Steel Fibers
Shotcrete

Fibercon: We do not claim — We Prove

Fibercon International
100 South Third Street Evans City, PA 16033
Tel: 724-538-5006  Fax: 724-538-9118
www.fiberconfiber.com
We want to thank you for considering the use of Fibercon steel fiber reinforced concrete on your upcoming shotcrete project.

Steel fibers have proven themselves for many years to provide excellent crack containment on these structures. The random distribution of steel fiber reinforcement means that micro-cracks that increase in size through normal development are subjected to a steel fiber barrier. Thus, small cracks are interrupted before developing into larger cracks. Add to this the safety factor of not tripping over the mesh and the ease of delivering the reinforcement with the concrete not cranes the day before, you can see the benefits of using steel fiber reinforcement on these applications.

Serving the concrete industry since 1972, Fibercon’s Research and Development department is continually refining its products and developing solutions to industry problems, both in the lab and in real-world conditions. In this way, Fibercon plans to remain the leader in providing steel fiber for the concrete industry for the next 37 years.

We look forward to working with you in the future.

George N. Mitchell
President, Fibercon International

Nicholas C. Mitchell, Jr.
Vice-President, Fibercon International
MATERIAL DATA SHEET
ASTM A820 TYPE II
Steel Fiber Reinforcement for Concrete

<table>
<thead>
<tr>
<th>Fiber Type:</th>
<th>Low carbon cut sheet steel fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product:</td>
<td>CAR35EDM</td>
</tr>
<tr>
<td>Dimensions:</td>
<td>Fibers are manufactured with tolerances set forth in ASTM A820-06</td>
</tr>
<tr>
<td>Aspect Ratio:</td>
<td>56 (as per customer specification or requirement)</td>
</tr>
<tr>
<td>Tensile Strength:</td>
<td>100,000 psi</td>
</tr>
<tr>
<td>Specific Gravity:</td>
<td>7.86</td>
</tr>
<tr>
<td>Melting Point:</td>
<td>2760° F</td>
</tr>
<tr>
<td>Specification:</td>
<td>The steel fiber specified shall be manufactured from a low carbon steel and meet physical property requirements of ASTM A820 Type II steel fiber. Fiber length shall be 35mm. The configuration required is end deformed mild. Aspect ratio required is 56. The steel fibers must be clean and free from rust, oil and deleterious material.</td>
</tr>
</tbody>
</table>
Fibercon® steel fibers are manufactured using a method known as “Slit Sheet” processing giving the product a rectangular cross-section. Fibercon® steel fibers are manufactured under a quality plan in compliance to ASTM A820-06 Type II.

Produced from low carbon steel and various grades of stainless steel, Fibercon fibers are available in lengths from $\frac{1}{2}$” (13mm) to 2.0” (50mm). The fibers are available in straight, continuously deformed (wavy), or end-deformed versions.

The following are typical dimensions of the 3 most popular types:

<table>
<thead>
<tr>
<th>Product Nomenclature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAR-25-CDM</td>
<td>CAR - Low Carbon Steel</td>
</tr>
<tr>
<td></td>
<td>25 - 1.0” (25mm) in length</td>
</tr>
<tr>
<td></td>
<td>CDM - Continuous Deformed Medium</td>
</tr>
<tr>
<td>CAR-35-EDM</td>
<td>CAR - Low Carbon Steel</td>
</tr>
<tr>
<td></td>
<td>35 - $1\frac{3}{8}$” (35mm) in length</td>
</tr>
<tr>
<td></td>
<td>EDM - End Deformed Medium</td>
</tr>
<tr>
<td>CAR-50-EDM</td>
<td>CAR - Low Carbon Steel</td>
</tr>
<tr>
<td></td>
<td>50 - 2” (50mm) in length</td>
</tr>
<tr>
<td></td>
<td>EDM - End Deformed Mild</td>
</tr>
</tbody>
</table>
Fibercon® Technology Described

Small Fibers are used where crack propagation is the most important design consideration. High fiber count (number of fiber per lb or kg) permits a better distribution of steel fiber throughout the concrete matrix and consequently, greater crack control.

Higher fiber count FIBERCON steel fibers can yield as much as 9 times more reinforcing elements per unit of fiber weight than larger 2” fibers currently on the market. There is simply a greater quantity of shorter steel fibers per given unit of weight than with longer fibers. So as a crack progresses, the chance of it being physically stopped by the presence of a reinforcing fiber increases. This enhanced “crack arresting” ability holds the key to the outstanding performance of large numbers of shorter steel fibers in crack containment applications, such as slab-on-ground composite metal deck.

