Jan-16

Mixture	Fiber Content		Slump (mm)	Air Content (%)	Concrete Temperature (^oC)	Superplasticizer, Glenium 7100, (ml/m^3)	Air Entraining Agent (ml/m^3)	Evaporation Rate (kg/m^2.h) in ASTM C1579 Test
	(kg/m^3)	(% volume)						
CNF (1.35)	1.35	0.10	65	6.1	16.0	0	200	1.17
CSF	1.35	0.15	50	6.0	18.0	0	200	1.17

Date Cast: 12-Jan-16

Mixture	Fiber Content		Slump (mm)	Air Content (%)	Concrete Temperature (^oC)	Superplasticizer, Glenium 7100, (ml/m^3)	Air Entraining Agent (ml/m^3)	Evaporation Rate (kg/m^2.h) in ASTM C1579 Test
	(kg/m^3)	(% volume)						
CP	0	0	65	6.4	21.0	0	250	1.15
CNF (2.0)	2	0.15	50	7.9	18.0	200	300	1.15

Per: Lihe (John) Zhang, Ph.D., P.Eng
LZhang Consulting & Testing Ltd
5069 7B Avenue Delta, BC, V4M 1S3

Appendix D: Plastic Shrinkage Test

CANADIAN GREENFIELD TECHNOLOGIES CORP.
Mr. Mike Pildysh, M.Eng., P.Eng, President
#159, 3953 112 Ave SE
Calgary, AB
Canada, T2C 0J4

LZhang File No: 11VA062
Date: 13-Jan-16

PROJECT: NForce-Fiber Reinforced Concrete Evaluation

SUBJECT: Plastic Shrinkage Test to ASTM C1579

Jan 5, 2016 Batch Record			
Temperature	38 C	**Initial Set**	2 hrs 15 mins
Wind Velicty	4.8 m/s	**Final Set**	5 hrs
Relative Humidity	32%	**Evaporation Rate**	1.17 kg/m^2.h

Jan 12, 2016 Batch Record			
Temperature	39 C	**Initial Set**	2 hrs
Wind Velicty	4.8 m/s	**Final Set**	5.5 hrs
Relative Humidity	35%	**Evaporation Rate**	1.15 kg/m^2.h

Mixture	Cast Date	Fiber Content		Crack	Crack Width (mm)	Crack Reduction Ratio (CRR), %
		(kg/m^3)	(% volume)			
CNF (1.35)	**05-Jan-16**	NForce-Fiber, 1.35	0.10	Panel #1	0.3	**60**
				Panel #2	0.2	
				Average	0.25	
CSF*		Microsynthetic fiber, 1.35	0.15	Panel #1	0.1	**92**
				Panel #2	0.0	
				Average	0.05	
CP	**12-Jan-16**	Plain Concrete, 0	0	Panel #1	0.75	**N/A**
				Panel #2	0.50	
				Average	0.63	
CNF (2.0)*		NForce-Fiber, 2.0	0.15	Panel #1	0.0	**100**
				Panel #2	0.0	
				Average	0.0	

*CNF (2.0) and CSF have the same % volume of fiber in the mixture

Per: Lihe (John) Zhang, Ph.D., P.Eng
LZhang Consulting & Testing Ltd
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Delta, BC, V4M 1S3

Figure D-1: Controlled panel #1, 0 kg/m^3 fiber, crack width of 0.5-0.6 mm

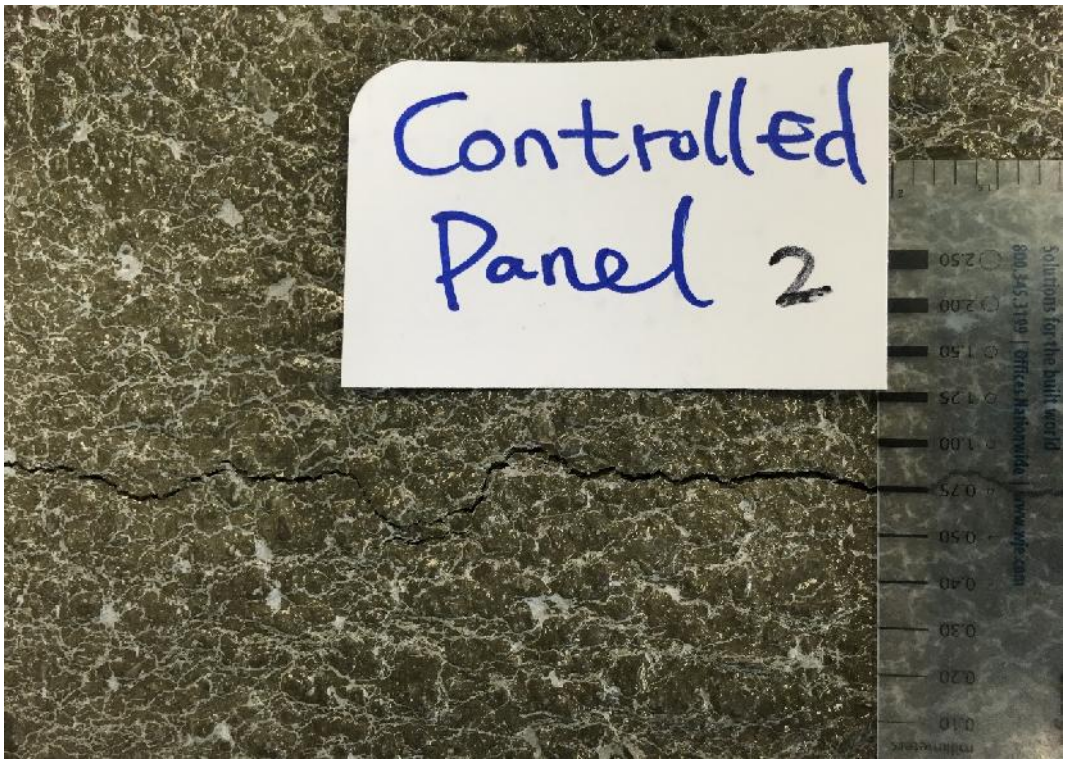

Figure D-2: Controlled panel #1, 0 kg/m^3 fiber, crack width of 0.75 mm

Figure D-3: NForce-Fiber panel #1, 2 kg/m^3 fiber, 0 mm crack width

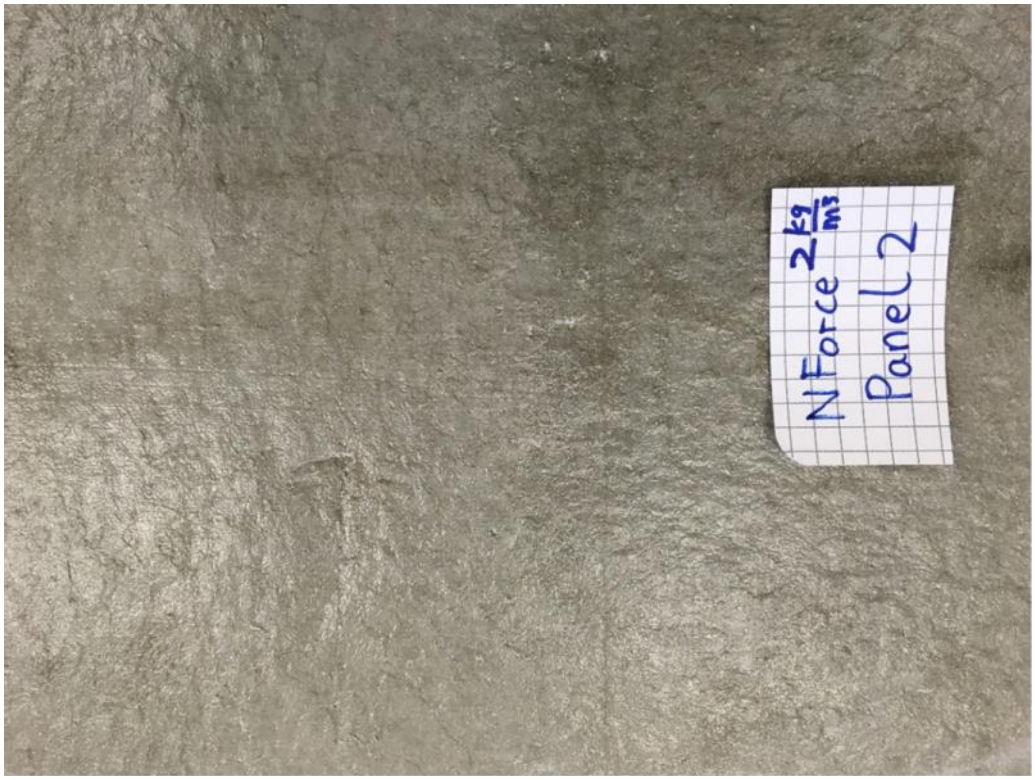

Figure D-4: NForce-Fiber panel #2, 2 kg/m^3 fiber, 0mm crack width

Figure D-5: NForce-Fiber panel #1, 1.35 kg/m^3 fiber, crack width of 0.2-0.3 mm

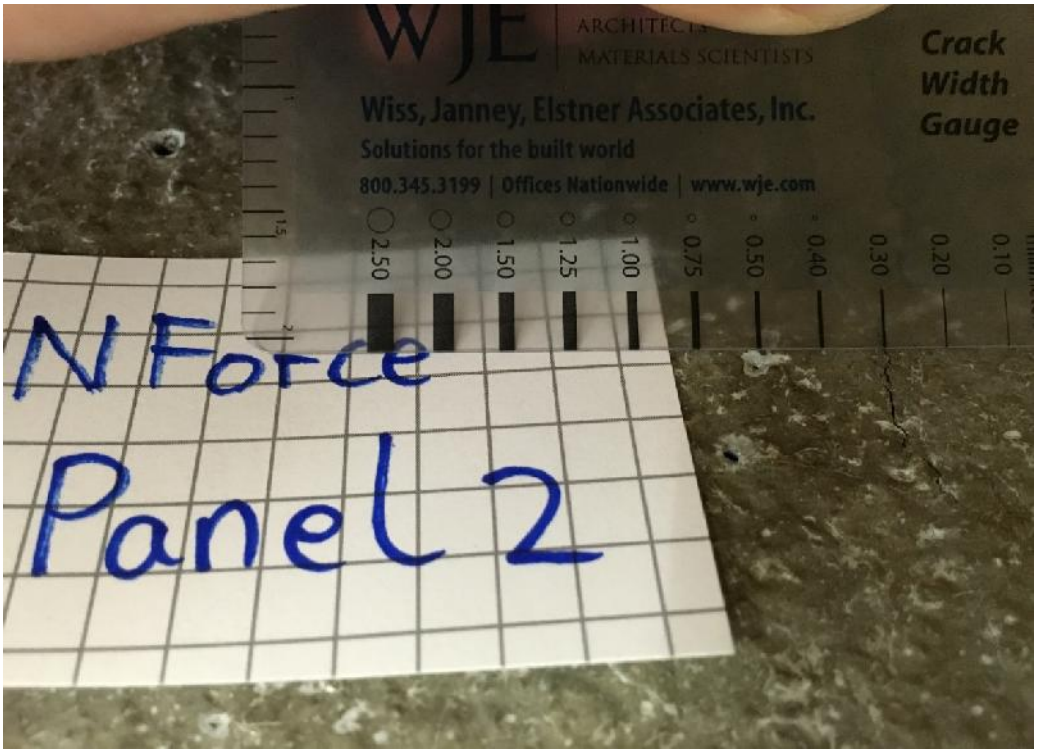

Figure D-6: NForce-Fiber fiber panel #2, 1.35 kg/m^3 fiber, crack width of 0.3 mm

