Concrete is a mixture of sand, several sizes of aggregates such as gravel and small stones, Portland cement that is added in a quantity that is known to produce concrete of a certain strength when it has aged and cured, and enough water so that it will slide down a chute or concrete pump easily into forms without being so loose that it cannot retain its shape with the help of the forms until it has set.

Plain concrete that has cured has compressive strength but little strength in tension or shear.

To increase concrete’s tensile and shear strength, it is reinforced frequently. Several types of concrete reinforcement are used to achieve greater strength in different applications and environments.

Photo 1 shows the floor of a factory addition before the concrete was poured. Near the middle of the photo, the existing wall of the factory is visible, with steel rebar dowels drilled into the edge of the existing floor to bind it to the new floor that will be poured.
The foreground shows the plastic foam insulation board laid over the gravel base, topped with a sheet plastic moisture barrier and **welded wire mesh** to reinforce the new concrete floor to reduce the possibility that it will crack. The “V” of steel rebar that is visible on both sides of the square tubular column is connected to the column and uses the concrete floor to help stabilize the column. Welded wire mesh is available in light gauge in cylindrical rolls and in heavier gauges; they are shipped in flat sheets because they are too stiff to roll.

Photo 2 shows the mats of **steel reinforcing rods** or **bars (rebar)** that will reinforce the bottom and sides of a poured-in-place underground concrete tank. These are of plain, uncoated steel that has ridges rolled into the bars to help the concrete bond to them.
These rebar are spliced with lap joints connected with steel tie wire. Rebar crossing at right angles are tied with the same kind of wire to provide stability to the mat of rebar and increase its strength. The multiple mats of rebar in the floor are separated by chairs (supports) of smaller rebar, heavy wire, or brick-sized concrete masonry units. The rebar for the sides of the tank will be connected by lap joints tied with steel wire and the rebar in the roof of the tank.

Photo 3 shows preshaped epoxy-coated rebar that will be used in columns and beams in a bridge or a parking structure, which will be exposed to the weather from all sides.
This epoxy coating is sprayed on at the steel mill after the rebar is formed by conventional means and after the surface of the rebar has been abraded and cleaned of any rust or oil residue that would prevent the epoxy coating from sticking to the steel. This coated rebar is connected by lap joints and tie wire, which must be sprayed with an aerosol epoxy coating to prevent rust from forming where there is no epoxy paint or where the paint is chipped.

According to architectural and engineering journals, high-strength alloy steel rebar is available that has the same strength in smaller sizes; conventional rebar is a size or two larger. This type of rebar is manufactured, has the same appearance as conventional steel rebar, and is installed using lap joints and steel tie wire. The increased cost per pound of the steel alloy is offset by the savings in weight by using smaller sizes of rebar. Manufacturers state that this high-strength rebar can be used in fire-rated reinforced concrete walls and floor-ceiling assemblies without affecting the performance of the assemblies in laboratory test furnaces.

Architectural and engineering journals have also discussed developing and testing plastic rebar (reinforced with glass or carbon fibers) to use in marine environments, in structures in other types of corrosive environments, and bamboo fiber reinforced plastic rebar. This could eventually replace conventional steel rebar in some applications and would be considered “sustainable” building material.
Photo 4 shows a floor of fiber-reinforced concrete. This fiber is added to the concrete in the mixer in predetermined ratios to increase the resistance of the cured concrete to cracking.

The synthetic fibers are usually polyethylene, nylon, or polypropylene (photo 5) and can be used alone or in combination with welded steel wire mesh or rebar. For even greater strength, metal fibers, usually of steel or stainless-steel wire, can also be used.
A concrete floor that is reinforced with metal fibers is more electrically conductive than ordinary concrete and easily dissipates static electricity. For this reason, it is sometimes used in the pavement around fuel pumps and in floors inside buildings in areas that are sensitive to static electricity.

Steel cables or “tendons” can also be used to reinforce concrete for specific applications.

“Pre-tensioned” or “pre-stressed” concrete is the result of applying tension to the tendons supported by a steel concrete form. When the concrete is poured into the form and rapidly cured by external heating of the form, the concrete bonds to the cable tendon. When the concrete is cured, the tension on the cable tendons is released, and the contracting tendons pull the concrete together, giving it great strength in long spans that can exceed 100 feet (30.48 meters). This process is used in manufacturing “tees,” “double tees,” hollow-core concrete plank, girders, beams, and other structural concrete shapes.

Photo 6 shows a broken piece of pre-stressed concrete from a building under demolition. In this photo, the bottom of this piece of hollow-core concrete plank is on top, with its
three large cable tendons bonded directly to the concrete. The smaller single tendon from the top of the prestressed concrete is visibly lying on the ground.

Post-tensioned concrete is the result of applying tension to steel cable tendons in kraft-paper or plastic sleeves that have been embedded in concrete poured on a form supported by falsework, much like structural concrete with steel rebar. After the concrete is cured, each tendon is anchored to the concrete at one end, and a hydraulic machine attached to one end of each tendon applies tension to it, which is permitted by the tendon’s ability to move freely inside its sleeve. After the proper amount of tension is applied, the tendon is connected to the opening in the concrete with a bolted-on cylindrical wedge anchor in each tendon sleeve. The tendons are then cut off and the openings around them are filled and protected with a concrete patch. This type of reinforcement gives great strength to a relatively thin structural slab that is flat on both top and bottom.

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Photo 7 shows the underside of a post-tensioned concrete floor that spalled when tension was applied to tendons that were not perfectly straight. The black-sleeved tendons are under tension and caused the spalling when they straightened.

The gray-sleeved tendons are not yet under tension. The concrete around them will chip away, tension will be reapplied, and they will be embedded in an epoxy concrete mixture that will bond to the concrete and tendon sleeves.

Photo 8 shows the edges of post-tensioned concrete floors that have been tensioned, and the ends of the tendons and their anchors are sealed in the concrete. These concrete patches concealing the ends of the tendons appear as round “dots” on the edge of the floor slabs.
Research and development will result in additional types of reinforcement for concrete. Knowledge of the methods used to reinforce concrete, especially in structural systems, is of interest to firefighters simply because the less mass the structural system has, and the thinner the covering of concrete over the reinforcement of steel or other materials, the less fire resistive it is likely to be.

It is also necessary to be able to recognize the type of concrete structure with which we are dealing if we are called on to breach a floor system. Cutting one or more cable tendons in either a pre-stressed or post-tensioned concrete floor will weaken the floor and can cause the collapse of a large area of floor even at a distance away from where we are working.

For more information on the materials and methods used to reinforce concrete, do an Internet search for any of the terms “in quotation marks” or in bold type.
Gregory Havel is a member of the Town of Burlington (WI) Fire Department; a retired deputy chief and training officer; and a 40-year veteran of the fire service. He is a Wisconsin-certified fire instructor II, fire officer II, and fire inspector; an adjunct instructor in fire service programs at Gateway Technical College; and safety director for Scherrer Construction Co., Inc. Havel has a bachelor's degree from St. Norbert College, has more than 40 years of experience in facilities management and building construction, and presents classes at FDIC and other venues.

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