STRUX® 90/40 Macro Synthetic Fiber for Slab on Ground Applications

Frequently Asked Questions

List of questions from the engineer, contractor and ready mix supplier point of view.

Which "FIBERMESH®" product are you referring to?

STRUX® 90/40, a macro synthetic fiber from Grace. FIBERMESH® is a brand of fibers that is often used generically to describe synthetic fibers used in concrete. There are two types of fibers in the market; micro type and macro type fibers and both have different purposes.

What is the difference between "Micro" and "Macro" fiber?

"Micro" type fibers are typically polypropylene, cellulose or nylon monofilament (see Figure 1) or fibrillated (see Figure 2) fibers with diameters less than .004 in. (0.22 mm), length ranging from 0.5–0.75 in. (12.7 mm–19 mm), with addition rates between 0.5 lbs/yd^3–1.5 lbs/yd^3 (0.30 kg/m^3–0.88 kg/m^3) and specifically designed to control/reduce **plastic shrinkage cracks** that occur within the first 24 hours. Grace offers the following micro type fibers: Grace MicroFibers™ (monofilament), Grace Fibers™ (fibrillated) and Gilco® Fibers (monofilament).

"Macro" type fibers (see Figure 3) are typically monofilament with a diameter between .012 in.–.05 in., lengths ranging from 1.5 in.–2.5 in. (38 mm–64 mm) and made with polyolefin or steel. The typical synthetic macro fiber addition rate is between 3 lbs/yd^3–10 lbs/yd^3 (1.8 kg/m^3–7.0 kg/m^3) while steel macro fibers have an addition rate between 25 lbs/yd^3–100 lbs/yd^3 (15 kg/m^3–60 kg/m^3). The primary benefit of "Macro" type fibers is post crack control and/or to meet temperature/shrinkage reinforcement similar to welded wire fabric when properly positioned. In other words it can substitute the crack control steel required in slabs on ground, precast and composite deck applications.

Figure 1: Monofilament fibers (Grace MicroFibers shown)

Figure 2: Fibrillated fibers (Grace Fibers shown)

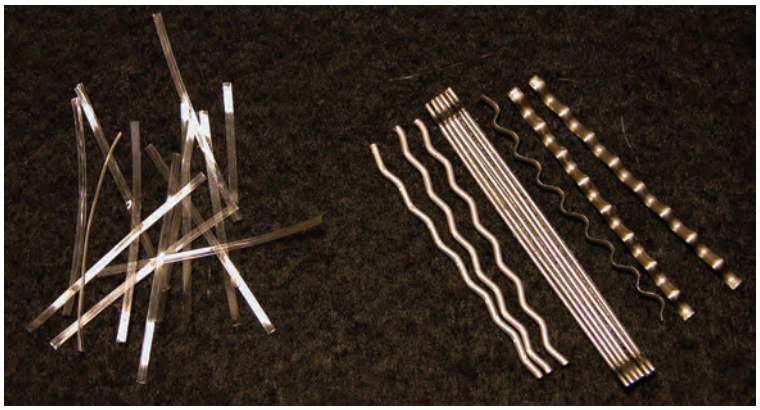
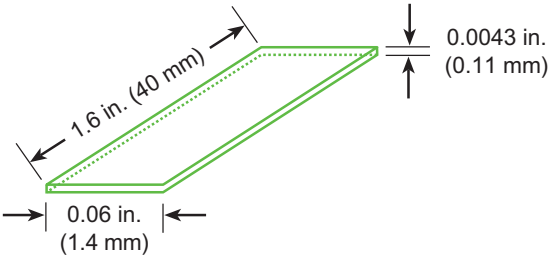


Figure 3: "Macro" fibers (STRUX 90/40 left, steel fiber right)

What are the primary properties of STRUX 90/40?

STRUX 90/40 is a polyolefin (blend of polypropylene and polyethylene) product with the following dimensions and physical properties:



Tensile strength	90 ksi (620 MPa)
Modulus of elasticity	1,378 ksi (9.5 GPa)
Alkali, acid & salt resistance	High
Absorption	None
Specific gravity	0.92
Melting point	320°F (160°C)
Ignition point	1,094°F (590°C)

What is the tensile strength of STRUX 90/40?