Figure D-7: Microsynthetic fiber panel #1, 1.35 kg/m^3 fiber, crack width of 0 mm

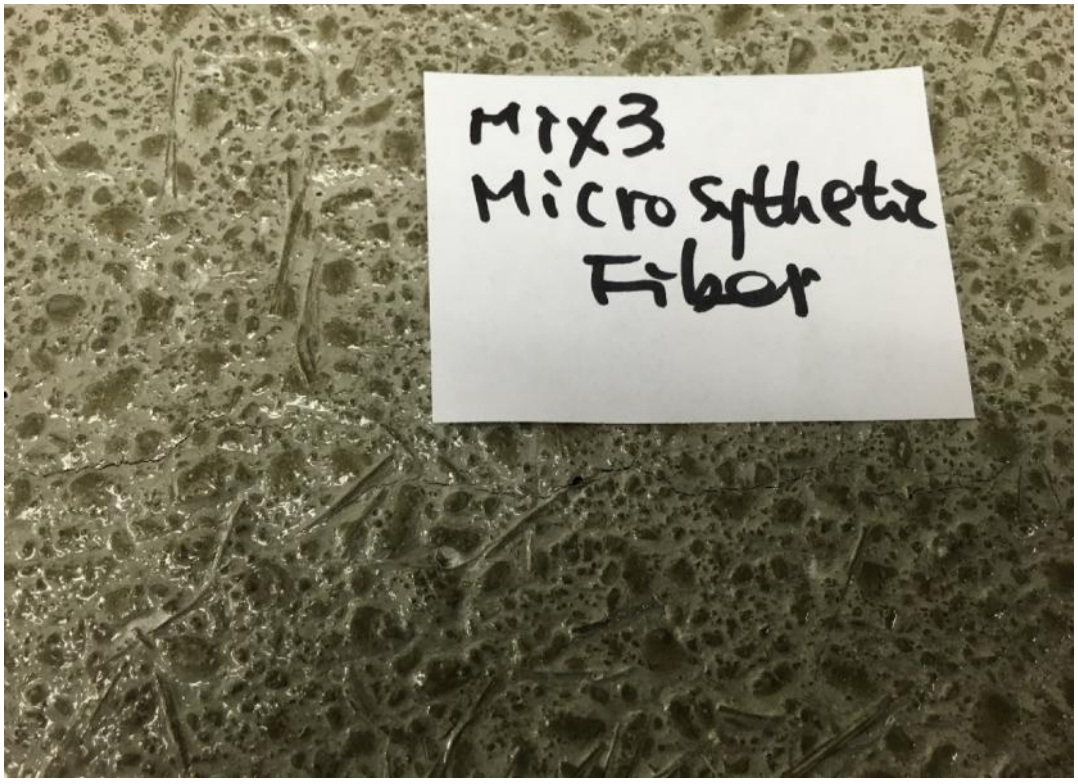

Figure D-8: Microsynthetic fiber panel #2, 1.35 kg/m^3 fiber, crack width of 0.1mm

APPENDIX E Finishability Evaluation

Figure E-1: Finishing tools (left to right): steel trowel, magnesium trowel, wood float, hard rubber float, textured rubber float, sponge float

Figure E-2: 1.35 kg/m^3 NForce-Fiber mix finish: steel trowel finish

Figure E-3: 1.35 kg/m^3 NForce-Fiber mix finish: magnesium finish

Figure E-4: 1.35 kg/m^3 NForce-Fiber mix finish: wood float finish

Figure E-5: 1.35 kg/m^3 NForce-Fiber mix finish: hard rubber float finish

Figure E-6: 1.35 kg/m^3 NForce-Fiber mix finish: textured rubber float finish

Figure E-7: 1.35 kg/m^3 NForce-Fiber mix finish: sponge float finish

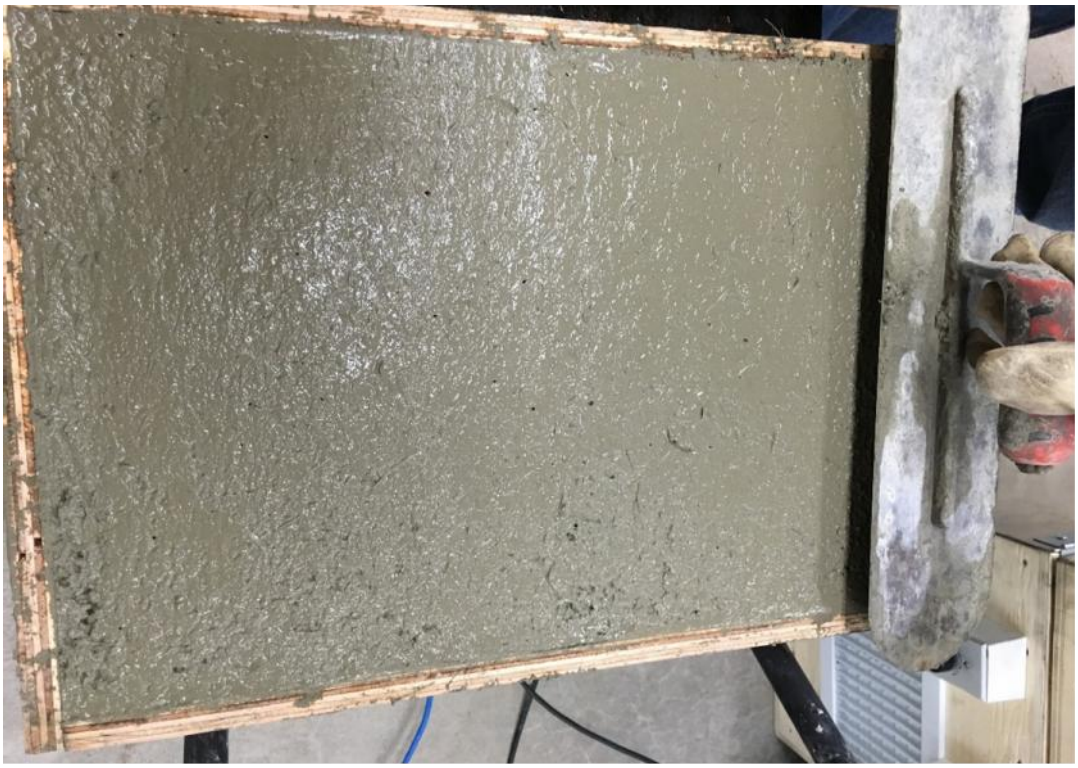

Figure E-8: 1.35 kg/m^3 microsynthetic fiber mix finish: steel trowel finish

Figure E-9: 1.35 kg/m^3 microsynthetic fiber mix finish: magnesium finish

Figure E-10: 1.35 kg/m^3 microsynthetic fiber mix finish: wood float finish

Figure E-11: 1.35 kg/m^3 microsynthetic fiber mix finish: hard rubber float finish

Figure E-12: 1.35 kg/m^3 microsynthetic fiber mix finish: textured rubber float finish

Figure E-13: 1.35 kg/m^3 microsynthetic fiber mix finish: sponge float finish

Figure E-14: 2 kg/m^3 NForce-Fiber finish: steel trowel finish

Figure E-15: 2 kg/m^3 NForce-Fiber finish: magnesium finish

Figure E-16: 2 kg/m^3 NForce-Fiber finish: wood float finish

Figure E-17: 2 kg/m^3 NForce-Fiber finish: hard rubber float finish

Figure E-18: 2 kg/m^3 NForce-Fiber finish: textured rubber float finish

Figure E-19: 2 kg/m^3 NForce-Fiber finish: sponge float finish

Appendix F: Compressive Strength

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LZhang File No: 11VA062
Date: 09-Feb-16

PROJECT: Nforce-Fiber Reinforced Concrete Evaluation

SUBJECT: Compressive Strength for Concrete Cylinders to ASTM C39

Date Cast: 21-Dec-15

Mixture	Fiber Content		Cylinder #	Age (days)	Load (kN)	Compressive Strength (MPa)	Average Compressive Strength (MPa)	Average Compressive Strength (psi)
	(kg/m^3)	(% volume)						
CP	0	0	1	7	278.3	34.2	34.7	5038
			2	7	282.1	34.7		
			3	7	287.6	35.3		
			4	28	348.7	42.8	41.5	6025
			5	28	332.4	40.8		
			6	28	333.3	40.9		
CNF (1.35)	1.35	0.1	1	7	282.3	34.7	35.4	5136
			2	7	288.1	35.4		
			3	7	294.2	36.2		
			4	28	338.4	41.6	41.1	5955
			5	28	319.6	39.3		
			6	28	344.5	42.3		
CNF (2.0)	2.0	0.15	1	7	274.3	33.7	33.4	4845
			2	7	272.1	33.4		
			3	7	269.2	33.1		
			4	28	330.7	40.6	40.7	5910
			5	28	335.8	41.3		
			6	28	328.5	40.4		
CSF	1.35	0.15	1	7	288.3	35.4	35.4	5130
			2	7	294.9	36.2		
			3	7	280.6	34.5		
			4	28	336.0	41.3	42.8	6207
			5	28	354.2	43.5		
			6	28	354.9	43.6		

Per: Lihe (John) Zhang, Ph.D., P.Eng
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Appendix G: Boiled Absorption and Volume of Permeable Voids

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LZhang File No: 11VA062
Date: 16-Feb-16

LZhang Consulting & Testing

PROJECT: **NForce-Fiber Reinforced Concrete Evaluation**
SUBJECT: **Boiled Absorption and Volume of Permeable Voids to ASTM C 642 at 28 Days of Age**

Date Cast: 21-Dec-15
Date Test: 18-Jan-16

Specified BV & VPV: 8% Boiled Absorption, 17% Volume of Permeable Voids

Sample No.	Batch Ticket # & Location	Absorption after immersion, %	Absorption after immersion and boiling, %	Bulk density, g1 (Mg/m3)	Bulk density after immersion (Mg/m3)	Bulk density after immersion and boiling (Mg/m3)	Apparent density (Mg/m3)	Volume of permeable voids, %
CP	No Fiber	4.8	5.1	2.251	2.360	2.365	2.540	11.4
		5.1	5.3	2.216	2.329	2.333	2.509	11.7
		5.1	5.3	2.231	2.344	2.348	2.527	11.7
Average		**5.0**	**5.2**	**2.232**	**2.344**	**2.348**	**2.525**	**11.6**
CNF (1.35)	NForce-Fiber, 1.35 kg/m^3	5.0	5.5	2.257	2.371	2.382	2.578	12.4
		5.3	5.8	2.260	2.380	2.391	2.601	13.1
		5.0	5.4	2.265	2.377	2.388	2.583	12.3
Average		**5.1**	**5.6**	**2.261**	**2.376**	**2.387**	**2.587**	**12.6**
CNF (2.0)	NForce-Fiber, 2.0 kg/m^3	5.5	5.6	2.166	2.285	2.288	2.465	12.1
		5.5	5.7	2.155	2.275	2.278	2.456	12.3
		5.4	5.6	2.341	2.468	2.473	2.696	13.2
Average		**5.5**	**5.6**	**2.221**	**2.342**	**2.346**	**2.539**	**12.5**
CSF	Microsynthetic fiber, 1.35 kg/m^3	5.3	5.7	2.249	2.370	2.377	2.579	12.8
		5.3	5.6	2.246	2.364	2.372	2.570	12.6
		5.2	5.5	2.257	2.374	2.382	2.579	12.5
Average		**5.3**	**5.6**	**2.251**	**2.369**	**2.377**	**2.576**	**12.6**