Fibercon CAR-25-CDM fiber gives the best compromise between high fiber count and the requirements for workability and finishability. This makes it ideal for industrial floor slabs, highway pavements, bridge deck overlays, floors over composite metal deck and other applications. These fibers mix easily and lays into the concrete surface much more effectively than longer, stiffer fibers facilitating easier placement and resulting in a more “fiber free” finish.

Fibercon CAR-35-EDM fiber gives the best fiber performance for shotcrete applications subjected to ASTM 1609 testing requirements.

Standard fiber types

CAR-25-CDM
CAR-35-EDM
CAR-38-CDM
CAR-50-EDM

Other sizes available upon request.

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Standard Specification for
Steel Fibers for Fiber-Reinforced Concrete

1. Scope*

1.1 This specification covers minimum requirements for steel fibers intended for use in fiber-reinforced concrete. Five types of steel fibers for this purpose are defined as pieces of smooth or deformed cold-drawn wire; smooth or deformed cut sheet; melt-extracted fibers; mill-cut or modified cold-drawn wire steel fibers that are sufficiently small to be dispersed at random in a concrete mixture.

1.2 This specification provides for measurement of dimensions, tolerances from specified dimensions, and required minimum physical properties, and prescribes testing procedures to establish conformance to these requirements.

1.3 In the case of conflict between a requirement of a product specification and a requirement of this specification, the product specification shall prevail. In the case of a conflict between a requirement of the product specification or a requirement of this specification and a more stringent requirement of the purchase order, the purchase order shall prevail. The purchase order requirements shall not take precedence if they, in any way, violate the requirements of the product specification or this specification; for example, by the waiving of a test requirement or by making a test requirement less stringent.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as the standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

2. Referenced Documents

2.1 The following documents, of the issue in effect on the date of material purchase, form a part of this specification to the extent referenced herein.

2.2 ASTM Standards: 2
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment
C 1116 Specification for Fiber-Reinforced Concrete and Shotcrete
2.3 ACI Document:
544.1R Committee Report on Fiber-Reinforced Concrete
2.4 U.S. Military Standard:
MIL-STD-129 Marking for Shipment and Storage
2.5 U.S. Federal Standard:
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

3. Terminology

3.1 Definitions of Terms Specific to This Standard:
3.1.1 deformed fiber, n—a fiber that is bent, flattened, or roughened to improve mechanical bond to the concrete matrix.
3.1.2 modified fiber, n—a cold-drawn wire fiber whose cross-section has been changed from circular by shaving the wire.
3.1.3 nominal length, n—the length of a deformed fiber, out-to-out, after being deformed.
3.1.4 range of equivalent diameter, d_{eq}, n—a set of limits placed on the equivalent diameter by the specifier. See 8.1.6 and Note 3.

3.2 Symbols—The following symbols used in this specification are defined as follows:
A = cross-sectional area, mm²[in.²]
d = diameter, mm [in.]
f_{u} = ultimate tensile strength, MPa [psi]
l = length, mm [in.]
λ = l/d = aspect ratio

3.2.1 The subscript n on dimensional units indicates “nominal” and the subscript e indicates “equivalent.” “Nominal” and

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1 This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.05 on Steel Reinforcement.

2 For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard’s Document Summary page on the ASTM website.

3 Available from American Concrete Institute, 38800 Country Club Drive, Farmington Hills, MI 48331.


*A Summary of Changes section appears at the end of this standard.

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equivalent diameters of the parent source material specimen, or if fibers are tested, the area calculated from the actual diameter of the parent source material or finished fiber; the area calculated from the equivalent diameter of the fiber. See 8.1.5, (3) for melt-extracted fibers, Type III, or mill-cut fibers, Type IV, specified by equivalent diameter, the area calculated from the equivalent diameter of the fiber. See 8.1.5; and (4) for modified cold drawn wire fibers, Type V, specified by a range of equivalent diameters, the area of each individual fiber calculated from the measured length and mass [weight] of the fiber. See 8.1.6. The ultimate tensile load in newtons [pounds-force] for individual fibers shall be measured to at least three significant figures. Testing shall be in accordance with Test Methods and Definitions A 370, where applicable.

7.2 Bending Requirements:
7.2.1 Fibers shall withstand being bent around a 3.2 mm [0.125] diameter pin to an angle of 90° at temperatures not less than 16°C [60°F] without breaking.

NOTE 2—The bending requirements of this specification provide a general indication of fiber ductility, as may be important in resisting breakage during handling and mixing operations. Ductility measures of fiber-reinforced concrete are outside the scope of this specification; see ACI 544.1R.