Tensile strength is the maximum tensile stress sustained by the fiber before failure in a tension test. Usually expressed in pounds per square inch or megapascals. STRUX 90/40 is a highly engineered fiber—not all plastics are the same. For instance, common household plastic articles have a tensile strength of just 5,000 psi while micro fibers have a strength of 50,000 psi and STRUX 90/40's strength is 90,000 psi. A single STRUX 90/40 fiber has a breaking load of 21 lbs. As compared to steel reinforcement such as rebar/WWF and steel fibers STRUX 90/40 lies between both; its tensile strength is 60,000–80,000 psi and 150,000 psi respectively.

Why is the modulus of elasticity of synthetic fibers important?

Modulus of elasticity is a measure of a material's stiffness under tension: The constant relating stress (force) and strain (deformation) within the elastic range of a material or an engineering term used to describe a material's ability to stretch without losing its ability to return to its original physical properties. The higher the modulus of elasticity, the stiffer the material.

STRUX 90/40 has a modulus of elasticity typically twice that of most other synthetic macro fibers (1,400,000 psi or 9.5 GPa vs. range of 400,000–600,000 psi or 4–6 GPa) on the market and comparable to that of cement paste (1,500,000–2,200,000 psi or 10–15 GPa) with which it interacts. Therefore especially after first crack lower modulus fibers show a steeper drop in performance vs. STRUX 90/40 as it will hold cracks tighter and longer than other synthetic macro fibers.

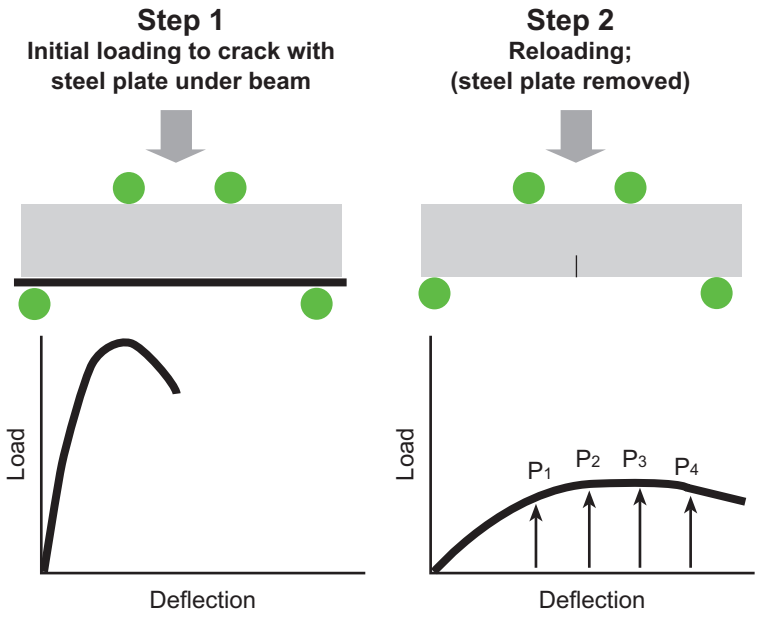
How are fibers tested and evaluated in concrete?

There are two ASTM flexural test procedures used to evaluate the performance of "macro" synthetic fibers, ASTM C1399 and ASTM C1609. ASTM C1399 and ASTM C1609 are commonly used but there are some major differences between both and where they should be specified. Briefly, ASTM C1399 is the most commonly used and specified because many concrete testing labs can perform this test but this test has certain limitations as compared to ASTM C1609.

What is ASTM C1399?

This test method covers the determination of the average residual strength (ARS) of a fiber-reinforced concrete test beam supported by a steel plate underneath the entire length.

Figure 4



The flexural beam is initially cracked from an applied load up to a deflection of 0.008 in. (0.2 mm) (see Figure 4). The steel plate is then removed and the post-crack deflections and loads are measured and recorded during the test up to a final deflection of 0.05 in. (1.25 mm). The ARS is computed using loads at specified beam deflections that are obtained during the test. This test provides the data needed to obtain the portion of the load-deflection curve beyond which a significant amount of cracking damage has occurred. It also provides an average measure of post-cracking or residual strength obtained by the use of fiber-reinforcement.

What applications should ASTM C1399 be specified for and why?

Since ASTM C1399 only allows the use of 4 in. x 4 in. x 14 in. (100 mm x 100 mm x 350 mm) beams, Grace recommends it to be used for concrete applications of 4 in. (100 mm) thickness or less if the fiber length is less than or equal to 1.5 in. (40 mm). Therefore applications such as precast, thin overlays, whitetoppings, and slab-on-ground with thicknesses 4 in. (100 mm) or less should be specified by ASTM C1399.