Tested by: Manuel Garcia
Technician

Reported by: Lihe (John) Zhang, Ph.D., P.Eng
Materials Engineer
LZhang Consulting & Testing Ltd

Appendix H: Rapid Chloride Penetration Test Results

LZhang
Consulting & Testing

CANADIAN GREENFIELD TECHNOLOGIES CORP.
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Calgary, AB
Canada, T2C 0J4

LZhang File No: 11VA062
Date: 13-Apr-16

PROJECT: NForce-Fiber Reinforced Concrete Evaluation
SUBJECT: Rapid Chlorid Penetration Test to ASTM C1202

Sample ID	Age (days)	Thickness (mm)	Diameter (mm)	Charge Passed after Six Hours (Coulombs)	Average Charge Passed after Six Hours (Coulombs)	ASTM C1202 Rating	
						Charged Passed (Coulombs)	Chloride Ion Penetrability
CP-1	91	50.9	102.3	1070	**1076**	>4,000	High
CP-2	91	51.3	102.3	1080		2,000-4,000	Moderate
CP-3	91	50.2	101.6	1078		1,000-2,000	Low
CNF (1.35)-1	91	50.6	101.7	1171	**1176**	100-1,000	Very Low
CNF (1.35)-2	91	51.3	102.3	1188			
CNF (1.35)-3	91	50.2	101.6	1168			
CNF (2.0)-1	91	50.6	101.7	1239	**1241**		
CNF (2.0)-2	91	51.3	102.3	1248			
CNF (2.0)-3	91	50.2	101.6	1236			
CSF-1	91	50.6	101.7	1091	**1085**		
CSF-2	91	51.3	102.3	1098			
CSF-3	91	50.2	101.6	1065			

Comments: 1- Samples are Disc with 50 mm thick saw cut from the top of the concrete cylinder.
2- Specimens cured in the lime water curing tank at 23±1 ° C.

Tested by: Manuel Garcia, Technician
Laboratory Technician

Reported by: Lihe (John) Zhang, Ph.D., P.Eng
Materials Engineer
LZhang Consulting & Testing Ltd

Appenix I: Flexural Toughness to ASTM C1609 Mix CP (No Fiber)

CANADIAN GREENFIELD TECHNOLOGIES CORP.
Mr. Mike Pildysh, M.Eng., P.Eng, President
#159, 3953 112 Ave SE
Calgary, AB
Canada, T2C 0J4

LZhang File No: 11VA062
Date: 09-Feb-16

PROJECT: Nforce-Fiber Reinforced Concrete Evaluation

SUBJECT: Flexural Performance of Non-Fiber-Reinforced Concrete to ASTM C 1609/C 1609 M - 12

Sample No.	Peak Load (kN)	Peak Strength (MPa)	Peak-Load Deflection (mm)	Residual Load (kN)		Residual Strength (MPa)		Toughness $T_{100,\ 2.0}$ (J)	Equivalent Flexural Strength
				$P_{100,0.5}$	$P_{100,2.0}$	$f_{100,0.5}$	$f_{100,2.0}$		$R_{100,\ 2.0}$
CP-1	21.10	6.14	0.0424	Not applicable*					
CP-2	20.01	5.83	0.0399						
CP-3	19.37	5.64	0.0413						
AVG.	**20.16**	**5.87**	**0.0412**						

*All three beams fractured into two parts at peak load, no residual load

Per: LZhang Consulting & Testing Ltd
5069 7B Avenue
Delta, BC V4M 1S3

Appenix I: Flexural Toughness to ASTM C1609 Mix CNF (1.35) (NForce-Fiber)

CANADIAN GREENFIELD TECHNOLOGIES CORP.
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Calgary, AB
Canada, T2C 0J4

LZhang File No: 11VA062
Date: 18-Jan-16

PROJECT: Nforce-Fiber Reinforced Concrete Evaluation

SUBJECT: Flexural Performance of Fiber-Reinforced Concrete to ASTM C 1609/C 1609 M - 12

Sample No.	Peak Load (kN)	Peak Strength (MPa)	Peak-Load Deflection (mm)	Residual Load (kN)		Residual Strength (MPa)		Toughness $T_{100,\ 2.0}$ (J)	Equivalent Flexural Strength
				$P_{100,0.5}$	$P_{100,2.0}$	$f_{100,0.5}$	$f_{100,2.0}$		$R_{100,\ 2.0}$
CNF (1.35)-1	21.16	6.05	0.043	Not applicable*					
CNF (1.35)-2	21.44	6.13	0.040						
CNF (1.35)-3	20.96	5.99	0.042						
AVG.	**21.19**	**6.06**	**0.042**						

*All three beams fractured into two parts at peak load, no residual load

Per: LZhang Consulting & Testing Ltd
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Delta, BC V4M 1S3

Appenix I: Flexural Toughness to ASTM C1609 Mix CNF (2.0) (NForce-Fiber)

CANADIAN GREENFIELD TECHNOLOGIES CORP.
Mr. Mike Pildysh, M.Eng., P.Eng, President
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Canada, T2C 0J4

LZhang File No: 11VA062
Date: 09-Feb-16

PROJECT: Nforce-Fiber Reinforced Concrete Evaluation

SUBJECT: Flexural Performance of Fiber-Reinforced Concrete to ASTM C 1609/C 1609 M - 12

Sample No.	Peak Load (kN)	Peak Strength (MPa)	Peak-Load Deflection (mm)	Residual Load (kN)		Residual Strength (MPa)		Toughness $T_{100,\ 2.0}$ (J)	Equivalent Flexural Strength
				$P_{100,0.5}$	$P_{100,2.0}$	$f_{100,0.5}$	$f_{100,2.0}$		$R_{100,\ 2.0}$
CNF (2.0)-1	19.70	5.74	0.043	Not applicable*					
CNF (2.0)-2	21.18	6.17	0.046						
CNF (2.0)-3	21.73	6.33	0.046						
AVG.	**20.87**	**6.08**	**0.045**						