7.2.2 Bend tests shall be conducted on ten randomly selected specimens of finished fibers. It shall be permissible to perform bend tests manually. At least one test consisting of ten specimens shall be made for each 4 500 kg [5 tons] of material. At least 90% of the specimens must pass the test.

8. Dimensions and Permissible Variations

8.1 Dimensions:
8.1.1 Straight cold-drawn wire (Type I) fibers are specified by diameter (d) or equivalent (de) and length (l), that establish a specified aspect ratio, (λ), or (λp), as (l / d) or (l / de).
8.1.2 Deformed cold-drawn wire (Type I) fibers are specified by the diameter (d) or equivalent diameter (de) and nominal length after bending (ln). Nominal aspect ratio (λn) is established as (ln / d) or (ln / de).
8.1.3 Cut sheet (Type II) fibers are specified by thickness (t), width (w), and length (l). Aspect ratio (λ) can be computed as:

\[
\lambda = l / d_e
\]

where:
\[ A = tw \]
\[ d_e = \text{equivalent diameter} = \sqrt{4A / \pi} \]

8.1.4 Deformed cut sheet (Type II) fibers are specified by thickness (t), width (w), and nominal length after deformation (ln). Nominal aspect ratio (λn) can be computed as follows.

\[
\lambda = l_n / d_e
\]

where:
\[ A = tw \]
\[ d_e = \text{equivalent diameter} = \sqrt{4A / \pi} \]

8.1.5 Melt-extracted (Type III) and mill-cut (Type IV) fibers are specified by equivalent diameter, (de), and length (l), or nominal length (ln). Equivalent diameter is computed from measured average nominal length and the mass [weight] of a
8.1.6 Modified cold-drawn wire fibers (Type V) are specified by a range of equivalent diameters, \( (d_{eq}) \), and length \( (l) \), or nominal length \( (l_n) \). Equivalent diameter is computed as in 8.1.5. A range of nominal aspect ratios, \( (\lambda_{n-r}) \) can be computed as follows:

\[
\lambda_{n-r} = l_n / d_{eq-r} = l_n / d_{r-eq-r}
\]

**Note 3**—Specifying a specific diameter or equivalent diameter for Type V fibers is not applicable as the diameters of many Type V fibers vary more than \( \pm 10\% \) in each lot. Therefore, a user should provide the limits on diameter or equivalent diameter allowable.

8.2 Measurement of Dimensions:

8.2.1 Measurement of dimensions shall be performed on not less than 10 randomly selected specimens for each test to establish the average for conformance to specified tolerances. At least 90% of the specimens in each test shall meet the specified tolerances for length, diameter, or equivalent diameter, and aspect ratio.

8.2.2 At least one test shall be performed for 4 500 kg [5 tons] of finished product.

8.3 Permissible Variations:

8.3.1 The length, or nominal length shall not vary from its specified value more than \( \pm 10\% \).

8.3.2 The diameter, equivalent diameter, or range of equivalent diameters shall not vary from its specified value more than \( \pm 10\% \).

8.3.3 The aspect ratio, nominal aspect ratio, or range of aspect ratios shall not vary from its specified value more than \( \pm 15\% \).

9. Workmanship, Finish, and Appearance

9.1 Surface Condition:

9.1.1 Seams and surface irregularities shall not be cause for rejection provided that tensile properties are not less than requirements of this specification and mixing performance in concrete is not adversely affected.

9.1.2 Rust, mill scale, or other coatings shall not be cause for rejection provided that the individual fibers separate when mixed in concrete in accordance with Specification C 1116, and tensile and bending properties are not less than the requirements of this specification.

10. Inspection

10.1 Unless otherwise specified in the purchase order or contract, the manufacturer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the purchase order or contract, the manufacturer may use his own or any other suitable facility for the performance of the inspection and test requirements specified herein unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

11. Rejection and Rehearing

11.1 Rejection:

11.1.1 If any test fails to conform to the requirements of this specification, it shall be cause for rejection of the material represented by the test. Material that is found to be defective subsequent to its acceptance at the manufacturer’s works may be rejected, and the manufacturer notified.

11.1.2 Rejection of fibers shall be reported to the manufacturer promptly and in writing. Samples representing fibers rejected by the purchaser shall be preserved until disposition of the claim has been agreed to between the supplier and the purchaser.

11.2 Rehearing—When any test fails to meet the requirements of tension, bending, or dimensional tolerances, a retest shall be allowed. This retest shall be performed on twice the number of randomly selected specimens originally tested. The results of the retest shall meet the requirements of this specification or the lot shall be rejected.

