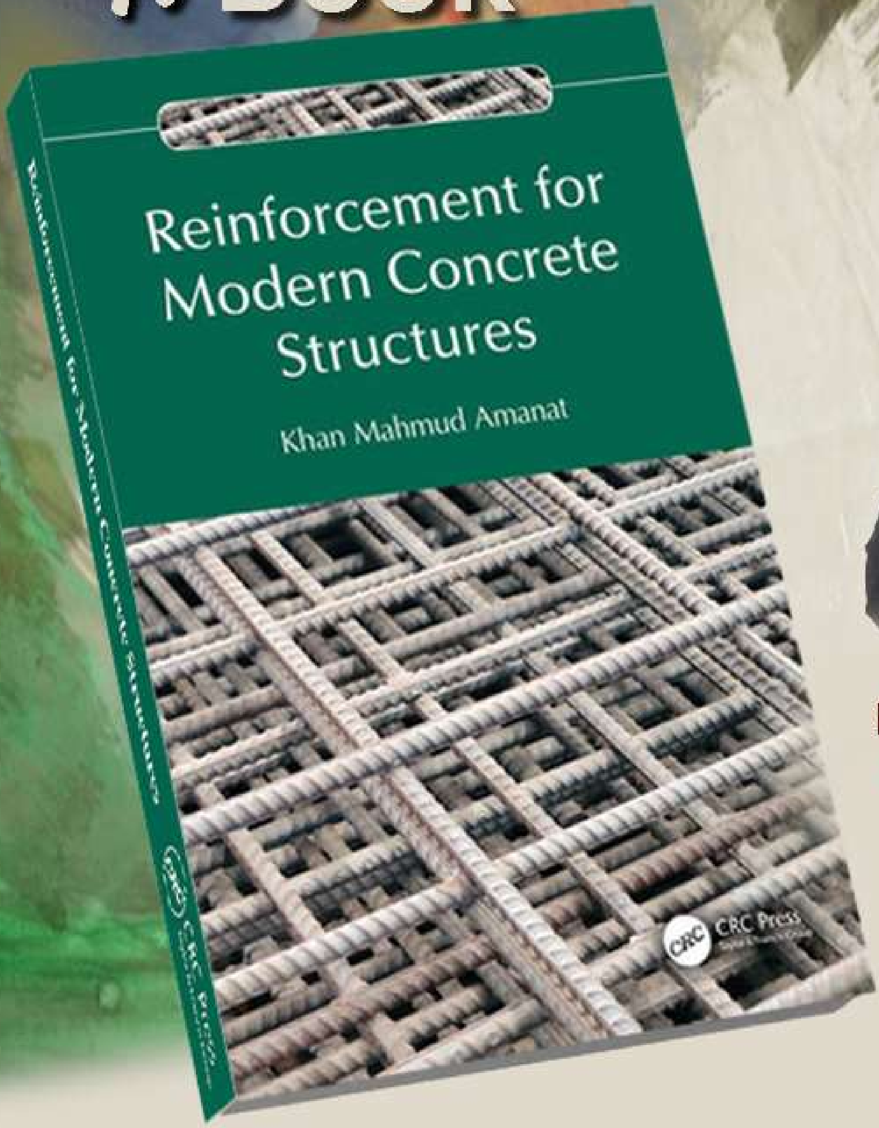
New Book



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About the book

The book is all about reinforcing materials. It consists of ten well-outlined chapters covering nearly 300 pages with 187 color illustrations and photographs. The reader will learn about all the essential physical, mechanical, and engineering properties of various reinforcing materials, interpreting test reports, seismic applications and limitations etc. The reader will also find an in-depth discussion of the usage of couplers and other splicing methods, the basic and essential information on epoxy or zinc-coated rebar, rebar made of special types of material such as stainless steel as well as non-metallic materials such as CFRP and GFRP. Civil engineering students, teachers, professionals, project owners—all are likely to find something interesting in this book. It is an all-in-one text and reference book on concrete reinforcing materials.