*All three beams fractured into two parts at peak load, no residual load

Per: LZhang Consulting & Testing Ltd
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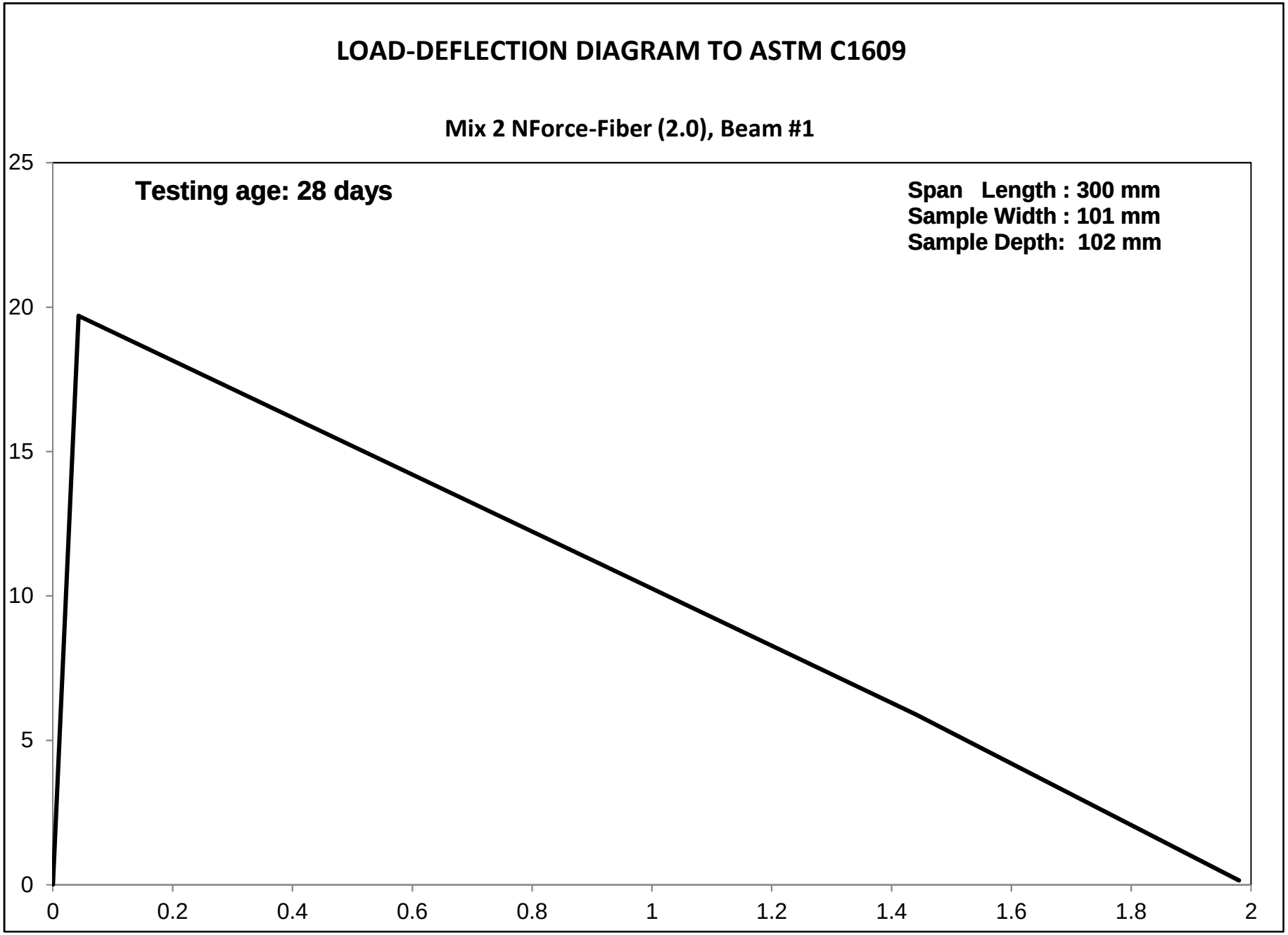
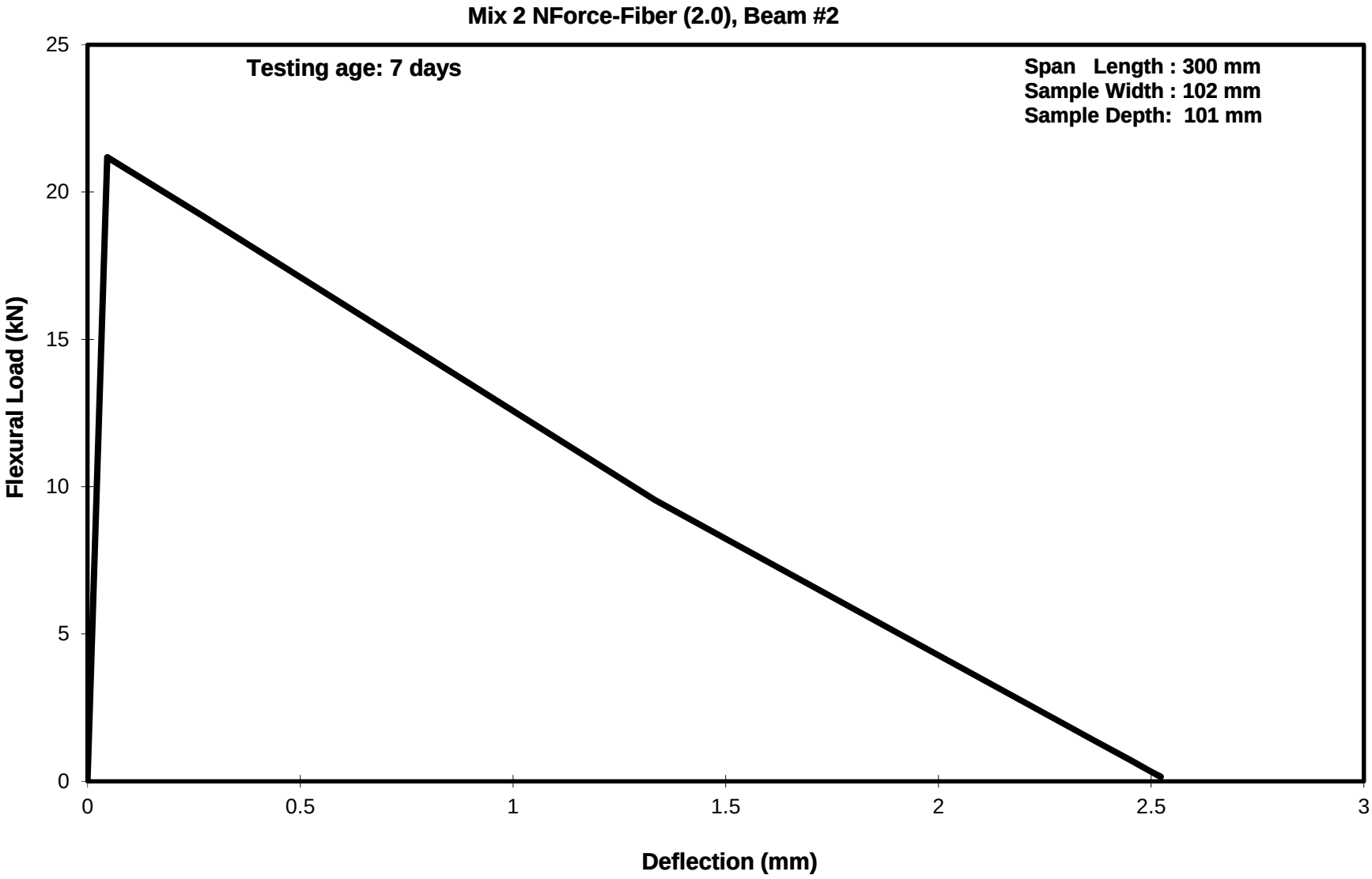
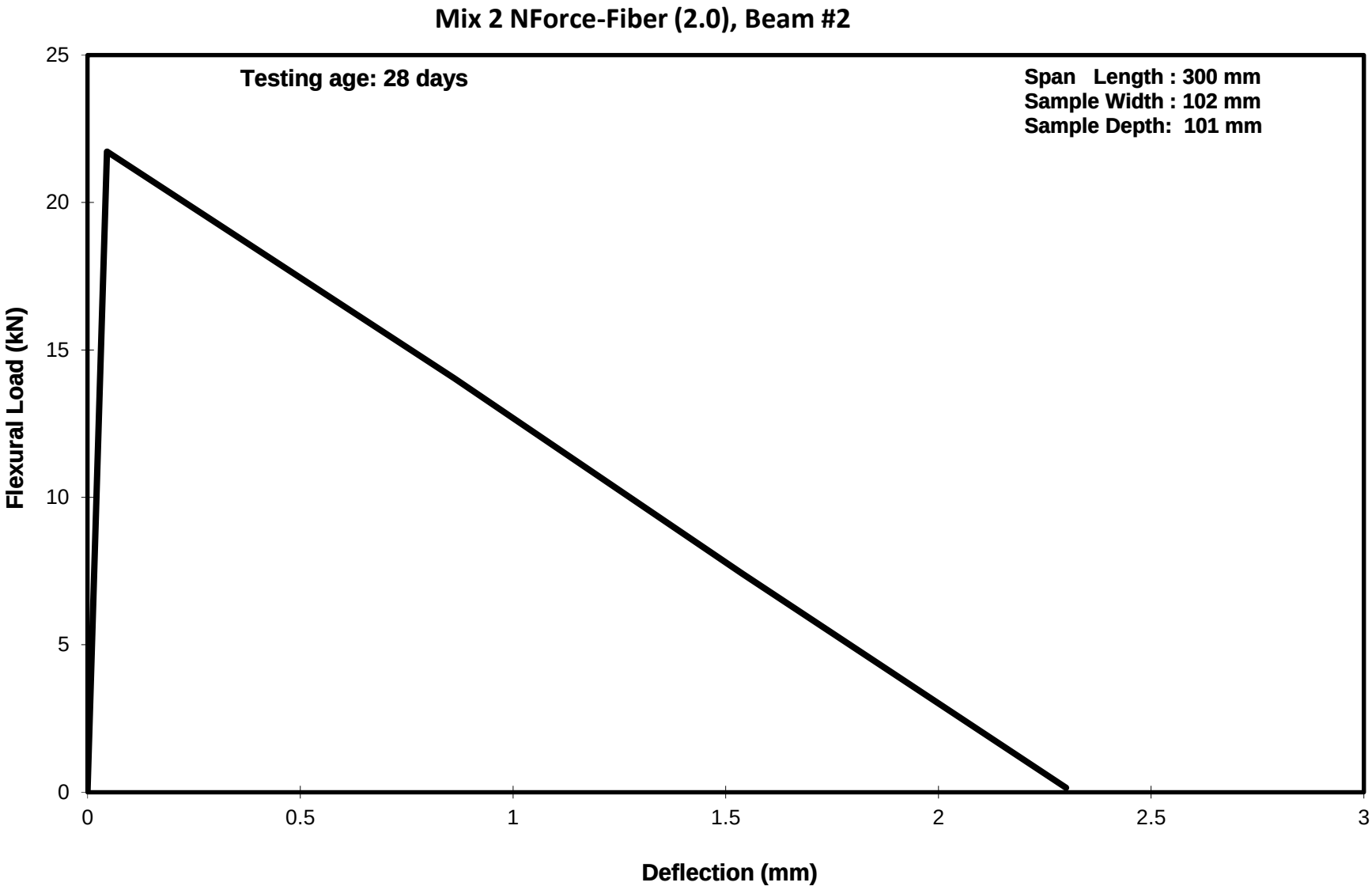

LOAD-DEFLECTION DIAGRAM TO ASTM C1609
Mix 2 NForce-Fiber (2.0), Beam #1
Testing age: 28 days
Span Length : 300 mm
Sample Width : 101 mm
Sample Depth: 102 mm
25
20
15
10
5
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

LOAD-DEFLECTION DIAGRAM TO ASTM C1609



LOAD-DEFLECTION DIAGRAM TO ASTM C1609



Appendix I: Flexural Toughness to ASTM C1609: Mix CSF (Microsynthetic Fiber)

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LZhang File No: 11VA062
Date: 18-Jan-16

PROJECT: Nforce-Fiber Reinforced Concrete Evaluation

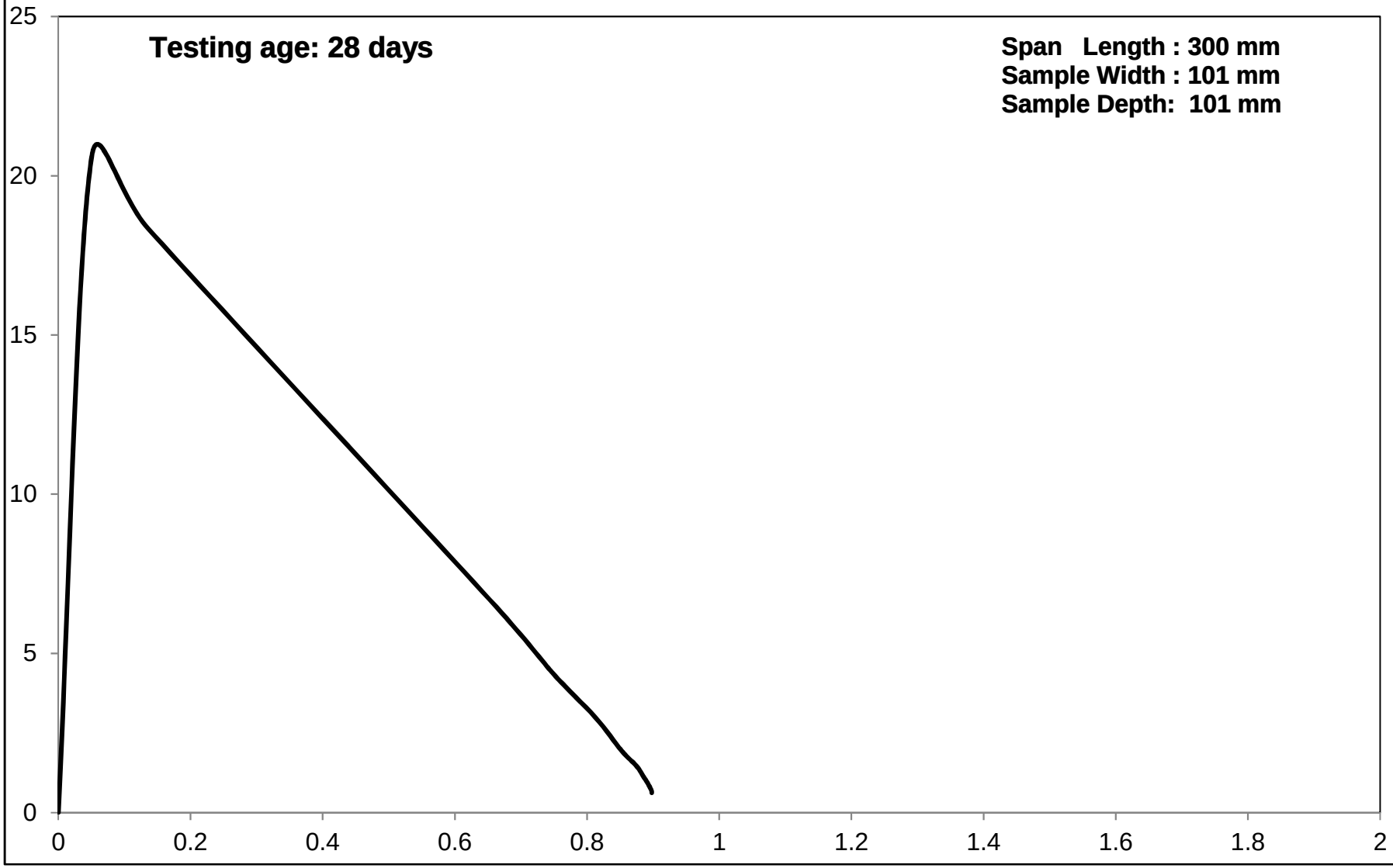
SUBJECT: Flexural Performance of Fiber-Reinforced Concrete to ASTM C 1609/C 1609 M - 12

Sample No.	Peak Load (kN)	Peak Strength (MPa)	Peak-Load Deflection (mm)	Residual Load (kN)		Residual Strength (MPa)		Toughness $T_{100,\ 2.0}$ (J)	Equivalent Flexural Strength
				$P_{100,0.5}$	$P_{100,2.0}$	$f_{100,0.5}$	$f_{100,2.0}$		$R_{100,\ 2.0}$
CSF-1	20.59	5.88	0.050	18.34	0.62	5.24	0.18	9.54	3.0%
CSF-2	21.71	6.21	0.045	9.97	1.32	2.85	0.38	11.21	6.1%
CSF-3	20.44	6.00	0.043	0.91	0.79	0.27	0.23	4.95	3.9%
AVG.	**20.91**	**6.03**	**0.046**	**9.74**	**0.91**	**2.79**	**0.26**	**8.57**	**4.3%**