12. Certification

12.1 Certificate of Compliance—When specified in the purchase order or contract, the producer or supplier shall furnish a certificate of compliance stating the product was manufactured, sampled, tested, and inspected in accordance with this specification (including year of issue) and any other requirements designated in the purchase order or contract, and has been found to meet such requirements.

12.2 Test Reports—When specified in the purchase order or contract, test reports shall be furnished to the purchaser containing the results of all tests required by this specification (including year of issue), and any other requirements designated in the purchase order or contract.

12.3 A signature or notarization is not required; however, the document shall clearly identify the organization submitting the document. Notwithstanding the absence of a signature, the organization submitting the document is responsible for its content.

12.4 Copies of the original manufacturer’s test report shall be included with any subsequent test report. A certificate of compliance (or test report) printed from or used in electronic form from an electronic data interchange (EDI) shall be regarded as having the same validity as a counterpart printed in the certifying organization’s facility. The content of the EDI-transmitted document must conform to any existing EDI agreement between the purchaser and the supplier.

13. Packaging and Package Marking

13.1 Packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

13.2 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and with Fed. Std. No. 123 for civil agencies.
13.3 The material shall be packaged to provide adequate protection during normal handling and transportation and each package shall contain only one type and size of material unless otherwise agreed upon. The type of packaging and gross mass [weight] of containers shall, unless otherwise agreed upon, be at the manufacturer’s discretion provided that they are such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

13.4 Each shipping container shall be marked with the material, size, type, specification designation, net mass [weight], and the manufacturer’s name or trademark.

14. Keywords

14.1 acceptance testing; classification; fiber-reinforced concrete; steel fibers; tensile strength; testing procedures

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 820 – 04) that may impact the use of this standard.

(1) Revised section 2.2 and Section 13.

(2) Added sections 2.4 and 2.5.

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

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Type I vs. Type II: Use the Right Type

Standard specifications for steel fibers for fiber reinforced concrete are spelled out in ASTM A 820. This specification describes five general types of steel fibers. The five types of fibers are indentified for purposes of this specification based upon the product or process used as a source of the steel fiber material.

The two most common types of fiber used in construction is a Type I, cold drawn wire and Type II, cut sheet. The difference in the two types of fibers is the shape. The common shape of a Type I fiber is circular while the Type II fiber is rectangular in shape.

All five types of fibers must meet the same requirements as outlined in ASTM A820.

Why does Fibercon manufacture a Type II fiber? The shape. The bond between the fiber and concrete matrix is important. This bond is influenced by the friction between the steel fiber and matrix. This bond friction depends on the surface area and texture of the steel fiber.

Which shape gives the greatest surface area? It is well known fact that a rectangular fiber of the same equivalent diameter as defined in ASTM A820 has more surface area than a circular fiber of the same diameter. Fibercon has conducted fiber pull-out tests to verify that a rectangular fiber has a higher bond strength based on the shape only.

LVDT to measure displacement during fiber pullout

Tension grip

3 inch by 3 inch grout cylinder with fiber embedded
Type I vs. Type II: Use the Right Type

Straight cut sheet fibers 2” long and straight cold drawn wire fibers 2” long were both embedded into a 5800psi grout. The fibers were then pulled out of the grout. The pullout bond strength of the cut sheet fiber was higher than the cold drawn wire fiber. The higher bond is due to the larger surface area available to develop the strength of the fiber.

Bond is important and everything should be done to improve this bond.

One way is by increasing the surface for an equivalent diameter. Following ASTM A820 guidelines and based on testing and research, a rectangular shape will increase this surface area.

By ASTM A820, if you want to use a rectangular shape, the manufacturer must use a Type II fiber. This is the reason Fibercon manufactures a Type II steel fiber.

- The slit sheet fiber has a smaller equivalent diameter and smaller area than the wire fiber.
- The pullout bond strength of the slit sheet fiber is higher than the wire fiber. Once the fiber is in motion, the slit sheet fiber has a higher bond to the grout than the wire fiber.
- The higher bond in the slit sheet fiber is due to the larger surface area available to develop the strength of the fiber.

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Small steel reinforcing fibers in shotcrete are offering proven, cost-effective performance and increased longevity for dams, spillways and other waterway construction applications—as on the $56.7 million Mt. St. Helens Sediment Control Structure.