Why?

1) Testing in our labs, pre-cast production, or thin overlays have shown there is a tendency for fibers to have preferential alignment thus giving good results but cannot be related to concrete members with a thickness greater than 4 inches.
2) ASTM C1399 recommends that for tests of fiber-reinforced concrete containing relatively rigid or stiff fibers of length greater than 1.5 in. (40 mm), the use of sawed beams cut from samples with an initial width and depth of at least 3 times the length of the fiber is recommended to minimize effects of fiber orientation. This requires special cutting equipment with a diamond saw and creates another procedural step for the concrete lab and is rarely performed.
3) With ASTM C1399 the flexural strength of the fiber-reinforced concrete cannot be obtained. Therefore another test such as ASTM C78 needs to be performed if the flexural strength has to be determined as well.
4) The fracture behavior of fiber reinforced concrete at small crack openings cannot be determined using ASTM C1399 since the ARS value is only an average load value taken at deflections equal and greater than 0.02 in. (0.5 mm) of deflection.

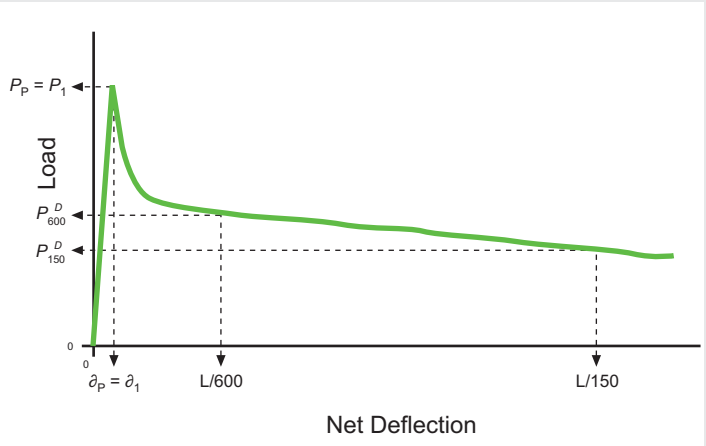
What is ASTM C1609?

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

This test method provides for the determination of first-peak and peak loads and the corresponding stresses calculated by inserting them in the formula for modulus of rupture.

Figure 5

Flexural Performance Evaluation—ASTM C1609-05



L = Span Length
$P_P = P_1$ = Peak Load = First-Peak Load
$\partial_P = \partial_1$ = Net Deflection at Peak and First-Peak Loads
$f_P = f_1$ = Peak Strength and First-Peak Strength
P^D_{600} = Residual Load at net deflection of L/600
f^D_{600} = Residual Strength at net deflection of L/600
P^D_{150} = Residual Load at net deflection of L/150
f^D_{150} = Residual Strength at net deflection of L/500
T^D_{150} = Area under the load vs. net deflection curve 0 to L/150

NOTE 1—Residual flexural strength is not a true stress but an engineering stress computed using simple engineering bending theory for linear elastic materials and gross (un-cracked) section properties.
NOTE 2—Specimen toughness expressed in terms of the area under the load-deflection curve is an indication of the energy absorption capability, which is direct proportional to the f_{e3} value.

It also requires determination of residual loads at specified deflections, and the corresponding residual flexural strength (see Note 1). At the option of the specifier, it provides for determination of specimen toughness based on the area under the load-deflection curve up to a prescribed deflection (see Note 2).

What applications should ASTM C1609 be specified for and why?

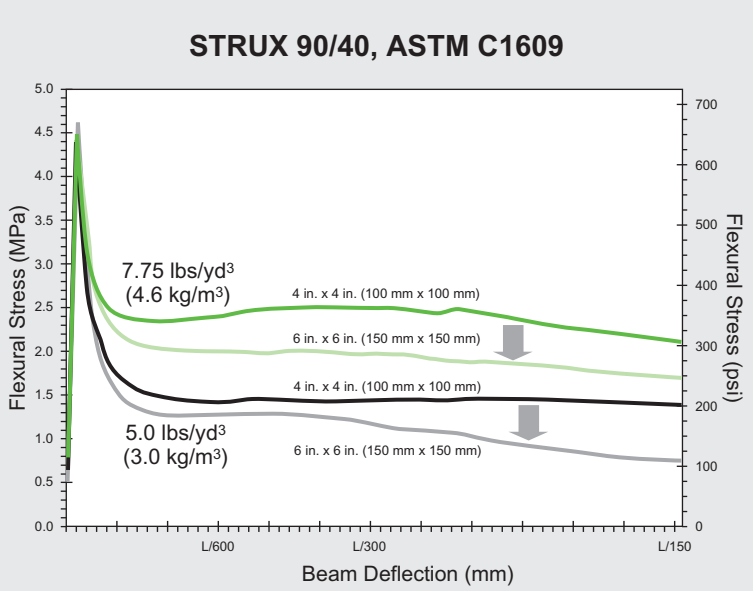
ASTM C1609 is a more controllable test and allows the use of small beams 4 in. x 4 in. x 14 in. (100 mm x 100 mm x 350 mm) and larger beams 6 in. x 6 in. x 20 in. (150 mm x 150 mm x 500 mm). Therefore for applications such as pre-cast and slab-on-ground greater than 4 in. (100 mm) thick, the larger beam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