Per: LZhang Consulting & Testing Ltd
5069 7B Avenue
Delta, BC V4M 1S3

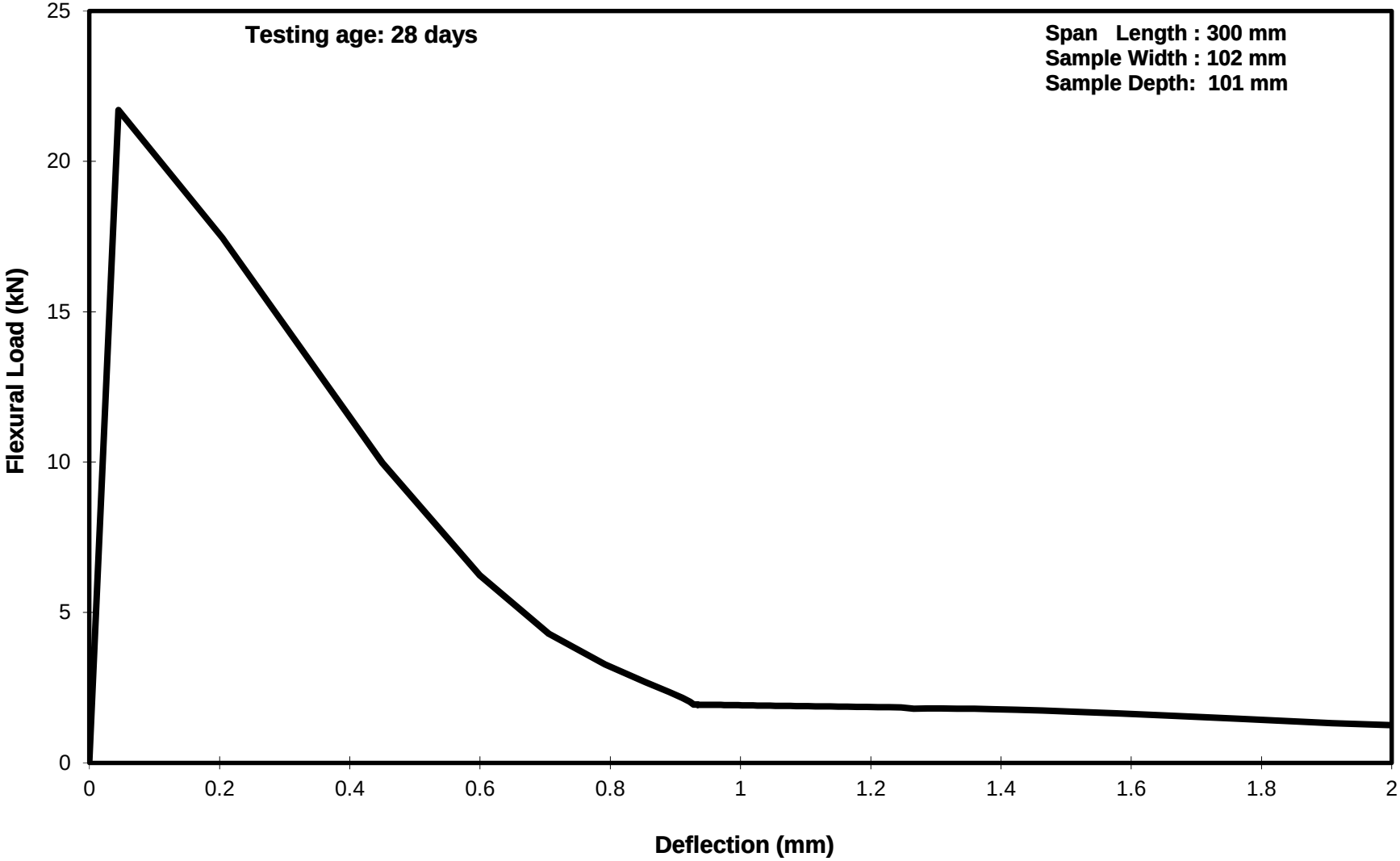
LOAD-DEFLECTION DIAGRAM TO ASTM C1609

Mix CSF: Microsynthetic Fiber at 1.35 kg/m³
Beam #1



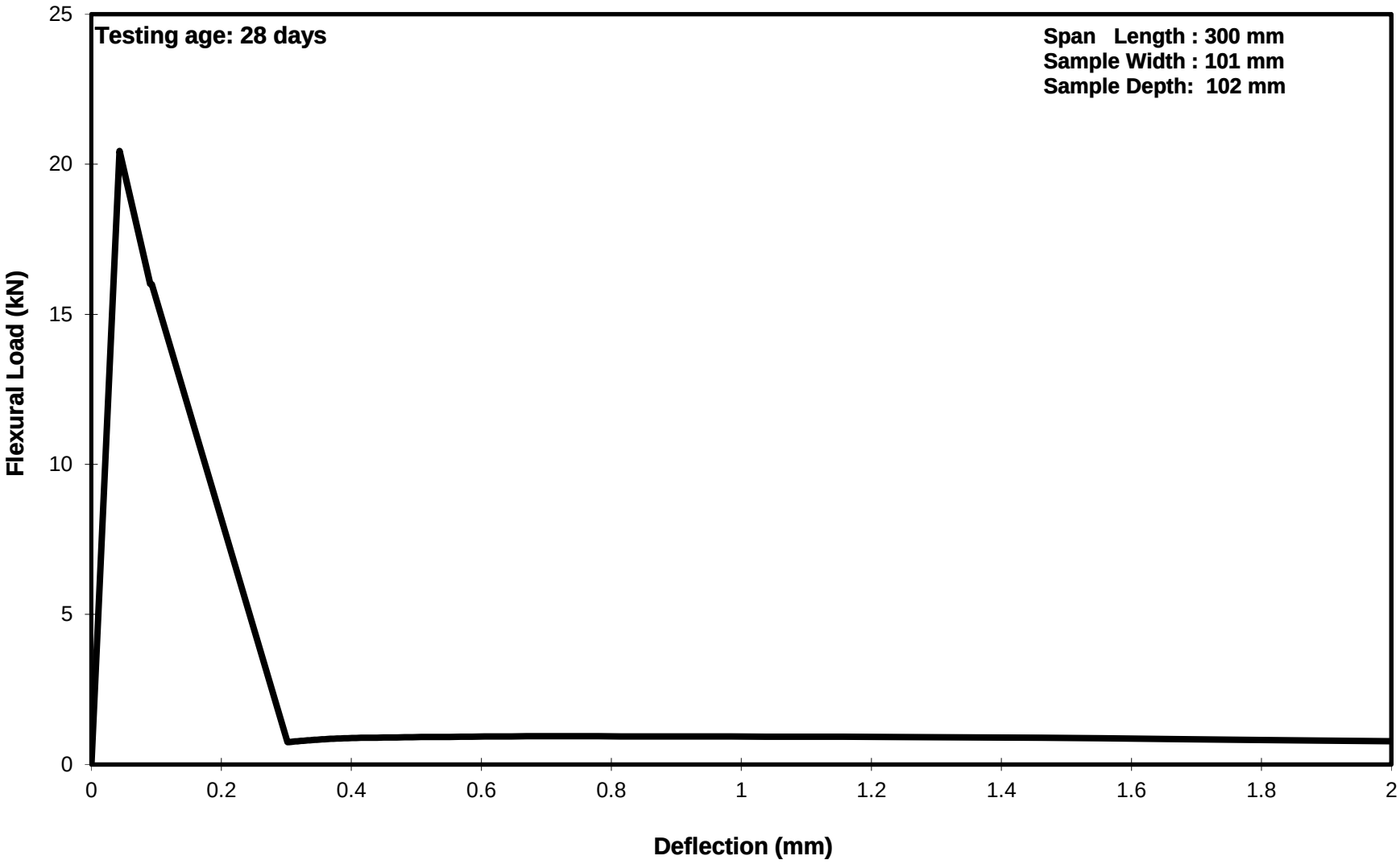
LOAD-DEFLECTION DIAGRAM TO ASTM C1609

Mix CSF: Microsynthetic Fiber at 1.35 kg/m^3
Beam #2



LOAD-DEFLECTION DIAGRAM TO ASTM C1609

Mix CSF: Microsynthetic Fiber at 1.35 kg/m^3
Beam #3



Appendix I: Residual Strength to ASTM C1399: Mix CP (No Fiber)

CANADIAN GREENFIELD TECHNOLOGIES CORP.
Mr. Mike Pildysh, M.Eng., P.Eng, President
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Canada, T2C 0J4

LZhang File No: 11VA062
Date: 09-Feb-16

PROJECT: Nforce-Fiber Reinforced Concrete Evaluation

SUBJECT: Flexural Performance of Non-Fiber-Reinforced Concrete to ASTM C 1399 - 10

	Initial Loading		Reloading										
				Residual Load (kN)					Residual Strength (MPa)				
Sample No.	Peak Load (kN)	Deflection at Peak Load (mm)	Peak Load at Reloading (kN)	$P_{100,0.5}$**	$P_{100,0.75}$	$P_{100,1.0}$	$P_{100,1.25}$	Average Residual Load (kN)	$f_{100,0.5}$***	$f_{100,0.75}$	$f_{100,1.0}$	$f_{100,1.25}$	Average Residual Strength (MPa)
CP-1	26.41	0.040	No residual load & residual strength										
CP-2	24.00	0.045											
CP-3	23.35	0.043											
AVG.	**24.58**	**0.043**											

* $P_{100,0.5}$ is the residual load at 0.5 mm deflection

** $f_{100,0.5}$ is the residual strength at 0.5 mm deflection

Per: LZhang Consulting & Testing Ltd
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Appdneix I: Residual Strength to ASTM C1399 Mix CNF (1.35) (NForce-Fiber)

CANADIAN GREENFIELD TECHNOLOGIES CORP.
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LZhang File No: 11VA062
Date: 18-Jan-16

PROJECT: Nforce-Fiber Reinforced Concrete Evaluation

SUBJECT: Flexural Performance of NForce-Fiber Reinforced Concrete to ASTM C 1399 - 10

	Initial Loading		Reloading									
				Residual Load (kN)				Residual Strength (MPa)				
Sample No.	Peak Load (kN)	Deflection at Peak Load (mm)	Peak Load at Reloading (kN)	$P_{100,0.75}$	$P_{100,1.0}$	$P_{100,1.25}$	Average Residual Load (kN)	$f_{100,0.5}$***	$f_{100,0.75}$	$f_{100,1.0}$	$f_{100,1.25}$	Average Residual Strength (MPa)
CNF (1.35)-1	17.52	0.035	0.89	0.36	0.23	0.15	0.31	0.15	0.10	0.07	0.04	0.09
CNF(1.35)-2	23.12	0.041	0.71	0.12	0.08	0.06	0.11	0.05	0.04	0.02	0.02	0.03
CNF (1.35)-3	19.84	0.047	0.87	0.31	0.25	0.20	0.30	0.13	0.09	0.07	0.06	0.09
AVG.	**20.16**	**0.041**	**0.82**	**0.26**	**0.19**	**0.14**	**0.24**	**0.11**	**0.08**	**0.05**	**0.04**	**0.07**