Over 2 million lbs. of the fibers were used in channel linings and slope stabilization structures on the permanent project designed by the U.S. Army Corps of Engineers. Shotcrete with Fibercon steel reinforcing fibers was specified after field tests demonstrated its superiority over conventional wire mesh reinforcement and other fiber products.

Fibercon technology saved time and money by eliminating the need for conventional, labor-intensive wire-mesh reinforcement—without sacrificing shotcrete strength, ease of installation or the promise of greater longevity for the finished installation.

Located on the Toutle River in Cowlitz County, WA, the pioneering Mt. St. Helens project aims at allowing silt to accumulate behind an earthen dam, reducing its reservoir capacity and preventing downriver dredging. Should another volcanic eruption occur, the Corps of Engineers also designed a spillway to pass another mud flow.

The Mt. St. Helens Sediment Control Structure required a minimum of 700 lbs. of cement and 100-200 lbs. of steel fiber per cubic yard of concrete. Shotcrete with steel-fiber reinforcement generally exhibits 30-70% greater flexural strength than unreinforced shotcrete. Because fiber creates a less brittle, denser material, impact resistance is also excellent. Increased density makes the finished product less permeable than normal concrete. Shrinkage cracks are virtually eliminated and, if they do occur, are held tightly together without spalling.

In situations involving large volumes of fast moving, debris-laden water and mud—like the Mt. St. Helens silt-control effort—these benefits can significantly improve longevity for the concrete structures involved.
Since steel-fiber reinforcement substantially strengthens shotcrete by interrupting crack-forming processes, proper mixing is also critical. In either wet or dry process shotcrete and with standard equipment, Fibercon technology from Fibercon International ensures random dispersion of the fibers throughout the matrix. Other benefits include guaranteed availability, superior strength, highest fiber count, and a variety of fiber types and sizes available.

At Mt. St. Helens, for instance, project general contractor Granite Construction Company, Watsonville, CA, simply batched the shotcrete on-site and delivered it to the point of application by transit mixers. Placement remained substantially the same as that for conventionally reinforced shotcrete. Fibercon International production capacity was also a key factor in maintaining project schedules. Contracts initially called for 730,000 lbs. of Fibercon product, but needs eventually tripled to over 2 million lbs.

Years of use and on-site tests have shown that costs for equivalent work can be equal to, or less than, conventional shotcrete installations.

Savings Projected

Additionally, fiber-reinforced materials offer demonstrably superior strength for better durability and reduced long-term maintenance—especially when probable maintenance, repair and replacement cost are factored into original project estimates.

As recent Corps of Engineers river bed surveys evidently indicate, the $56.7 million cost of permanent Mt. St. Helens Sediment Control Structure should prove minimal compared to the reported $175 million in temporary solutions and $400 million in dredging projected over the next 50 years. So by engineering an effective long-term solution with small upfront cost increases—like the use of Fibercon steel fiber reinforcement in channel linings and slope stabilization structures—the Corps has probably saved taxpayers many millions more.

Benefits

Stronger Shotcrete, Crack Resistance, Easy Mixing, and Real Savings

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“We put strength in concrete”
Fibercon technology is once more the shotcrete reinforcing element of choice in a landmark tunnel construction effort.

Known as the “Forks of Butte,” the project diverts water from the upper fork of the Butte River in north-central California to a powerhouse in the valley below. Under programs designed to encourage development of alternative and renewable energy sources, the managing partnership will then sell electricity to Pacific Gas & Electric, the local utility. The aim is to generate 10.8MW of electricity during the winter months.

Located in the northwest corner of the Sierra Nevada range, project elements comprise a 560 ft. drop shaft, 12,000 ft. tunnel extending upstream under Butte Creek, and powerhouse. The powerhouse and lower tunnel portal sit at the base of the steep valley walls, with the portal itself roughly 50 ft. above the powerhouse. Tunnel water exiting the powerhouse is returned to Butte Creek.

Fibercon steel reinforcing fibers in the project’s tunnel shotcrete offer proven, cost-effective performance for tunnel linings and slope stabilization.

The Fibercon technology saves time and money by eliminating the need for conventional, labor-intensive wire-mesh reinforcement—without sacrificing shotcrete strength, ease of installation or the promise of greater longevity for the finished installation.

Nearly 300,000 lbs. of Fibercon fibers were specified for the Forks of Butte’s shotcrete tunnel lining—with each cubic yard of concrete requiring a minimum of 100 lbs. of steel fiber.

Shotcrete with steel-fiber reinforcement generally exhibits 30-70% greater flexural strength than unreinforced shotcrete. Because fiber creates a less brittle, denser material, impact resistance is also excellent. And increased density makes the finished product less permeable than normal concrete. Shrinkage cracks are virtually eliminated and, if they do occur, are held tightly together without spalling.