Why?

1) The larger beam allows the use of macro fibers up to 2.5 in. (65 mm) in length. This will accommodate for the majority of macro fibers on the market that have lengths between 1.5 to 2.5 in. (38 mm to 65 mm).
2) The potential preferential alignment of fibers is now reduced and a more random distribution of fibers both horizontally and vertically/diagonally will occur similar to "field" concrete with fibers.

To summarize the differences between ASTM C1399 versus ASTM C1609 with respect to preferential fiber alignment of small versus large beams, Figure 6 represents STRUX 90/40 cast from identical concrete placed in small and large beams and then tested.

Figure 6

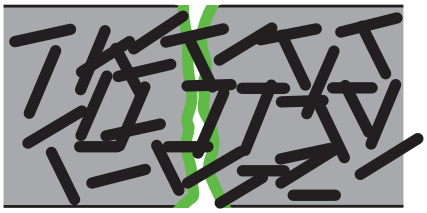


Residual flexural strength and toughness are lower when measured with the larger flexural beams!

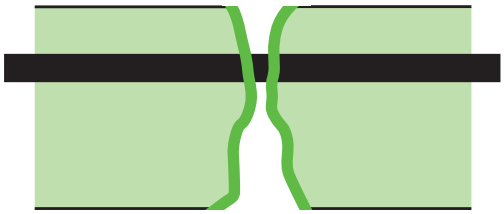
Can STRUX 90/40 be specified for slab on grade applications?

Yes. STRUX 90/40 has been utilized for slabs on grade for over 5 years for residential, commercial, manufacturing, distribution, institutional, agricultural and other applications. Grace's STRUX 90/40 SDS Software is also available to assist with all particular slab on ground designs from wheels loads, post loads to racking systems from edge loading to center loading cases. The result is a 25-page report showing the most cost-effective design using Yield Line theory backing up the calculations. Please contact your local Grace Engineer Service Group to get a copy or assistance with your slab on ground designs.

Figure 7



Uniform Crack Width with STRUX 90/40 (Synthetic Macro Fiber)



Wider Cracks Away from WWM/Rebar

What are the advantages of STRUX 90/40 vs. WWF?

Macro type fibers are uniformly dispersed throughout the concrete matrix to minimize the potential for cracks.

Macro synthetic fibers offer post-crack performance at all depths of the concrete no matter where the crack is developed. Cracks in concrete with WWF must propagate to the steel before it is controlled. Because there is only one layer of WWF running through the concrete, cracks can propagate and widen above and below this reinforcement layer, weakening the concrete (see Figure 7). The fiber count per unit volume of macro synthetic fibers, by contrast, provides uniform reinforcement throughout the concrete, from sub grade to surface.

What are the advantages of STRUX 90/40 vs. steel fibers?

The main advantage of STRUX 90/40 versus steel fibers is the ease of mixing, handling, placing and finishing. The key lies in the macro synthetic fiber count per unit volume. Pound for pound, macro synthetic fiber offers reinforcing performance that is superior to steel. At equal volumes in the mix, the best macro synthetic fiber products place 5 to 15 times more fibers in the concrete than steel fibers—up to 530,000 macro synthetic fibers versus about 35,000 steel fibers. [Note that the new ANSI/SDI standard calls for steel fibers to be specified at a minimum addition rate of 25 lbs/yd^3 (14.7 kg/m^3) vs. macro synthetic fiber at a minimum addition rate of just 4 lbs/yd^3 (2.4 kg/m^3)]. This far greater fiber count per unit volume results in superior post-crack performance, because there are many more fibers available to intercept a micro crack and keep it from expanding.