* $P_{100,0.5}$ is the residual load at 0.5 mm deflection

** $f_{100,0.5}$ is the residual strength at 0.5 mm deflection

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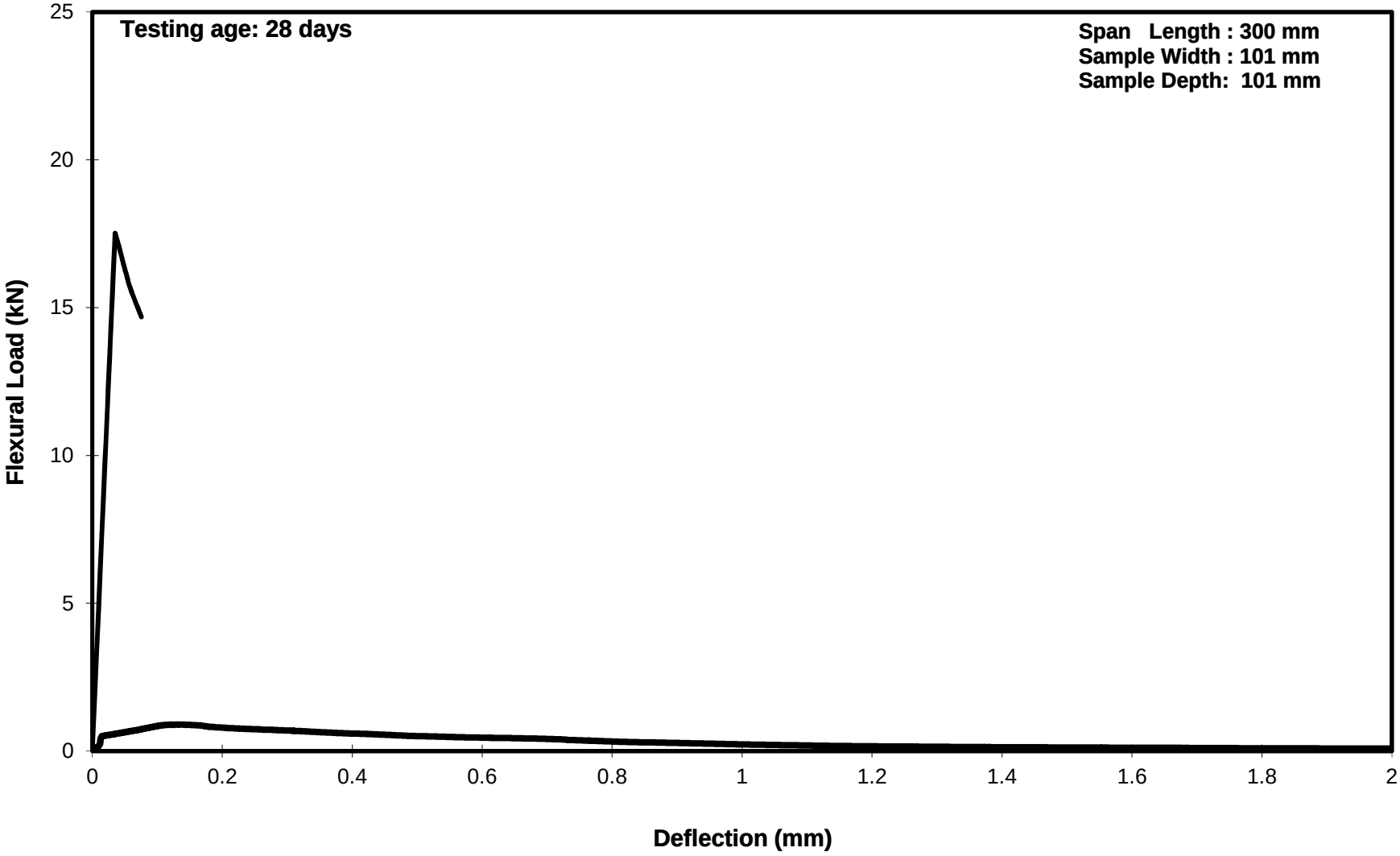
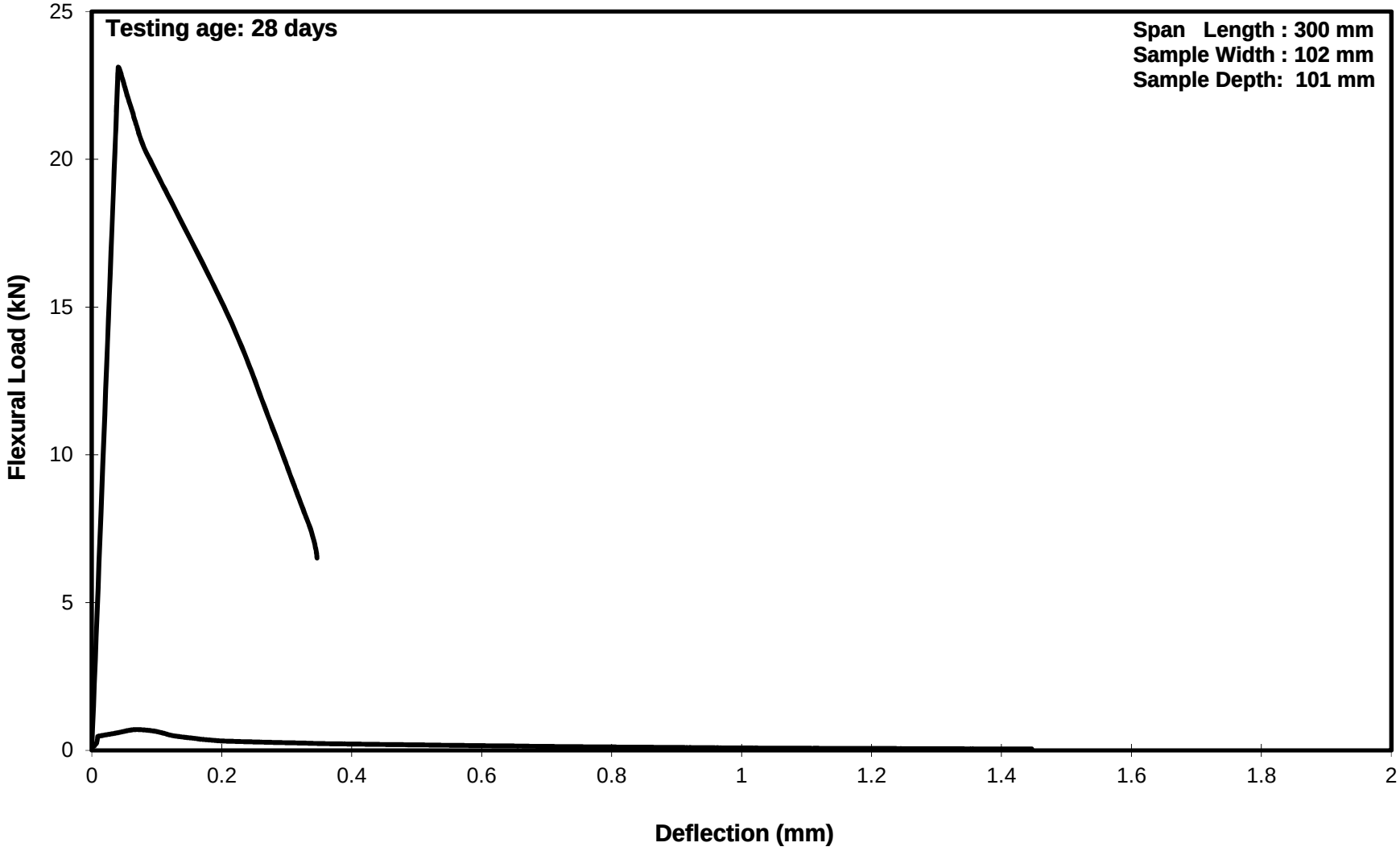
LOAD-DEFLECTION DIAGRAM TO ASTM C1399

Mix CNF: NForced-Fiber at 1.35 kg/m^3
Beam #1

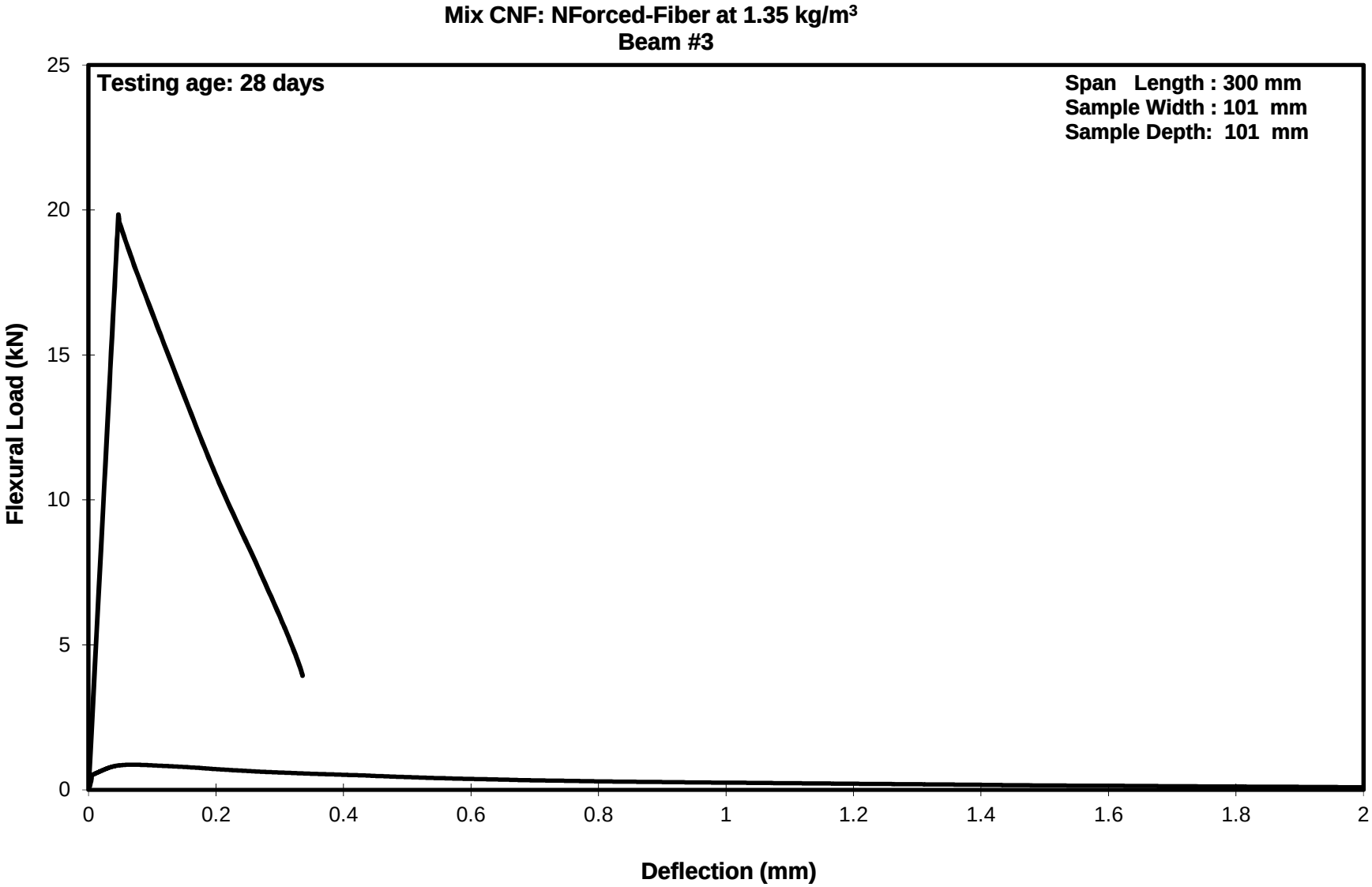


LOAD-DEFLECTION DIAGRAM TO ASTM C1399

Mix CNF: NForced-Fiber at 1.35 kg/m^3
Beam #2



LOAD-DEFLECTION DIAGRAM TO ASTM C1399



Appdneix I: Residual Strength to ASTM C1399 Mix CNF (2.0) (NForce-Fiber)