In situations involving large volumes of fast moving water—like the Forks of Butte Tunnel—these benefits can significantly improve longevity of the concrete structures involved.
Since steel-fiber reinforcement substantially strengthens shotcrete by interrupting crack-forming processes, proper mixing is also critical. In either wet or dry process shotcrete and with standard equipment, Fibercon technology ensures random dispersion of the fibers throughout the matrix. Other benefits include guaranteed availability, superior strength, highest fiber count, and a variety of fiber types and sizes available. The shotcrete was batched on-site and delivered to the point of application by railroad cars. Placement remained substantially the same as that for conventionally reinforced shotcrete.

Years of use and on-site tests have also shown that costs for equivalent work can be equal to, or less than, conventional shotcrete installations.

Additionally, fiber-reinforced materials offer demonstrably superior strength for better durability and reduced long-term maintenance—especially when probable maintenance, repair and replacement costs are factored into original project estimates.

**Benefits**

- Stronger Shotcrete, Crack Resistance, Easy Mixing, and Real Savings

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**Fibercon Shotcrete In First Phase Of Super Collider Project**

Fibercon steel reinforcing fibers have been specified for shotcrete lining a tunnel shaft in the first phase of the monumental Super Collider in Waxahachie, TX.

The $8 billion Super Collider is considered one of the most important projects in the history of science. When operational, the 54 mile underground ring is expected to yield new information on the sub-atomic particles that are the building blocks of the universe.

General Contractor is T.L. James, Baton Rouge, L.A.

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“We put strength in concrete”
Fibercon steel reinforcing fiber technology is playing a crucial role in one of the world’s most important tunneling projects—the Yacambu Quibor hydroelectric and irrigation system in Venezuela.

Located in the western part of this South American country, the scheme aims at diverting millions of gallons of much-needed water from the untapped Yacambu River to the fertile, but parched Quibor Valley. Authorities hope that, when completed in 1996, the project transforms the valley into one of the world’s most productive sources of vegetables.

To combat the project’s severe geology constraints, a combination of steel-fiber reinforced shotcrete and wire mesh—with either steel arches or rock bolts, depending on rock strength—drive the tunnel’s support system during excavation.

Even now, engineers are reportedly attempting to eliminate reliance on arches in favor of the more economical shotcrete-rock bolt blend. The combination is less expensive, offers more “give”, and uses the whole arch of the rock, they claim.

As the shotcrete reinforcing element of choice in this landmark tunnel construction effort, Fibercon steel fibers offer proven, cost-effective performance.

Laboratory test data confirms that steel fiber reinforced shotcrete performs on a par with shotcrete reinforced with conventional wire mesh. In fact, testing and field experience consistently show that placing shotcrete with Fibercon steel fiber reinforcement eliminates shadowing and other familiar quality problems associated with welded wire fabric.
Fibercon technology can be more economical than conventional wire mesh reinforcement. Labor intensive wire is difficult to handle and secure. In irregular surface situations, excessive shotcrete buildup and resulting increased material usage are commonplace—leading to increased labor hours, quality deficiencies, higher costs and lower profits. But Fibercon reinforcement can reduce the amount of rebound in a properly designed mix, In fact, with an experiences nozzleman, the rebound can be as much as half that of conventional shotcrete.

Fibercon technology offers the promise of superior shotcrete strength and durability, too. While compressive strength will remain similar at 6000 psi, flexural strength demonstrates a marked increase from 450 psi to 900 psi. This means high quality shotcrete in less time with maximum savings.

Just as importantly, all the cost effective advantages of Fibercon reinforcement are available with standard equipment and methods—regardless of the application involved. Fibercon fibers mix easily and can be used in either wet or dry process shotcrete with standard equipment. They can be added at most stages of the mixing process—at the central plant, in a transit mixer truck or at the job site itself.

Other benefits include guaranteed availability, highest fiber count and a variety of fiber types and sizes available.

From tunnel linings to slope stabilization, in either wet or dry process, a properly engineered shotcrete application can ensure random dispersion of Fibercon steel reinforcing fibers throughout the matrix, substantially improving shotcrete strength and performance.

Over 625,000 lbs. Of Fibercon fibers have been specified for the Yacambu-Quibor project to date—with as much as 4,000,000 lbs. slated for eventual use. Fibercon International production capacity is often a key factor in maintaining intense project demands and construction schedules like this.