Added to the mix at the batch plant, steel fibers are hard on equipment, including drums and ready mix trucks, shortening their lifespan. At the plant and at the job site, steel fibers are difficult to dispense and exposed steel fibers continue to present a hazard, especially on surfaces handling foot or vehicular traffic. Exposure of steel fibers can also result in unsightly staining due to corrosion.

Why should a “macro” type fiber be specified vs. WWF for slab on grade applications?

By using STRUX 90/40, there are many steps involving installation of WWF properly for slab on ground applications that can be eliminated.

1) Prior to WWF placement, estimating/scheduling/ordering.
2) Locating storage space at the job site.
3) Setting chairs and tying-off the WWF.
4) At minimum a 15% overlap of WWF sheets is required by the structural engineer thus resulting in material waste. (15% is an overlap of one square but it can be as much as 2 squares which is over 30% overlap).

After WWF placement:

1) Concrete pump lines can get caught on or tangled in the WWF, making the job more difficult and dangerous.
2) WWF presents other safety risks such as tripping and falling which may result in injury.
3) A concrete pump may be required to place the concrete vs. ready mix trucks driving over WWF through out an area being poured.

In Summary:

1) STRUX eliminates the time and labor involved from estimating/scheduling to installing WWF properly with chairs. Those employees can now perform other duties to speed up the construction schedule. Eliminating WWF from the equation results in faster, less costly and safer construction.
2) Safety issues, insurances and workers compensation from trips/falls and other injuries associated with WWF will be minimized.
3) Finally performance of STRUX 90/40 will hold cracks together tightly throughout the slab thickness vs. WWF.

What are the required addition rates of STRUX 90/40 for lightly loaded slab on ground applications?

For lightly loaded slabs with a minimum modulus of sub-grade of 100 pci for pedestrian traffic and vehicular loads less than 10,000 lbs (4,500 kg) for applications such as residential driveways, institutional buildings, offices, healthcare related buildings, etc., refer to Table 1 and 2 for typical addition rates per cubic yard and per cubic meter.

For slabs 5 in. (125 mm) or greater and considered lightly loaded slabs the addition rates is reduced to 3.0 lbs/yd^3 (1.8 kg/m^3) for 3000 to <4000 psi (20 to <28 MPa) concrete and 3.5 lbs/yd^3 (2.4 kg/m^3) for 4000 to <5500 psi (28 to 38 MPa) concrete. The reason for the extra 0.5 lbs/yd^3 (0.30 kg/m^3) is to compensate for the increased amount of energy released during cracking of higher strength concrete.

Table 1

Slab Thickness (inches)	Concrete Strength (psi)	Addition Rate of STRUX (lbs/yd^3)
4	3000–<4000	3.5
4	4000–5500	4.0
= >5	3000–<4000	3.0
= >5	4000–5500	3.5

Table 2

Slab Thickness (mm)	Concrete Strength (MPa)	Addition Rate of STRUX (kg/m^3)
100	20–<28	2.1
100	28–38	2.4
= >125	20–<28	1.8
= >125	28–38	2.1

What is the required addition rate of STRUX 90/40 for medium to heavy loaded slabs on ground?

Addition rates for medium and heavy loaded slabs will vary greatly depending on applied loads whether it is uniformly distributed, axle loads (dynamic) or point loaded such as for racking systems along with varying modulus of sub-grade and concrete strengths. Therefore please consult with a Grace Engineering Service Group representative to gather the information needed to input into the Grace SDS STRUX Software for the most economic concrete thickness and addition rate of STRUX 90/40.

Are “macro” fibers accepted by ACI?

Yes. From the engineer’s view, Chapter 10 ACI 360 Slab on Ground Design presents both steel and polymeric high volume fibers as valid materials for reinforcement of slabs-on-ground. Yield line theory as a design methodology is discussed and examples are presented.

Can you extend joint spacing with the use of STRUX 90/40?

No. Grace's recommendation is to stay within ACI guidelines for proper joint spacing for slab on ground applications.

Yes. ONLY in combination with Grace's SRA (Shrinkage Reducing Admixture) Eclipse® Floor have we successfully extended joint spacing over 50 ft to 150 ft (15 m to 45 m) for slab on ground applications. For further information please contact your local Grace Engineering Service representative for recommended guidelines.

Can STRUX 90/40 be specified for composite steel floor deck applications?