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LZhang File No: 11VA062
Date: 09-Feb-16

PROJECT: Nforce-Fiber Reinforced Concrete Evaluation

SUBJECT: Flexural Performance of NForce-Fiber Reinforced Concrete to ASTM C 1399 - 10

	Initial Loading		Reloading										
				Residual Load (kN)					Residual Strength (MPa)				
Sample No.	Peak Load (kN)	Deflection at Peak Load (mm)	Peak Load at Reloading (kN)	$P_{100,0.5}$**	$P_{100,0.75}$	$P_{100,1.0}$	$P_{100,1.25}$	Average Residual Load (kN)	$f_{100,0.5}$***	$f_{100,0.75}$	$f_{100,1.0}$	$f_{100,1.25}$	Average Residual Strength (MPa)
CNF (2.0)-1	19.25	0.056	1.07	0.61	0.44	0.27	0.18	0.38	0.17	0.13	0.08	0.05	0.11
CNF (2.0)-2	20.50	0.033	0.86	0.70	0.40	0.31	0.22	0.41	0.14	0.12	0.09	0.06	0.10
CNF (2.0)-3	25.00	0.047	1.61	0.66	0.46	0.35	0.26	0.43	0.19	0.13	0.10	0.08	0.13
AVG.	**21.58**	**0.045**	**1.18**	**0.66**	**0.43**	**0.31**	**0.22**	**0.41**	**0.17**	**0.13**	**0.09**	**0.06**	**0.11**

* $P_{100,0.5}$ is the residual load at 0.5 mm deflection

** $f_{100,0.5}$ is the residual strength at 0.5 mm deflection

Per: LZhang Consulting & Testing Ltd
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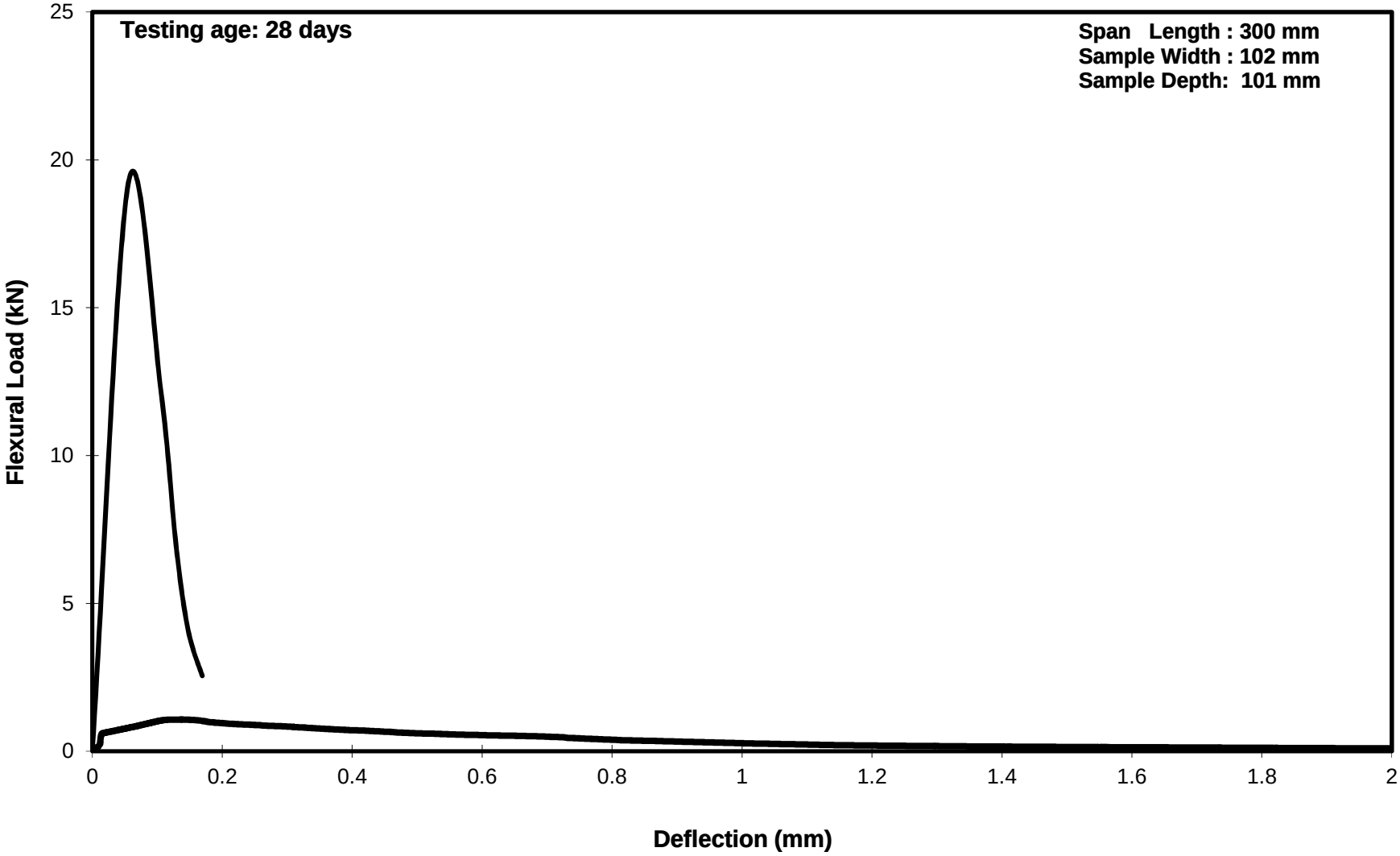
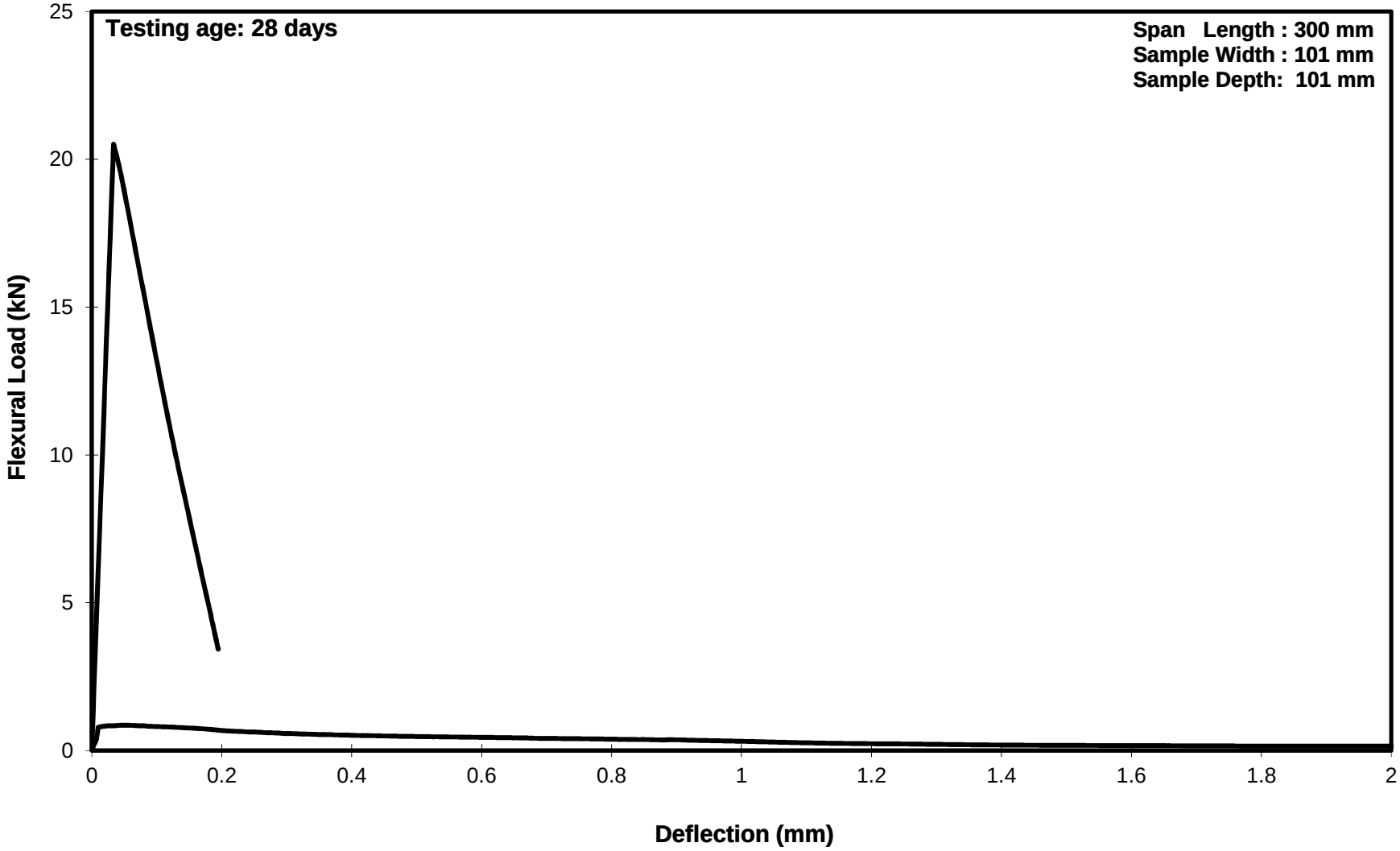
LOAD-DEFLECTION DIAGRAM TO ASTM C1399