The Yacambu-Quibor hydroelectric and irrigation system has also managed to increase the effectiveness of its shotcrete by adding 110 lbs./cu.yd. (65kg/m³) of micro-silica to the dry mix.

Authorities see the successful completion of this project as critical to the region’s future. Sound engineering and the right construction materials just may spell the difference between the Quibor Valley becoming a desert—or a breadbasket.

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With an eye on the future and ending with an eye on the past, Alabama Power started construction on a new scrubbing facility at its’ Gorgas power plant. Soon after construction started on the site-work for this facility which will help control emissions from this plant, a cemetery was discovered on a hill overlooking this modern facility. As it turned out, the cemetery contained graves of some of the workers who constructed the original power generating facility back in the 1860’s.

Due to the historical importance of this site, it was determined that the cemetery must be protected from sliding down the hill and honor the past construction workers at this facility. Nicholson Construction was hired to stabilize the hillside. Nicholson choose to use shotcrete reinforced with Fibercon’s CAR25CDM steel fibers to do this important job. The mix for this project was batched and delivered by Sherman Industries to the site in 4 yard batches. Each cubic yard was reinforced with 50 pounds of steel fibers. As the excavation removed the hillside, shotcrete was sprayed on the slope to stabilize the exposed surface.

Nicholson choose steel fiber over welded wire reinforcement due to it ease of use, not hanging mesh from the irregular hillside, and the speed of construction. Steel fibers are used to keep crack widths at a minimum to ensure a long life for the shotcrete and the memory of the past.

Alabama Power – Gorgas Electric Generating Plant, Jasper, AL

Fibercon Shotcrete
Specified For Gorgas Electric Plant in Alabama

“We put strength in concrete”

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Shotcrete with Steel Fiber Helps Reinforce Mount St. Helens Project Savings

On May 18, 1980, at 8:32 AM Pacific Daylight Time, a magnitude 5.1 earthquake shook Mount St. Helens. The bulge and surrounding area slid away in a gigantic rockslide and debris avalanche, releasing pressure and triggering a major pumice and ash eruption of the volcano.

by Alex Kefalas

Three hundred feet (400 m) of the peak collapsed or blew outwards. As a result, 24 square miles (62 square km) of valley was filled by a debris avalanche; 250 square miles (650 square km) of recreation, timber, and private lands were damaged by a lateral blast; and an estimated 200 million cubic yards (150 million cubic meters) of material was deposited directly by lahars (volcanic mudflows) into the river channels. Fifty-seven people were killed or are still missing.

Steel fiber-reinforced shotcrete (SFRS) is offering proven, cost-effective performance and increased longevity for dams, spillways and other waterway construction applications. SFRS was used successfully on the $72.8 million Mount St. Helens Sediment Retention Structure built by Granite Construction Company from 1986 to 1989.

Over 2 million lb (908 000 kg) of steel fibers were used in shotcrete channel linings and slope stabilization structures on the permanent project. Steel fiber-reinforced shotcrete was specified after field tests demonstrated its superiority over conventional wire mesh reinforcement.

Steel fiber-reinforced shotcrete saved time and money by eliminating a portion of the labor required to install wire-mesh reinforcement without sacrificing shotcrete strength. SFRS provided an opportunity to speed up the installation and
provide greater longevity for the finished structure.

Located on the Toutle River in Cowlitz County, WA, the pioneering Mount St. Helens project aims at allowing silt to accumulate behind an earthen dam, reducing its reservoir capacity and preventing down-river dredging. Should another volcanic eruption occur, a spillway was designed to pass another mud flow.

The Steel Fiber Advantage

The Mount St. Helens Sediment Retention Structure required a minimum of 700 lb/yd³ (415 kg/m³) of cement and 100 lb/yd³ (59 kg/m³) of steel fiber in the shotcrete. The function of steel fiber reinforcement in shotcrete is to impart ductility to a normally brittle material. The steel fibers provide an energy absorption capability as well as a load bearing capacity after cracking, which leads to enhanced static, impact, and fatigue resistance.

In situations involving large volumes of fast moving, debris laden water and mud-like the Mt. St. Helens silt retention effort—these benefits can significantly improve longevity for the concrete structures involved.

Since steel fiber reinforcement substantially strengthens shotcrete, proper mixing is critical. In either dry or wet shotcrete processes with standard equipment, steel fiber technology ensures random dispersion of the fibers throughout the matrix.

At Mount St. Helens, for instance, the project general contractor simply batched the shotcrete on site and delivered it to the point of application by transit mixers. Placement remained substantially the same as that for conventionally reinforced shotcrete. The production capacity of the steel fibers was also a key factor in maintaining project schedules. Contracts initially called for 730,000 lb (331 000 kg) of steel fiber product, but needs eventually tripled to over 2 million lb (908 000 kg).