Yes. The new ANSI/SDI C-1.0 Standard for Composite Steel Floor Decks allows "macro" synthetic fibers as a suitable alternative to replace temperature and shrinkage steel specified by deck manufactures/Engineers. STRUX 90/40 is UL and ULC listed up to a 2 hr rating for D700, F700, D800, F800, D900 and F900 except F909 floor ceiling designs. Please consult with a Grace Engineering Service Group representative to obtain the correct addition rate for this specific application and refer to FAQ for Composite Steel Floor Deck at www.graceconstruction.com/strux for more information.

Can STRUX 90/40 be specified for non-composite deck applications?

Yes and No. Typically, non-composite deck requires a primary reinforcement and not a temperature and shrinkage requirement, hence why STRUX 90/40 cannot be used. When primary reinforcing is utilized, temperature and shrinkage reinforcing is sometimes used. When this is the case, STRUX 90/40 may be substituted for this portion of the steel.

Where can customers purchase STRUX 90/40?

Your local ready mix producer can purchase STRUX 90/40 anytime and shipment will be received within standard lead times of 3 to 5 days.

How is STRUX 90/40 mixed in the ready mix truck?

STRUX 90/40 is packaged in concrete ready bags that break down during mixing. Typically in a dry batch plant STRUX 90/40 bags are added to the concrete truck prior to batching. In a central batch facility STRUX 90/40 bags can be added in three different ways:
1) Mixed directly into the central mixer,
2) Added to the truck prior to the concrete being dumped from the central mixer or
3) Added after the concrete has been dumped in the ready mix truck. Please consult with your Grace sales representative for proper batching procedures.

Are there any mix design requirements needed when utilizing STRUX 90/40?

Yes. Only a slight mix adjustment from the ready mix supplier is required due to slump loss of approximately 1 in. per 3 lbs/yd^3 (25 mm per 1.8 kg/m^3) addition rate. The addition of a mid-range or superplasticizer is recommended to stay within the water/cement ratio specified. It has been noted based upon actual job applications that pumping is easier with the addition of STRUX 90/40 in light weight concrete.

What type of finish should I expect when using fibers?

Proper finishing procedures are required to achieve a fiber free surface finish. The most effective way to screed the concrete is with either a laser screed (BEST), vibratory screed (Very Good) or handed screeded (Good). Follow normal power troweling methods for proper finish. A broom or course finish will reveal fibers at the surface.

Does STRUX 90/40 make pumping concrete difficult?

No. For normal weight concrete STRUX 90/40 does not increase the pressure needed to pump the concrete mix or cause any other issues. It is recommended that if a "fiber ball" appears it is best to remove it before being pumped. For light weight concrete, experience has shown that STRUX 90/40 makes it easier to pump with minimal slump loss at the end of the hose.

What is the packaging for STRUX 90/40?

STRUX 90/40 is packaged in 1 and 5 lb concrete ready bags therefore the handling is much easier than steel fibers (usually 25–50 lb bags) or managing WWF on site. STRUX 90/40 for slab on ground applications is in 5 lb (2.3 kg) bags (330 lbs/pallet). STRUX 90/40 is also packaged in 1 lb (0.45 kg) bags in a box of 24 bags/box, 18 boxes/pallet.

Can STRUX 90/40 be stored at the job site?

No. STRUX 90/40 is purchased by the ready mix supplier and added at the plant for proper mixing.

Can STRUX 90/40 provide plastic shrinkage crack reduction benefit?

Yes. Grace laboratory tests demonstrated 3 lbs/yd^3 (1.8 kg/m^3) of STRUX 90/40 reduced the amount of plastic shrinkage cracking by 85% which exceeds the ICBO AC32, Annex A acceptance criteria, which require that the synthetic fibers reduce the plastic shrinkage cracking of concrete by at least 40%. Some other synthetic fibers and steel fibers do not provide this benefit. Micro type fibers have to be used in addition to meet this requirement.

What other applications besides typical slabs on ground can STRUX 90/40 be specified?

STRUX 90/40 has been utilized in a multitude of applications such as precast, shotcrete, thin-overlays (concrete less than 4 in. (100 mm) thick), whitetoppings, concrete curbs, slabs with two mats of rebar (eliminating the temp/shrinkage layer) and used in combination with Eclipse Floor to extend joint spacing for distribution/warehouse projects. For more details on each of these applications and more please contact your local Grace representative.

www.graceconstruction.com/strux

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

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