A pultruded component might have an open cross-section, like a plate or a wide-flange profile, a single closed cross-section, like a hollow tube, or a multicellular cross-section, like a panel with internal webs. The thickness of the cross-section need not be uniform throughout. Although there is a large amount of flexibility in the shape, thickness variation, and size of the part's cross-section, the cross-section must be uniform along its length. In addition, the component cannot be cured into a curved shape; it must be straight. Any length of pultruded material may be manufactured, and if it is flexible enough, it can be wound onto a spool for shipment (such as a thin FRP strip for strengthening or a small-diameter FRP rebar). Non-constant cross sections and the production of curved pieces have led to the development of non-routine pultrusion process modifications. In some forms, a core substance is employed to fill the cavity of a cellular portion.

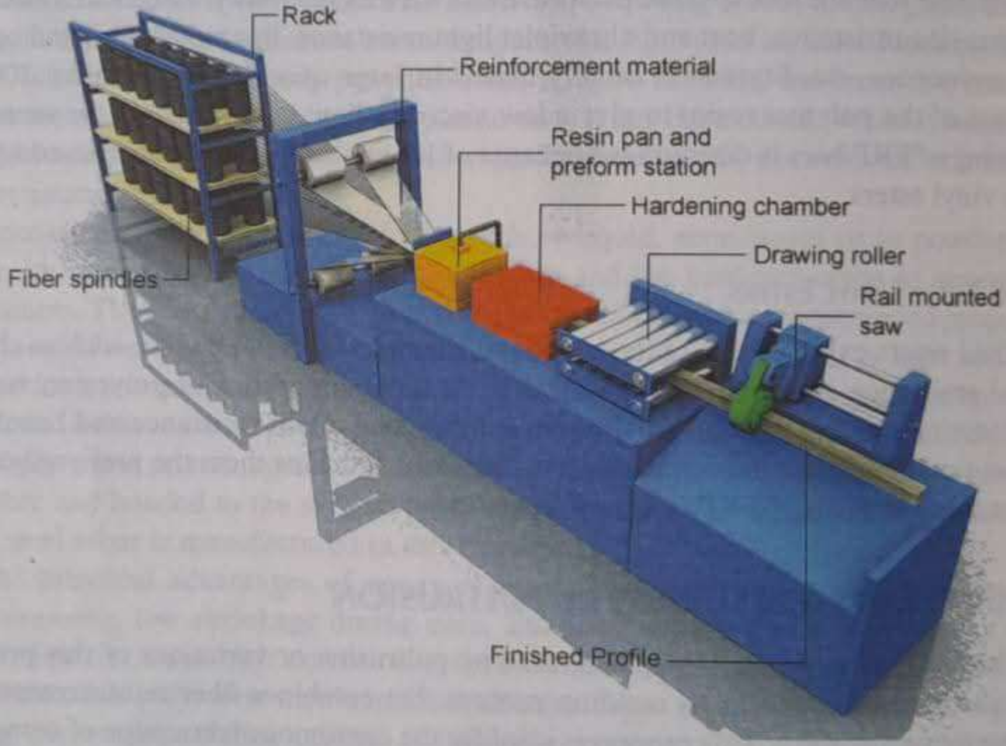


FIGURE 10.20 Pultrusion machine configurations (Photo © Florian.Arnd~commonswiki, background and language by the author, Wikimedia Commons CC by SA 3.0, original available at https://commons.wikimedia.org/wiki/File:Strangziehverfahren.png, accessed 16 Sept. 2024).

A pultrusion line or pultrusion machine is utilized to manufacture the pultruded component. Brandt Goldsworthy invented the Glastruder, the first pultrusion machine, in the early 1950s (Goldsworthy 1954). Goldsworthy and Landgraf were granted a U.S. patent for a pultrusion machine and method for producing pultruded parts in 1959. Pultrusion machines can now be purchased from a variety of companies or constructed from scratch using readily available materials and components. Experienced pultrusion are frequently used to strengthen molded and laminated plastics. Fiberglass wool is a thick, fluffy substance comprised of discontinuous fibers that are used for sound absorption and thermal insulation. It can be found in ship and submarine bulkheads and hulls, automobile engine compartments and body panel liners, furnaces and air conditioning units, acoustical wall and ceiling panels, and architectural partitions (Nanni *et al.* 2014). Examples of glass fiber rebar is shown in Figure 10.17.

FIGURE 10.17 Glass fiber reinforced polymer rebar.