Savings Projected

Steel fiber reinforced materials offer demonstrably superior toughness and impact resistance for better durability and reduced long-term maintenance—especially when probable maintenance, repair, and replacement costs are factored into original project estimates.

As engineering river bed surveys evidently indicate, the $72.8 million cost of a permanent Mount St. Helens Sediment Retention Structure should prove minimal compared to the $175 million spent in temporary solutions and $400 million projected in dredging over the next 50 years.

Reinforced Effectiveness

Over a decade has passed since the construction has been completed, and the Mount St. Helens Sediment Retention Structure continues to receive good reviews from the engineers who monitor the project. Steel fiber has proven to be a cost effective long-term solution for shotcrete reinforcement in channel linings and slope stabilization structures.
Liner introduced in research tunnel

Shotcrete product used to line collider facility

By Don Rose

Although steel-fiber reinforced concrete is a modern material commonly used in Scandinavia, it has only recently been introduced in North American tunnel applications.

Among the most impressive—and cost effective—of these applications is the use of steel-fiber reinforced shotcrete for initial and final linings of the linear collider tunnel at Stanford University's Linear Accelerator (SLAC) near San Francisco.

Financed by a $32 million U.S. Department of Energy grant, the tunnel is part of a $113 million project set for commissioning in 1986. SLAC physicists will use the tunnel to investigate results of the collision of subatomic particles. Collision en-

More than 700,000 lb. of Fibercon steel fibers reinforce the shotcrete walls of the new $112 million Stanford Linear Collider tunnel near San Francisco. The facility connects to a two-mile-long accelerator under meticulous tunneling requirements.
Energies of 100 billion electron volts are expected—a force rivaling the CERN project in Europe, currently the world’s largest such effort.

**Bidding**

Prospective tunnel lining contractors were permitted to choose steel-fiber reinforced shotcrete or the more conventional shotcrete with welded wire mesh. The two lowest bidders, and half of all 16 firms bidding on the project, chose steel-fiber reinforcement.

Half of the bids came in below project engineers’ estimates, with the lowest—$8,183,500, by Gates & Fox Construction Co.—just below 40% of anticipated costs.

**Specifications**

The SLC is actually Stanford’s second tunnel. An earlier 10-ft.-dia. tunnel, part of a 1978 project, used conventional shotcrete with welded wire mesh. Using the same source for circulating electrons and positrons as the earlier Stanford tunnel, the new project is 9,000 ft. long, features grades of up to 10% and also has a dia. of 10 ft.

The tunnel designer specified the use of steel fibers or welded wire mesh for the project. Steel fibers are generally considered more effective than conventional wire mesh installations and ensure random dispersion of fibers throughout the matrix for improved concrete durability and performance.

Specifications called for 80-cu.-yd. steel fibers and a 4,000-psi compressive strength after 28 days.

**Excavation**

Excavation was accomplished by two 44-ton roadheaders tunneling to a maximum depth of 49 ft., backed by integral muck conveyors. Because of the tunnel’s 10-ft. dia., though, there was some difficulty fitting the large units inside.

Tunnel contractors worked three shifts per day, five days a week. Shotcreting was done daily, usually on the night shift, except in areas where rock was unusually sound, standing open without need of prompt support. Soft Miocene sandstone was exposed without shotcrete as long as one week in some areas. However, the rock had a compressive strength of only 50 psi and at times exhibited poor shotcrete bonding. In fact, bonding capability to sandstone during construction of the previous Stanford tunnel also proved to be poor.

**The two lowest bidders, and half of all 16 firms bidding on the project, chose steel-fiber reinforcement.**

On both projects, local fall-off of hardened shotcrete occurred, with failure commonly at the bond between rock and shotcrete or an inch or more into the sandstone. In cases of bond failure, contractors failed to extend the shotcrete to the invert, which would have provided vertical support, experts say.

**Lining**

The SLC tunnel is lined with two layers of steel-fiber reinforced shotcrete, each 2 in. thick. In areas where sandstone is particularly soft or where the tunnel is close to existing structures, the lining was increased to 6 in.

Half of the tunnel was lined with steel-fiber reinforced concrete alone, while the remaining half was treated with the shotcrete mixture and steel ribs.

The SLC project, the longest steel-fiber reinforced tunnel in the world, was finished on schedule. Sources say the material shows promise for fast, efficient and economical tunnel support.