Mix CNF: NForced-Fiber at 2.0 kg/m^3
Beam #1

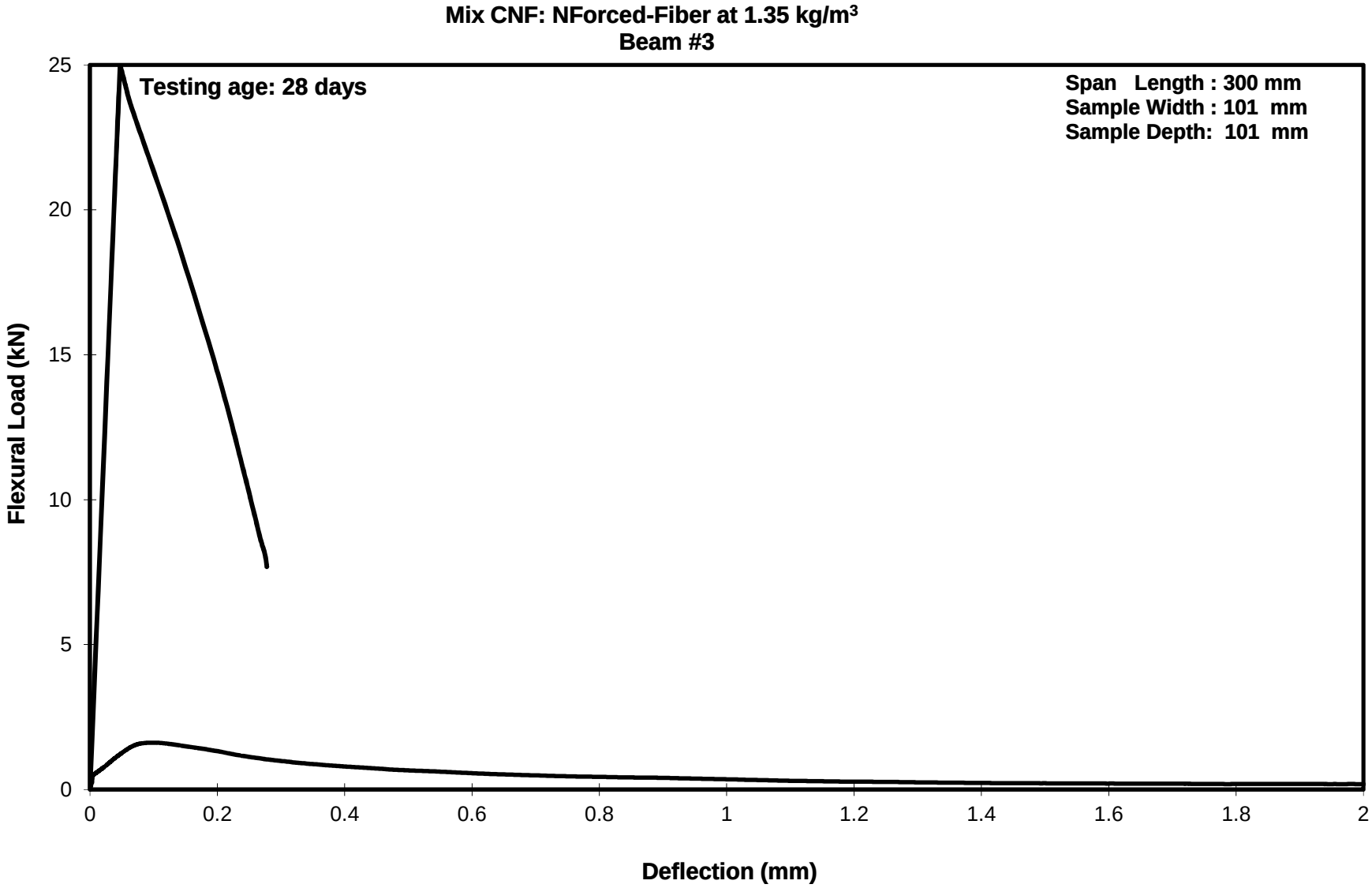


LOAD-DEFLECTION DIAGRAM TO ASTM C1399

Mix CNF: NForced-Fiber at 2.0 kg/m^3
Beam #2



LOAD-DEFLECTION DIAGRAM TO ASTM C1399



Appendix I: Residual Strength to ASTM C1399: Mix CSF (Microsynthetic Fiber)

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LZhang File No: 11VA062
Date: 18-Jan-16

PROJECT: Nforce-Fiber Reinforced Concrete Evaluation

SUBJECT: Flexural Performance of Microsynthetic Fiber-Reinforced Concrete to ASTM C 1399 - 10

	Initial Loading		Reloading										
				Residual Load (kN)					Residual Strength (MPa)				
Sample No.	Peak Load (kN)	Deflection at Peak Load (mm)	Peak Load at Reloading (kN)	$P_{100,0.5}$**	$P_{100,0.75}$	$P_{100,1.0}$	$P_{100,1.25}$	Average Residual Load (kN)	$f_{100,0.5}$***	$f_{100,0.75}$	$f_{100,1.0}$	$f_{100,1.25}$	Average Residual Strength (MPa)
CSF-1	17.53	0.042	1.50	1.48	1.47	1.43	1.35	1.43	0.43	0.42	0.41	0.39	0.41
CSF-2	25.21	0.043	2.97	1.93	1.89	1.78	1.69	1.82	0.56	0.54	0.52	0.49	0.53
CSF-3	23.71	0.048	8.85	2.33	2.12	1.97	1.85	2.07	0.67	0.61	0.56	0.53	0.59
AVG.	**22.15**	**0.044**	**4.44**	**1.91**	**1.83**	**1.73**	**1.63**	**1.77**	**0.55**	**0.53**	**0.50**	**0.47**	**0.51**

* $P_{100,0.5}$ is the residual load at 0.5 mm deflection

** $f_{100,0.5}$ is the residual strength at 0.5 mm deflection

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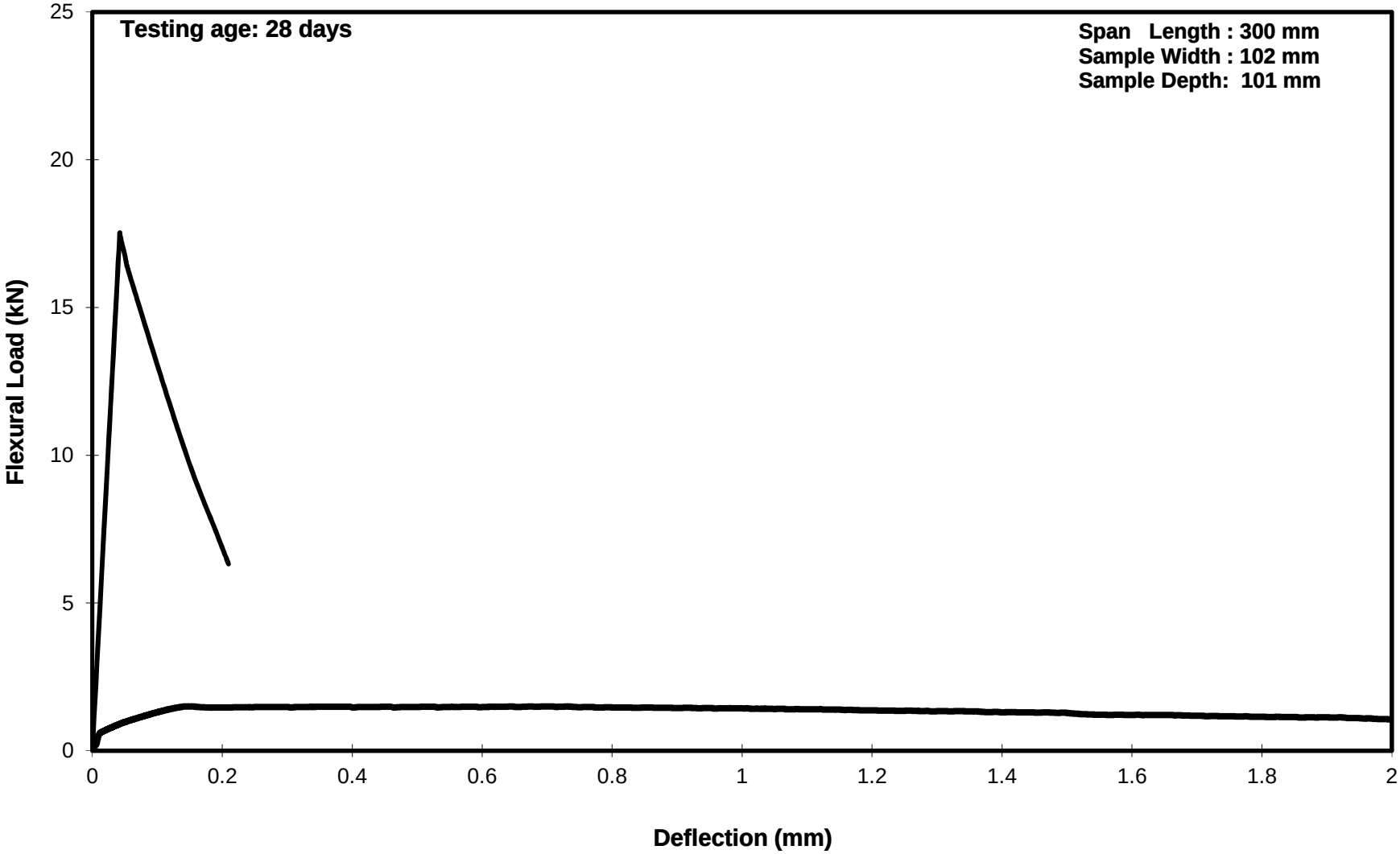
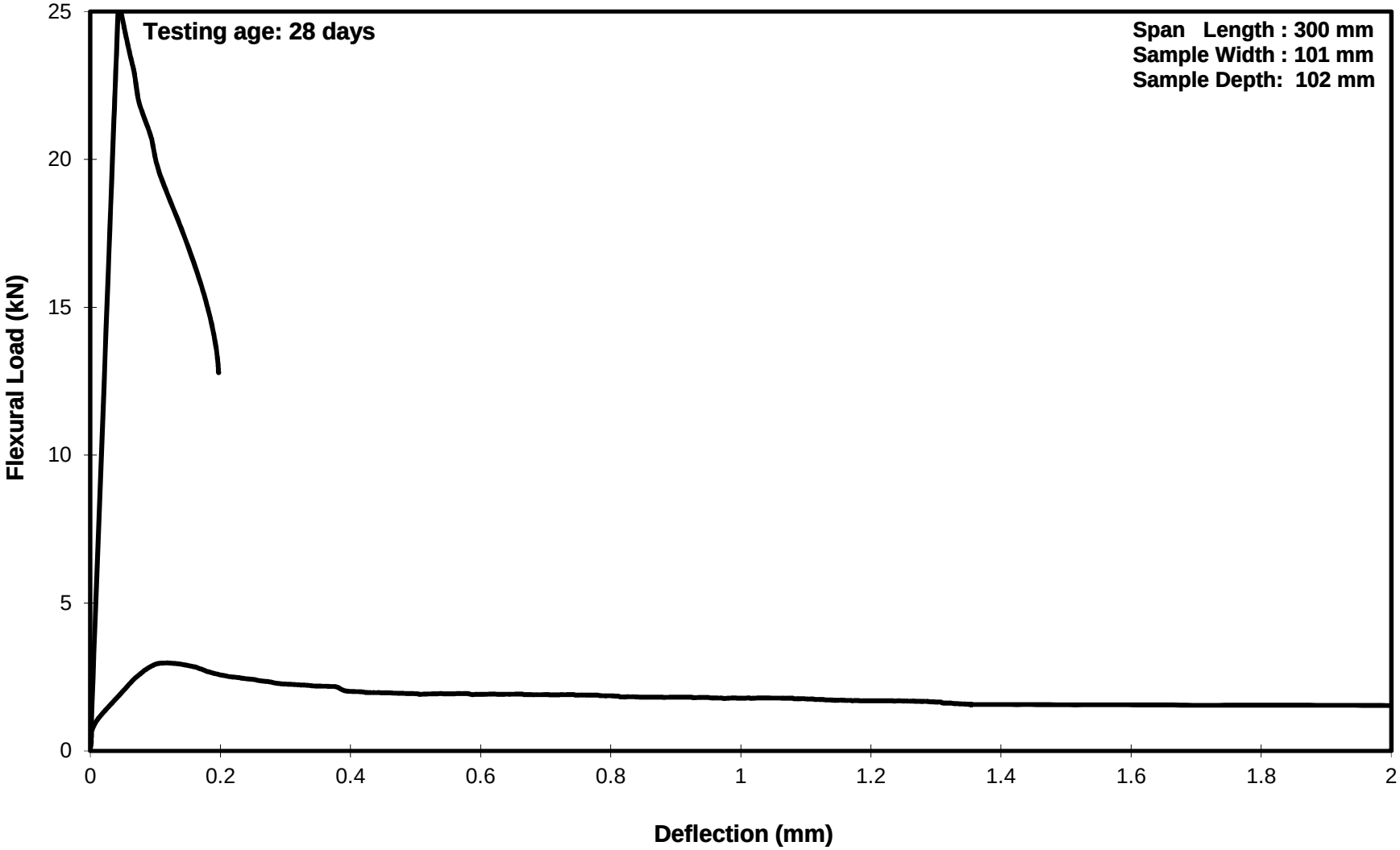
LOAD-DEFLECTION DIAGRAM TO ASTM C1399

Mix CSF: Microsynthetic Fiber at 1.35 kg/m^3
Beam #1



LOAD-DEFLECTION DIAGRAM TO ASTM C1399

Mix CSF: Microsynthetic Fiber at 1.35 kg/m^3
Beam #2



LOAD-DEFLECTION DIAGRAM TO ASTM C1399