10.6.2 Carbon Fiber

Carbon-fiber-reinforced polymer, often known as carbon-fiber-reinforced plastic (CFRP or CRP, or simply carbon fiber), is a strong and lightweight fiber-reinforced polymer containing carbon fibers. When polyacrylonitrile fibers (PAN), pitch resins, or rayon are carbonized (by oxidation and thermal pyrolysis) at high temperatures, carbon fibers are formed. The strength or flexibility of the fibers can be improved by further graphitizing or stretching operations. Carbon fibers are produced in diameters similar to glass fibers, ranging from 9 to 17 micrometers. For transportation and subsequent manufacturing operations, these fibers are wrapped into bigger threads. Examples of rebar made of CFRP are shown in Figure 10.18.

10.6.3 Aramid

Aramid fibers were used to produce first-generation FRP prestressing tendons in the 1980s in Europe and Japan; however, few manufacturers still produce aramid

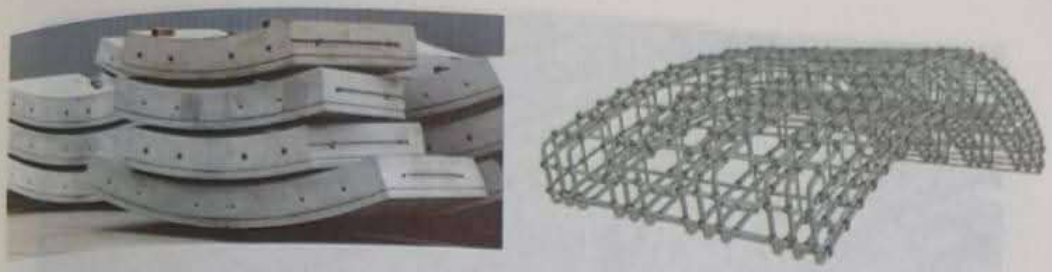


FIGURE 10.6 GFRP reinforcement cage for a tunnel segment.

FIGURE 10.7 FRP deck panels over concrete girders [©Berg *et al.* 2006, reproduced with permission].

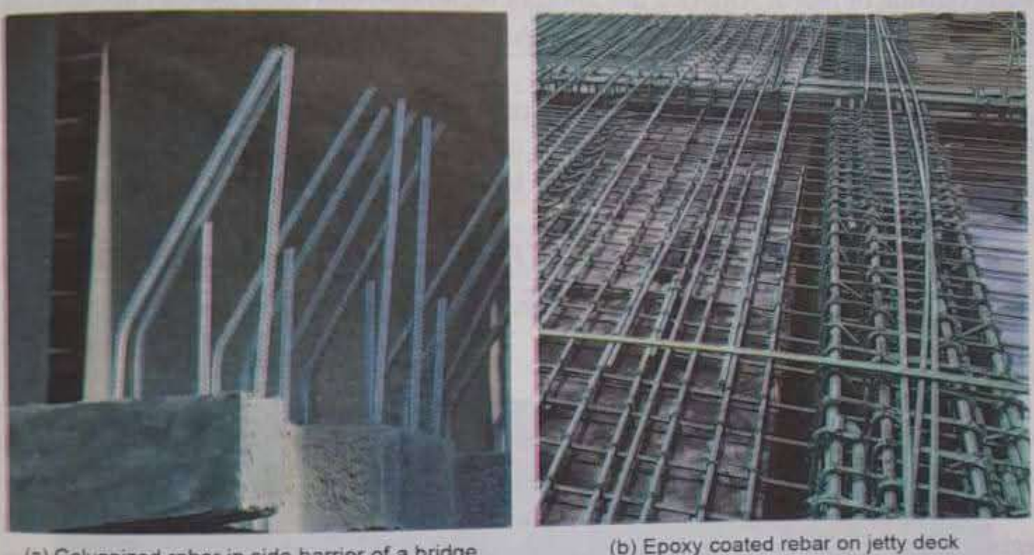
10.5 APPLICATIONS IN REPAIR AND RETROFITTING

FRP materials are extensively used to repair and retrofit concrete and other structures. Owing to their lighter weight, high strength, and durability, these materials, especially the CFRP, have found their way to almost every type of repair and retrofitting work.

Retrofitting applications are roughly categorized into two groups (Bank 2006). One type is strengthening, which involves increasing the strength or ductility of the original structure (usually, its deformation capacity) beyond the loads (or deformations) for which it was originally built. This increase may be required to make the structure compliant with existing building codes (especially in the case of seismic retrofitting), or it may be desirable owing to changes in the structure's usage. FRP retrofitting to increase a structure's performance (load carrying and ductility) when subjected to blast and impact loads has gained attention. The other sort of FRP retrofitting is repair. The FRP composite is utilized in this situation to retrofit an existing and deteriorating structure to restore its load-carrying capacity or ductility to the loads or displacements for which it was built (and hence is, in fact, a type of strengthening). When the original structure has deteriorated owing to environmental influences, such as corrosion of steel reinforcement in concrete, or when the original

Galvanizing, or coating a steel product with a thin layer of zinc (Zn), to protect steel from corrosion had been in practice for more than a century. The first standard specification for hot-dip galvanizing was published by ASTM in 1927 and the US Navy used galvanized rebar in a bridge in Bermuda in 1953 (Lane and Kleinhans 2016). It is an established means of protecting steel reinforcement and other embedded steel components against corrosion in concrete. It has been quite widely used for more than 100 years in many places for a variety of aggressive and mild-to-moderately corrosive environments for concrete structures (Figure 9.1a).

Compared to galvanizing, epoxy coating of reinforcement for corrosion protection is a relatively new technology that emerged in the 1970s. In 1973, a bridge in West Conshohocken, Pennsylvania, was the first to use epoxy-coated reinforcing steel. The epoxy-coated steel reinforcement bars were used on four of the bridge's spans. The National Institute of Standards and Technology (NIST) conducted testing on a variety of coatings to assess their corrosion-protective properties, chemical and physical durability, and chloride permeability characteristics (Clifton *et al.* 1975). Based on the results of the tests, a fusion-bonded epoxy coating applied to reinforcing steel was offered as a means to improve bridge deck corrosion resistance (Figure 9.1b).



(a) Galvanized rebar in side barrier of a bridge

(b) Epoxy coated rebar on jetty deck (Photo courtesy - BSRM)

FIGURE 9.1 Examples of zinc and epoxy-coated rebar.

9.3 STANDARD COATING FOR REINFORCEMENT

ASTM recognizes the following types of coated bars, wire, and welded-wire reinforcement.

a. Epoxy-coated (ASTM A775, A884, A934).
b. Galvanized (ASTM A767).
c. Dual-coated (ASTM A1055).
d. Vinyl-coated (ASTM A933).

FIGURE 9.5 Application of ECR in a spread footing (Photo courtesy – BSRM).

FIGURE 9.6 Application of ECR in floor slab (Photo courtesy – BSRM).

FIGURE 3.3 A modern 100-ton capacity universal testing machine.

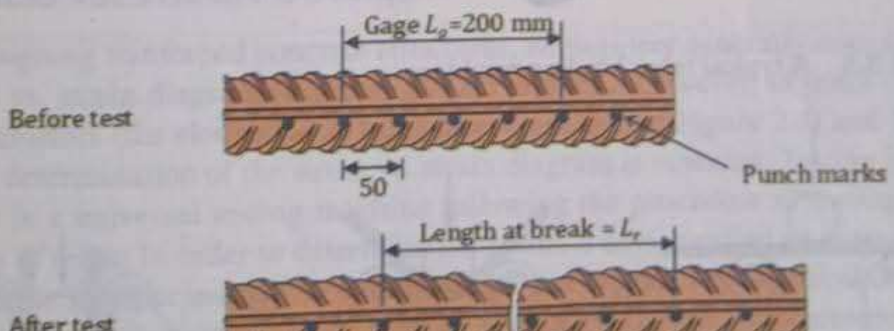


FIGURE 3.4 Marking of a specimen for elongation measurement.

3.5 BEND TESTING

Bendability of rebar is an important characteristic. This is an indirect measure of ductility. Bend testing of rebar is performed by bending a piece of rebar around a pin with a specific diameter. The bend-test specimen must withstand being bent around a pin without cracking on the bent portion's outside radius. The requirements for