(GFRP)
GLASS FIBER REINFORCED POLYMER

Contact: Brigadier Tariq Khalil (R)

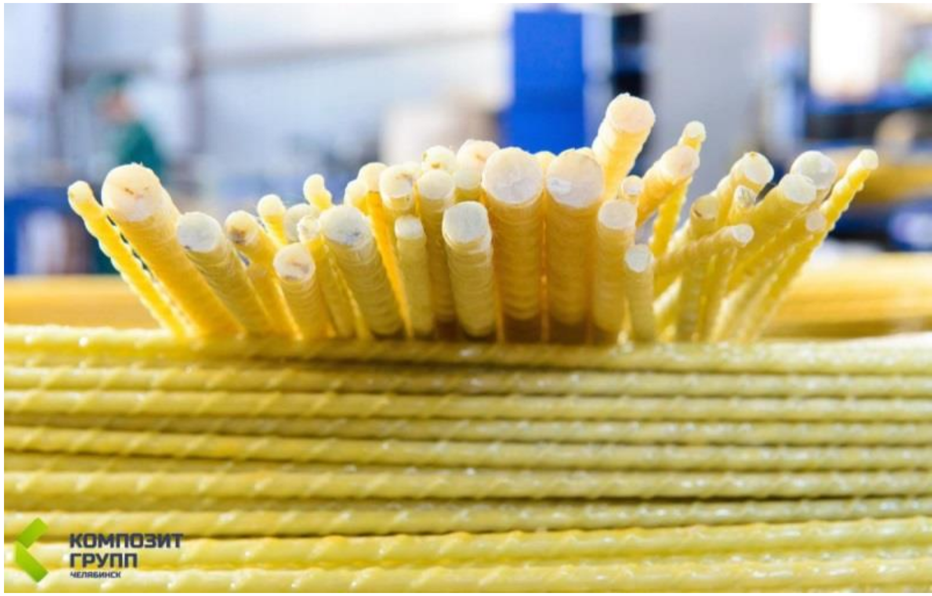
Tel: 021-35863795/97, 021-35863317, Cell / Whatsapp: 03008221084

Glass Fiber Reinforced Polymer Rebar

Glass Fiber Reinforced Polymer Rebar (GFRP)

Continually developing technologies and creating materials with unique features allow to achieve higher results in construction. Building rebar is an ancillary material, and its main purpose is to provide structural strength. GFRP is considered the best in comparison with other existing variants for reinforcing ferroconcrete and masonry constructions. Composite non-metallic reinforcing bars are bars with a spiral transverse riffling. This unique construction material is composed of fiberglass and thermosetting resins. The former guarantees high strength of reinforcing bars, while the latter functions as the binder. Main advantages of the composite fiberglass rebar are its lightness combined with high strength.


КОМПОЗИТ
ГРУПП
ЧЕЛЯБИНСК


КОМПОЗИТ
ГРУПП
ЧЕЛЯБИНСК


КОМПОЗИТ
ГРУПП
ЧЕЛЯБИНСК


КОМПОЗИТ
ГРУПП
ЧЕЛЯБИНСК


КОМПОЗИТ
ГРУПП
ЧЕЛЯБИНСК


КОМПОЗИТ
ГРУПП
ЧЕЛЯБИНСК


КОМПОЗИТ
ГРУПП
ЧЕЛЯБИНСК


КОМПОЗИТ
ГРУПП
ЧЕЛЯБИНСК

Polymer rebar made of fiberglass in building and construction work is the principal competitor for metal reinforcement materials. Its technical characteristics and mechanical-and-physical properties, i.e. hardness and corrosion resistance (inoxidizability) make it possible to apply this kind of rebar as flexible linking members for masonry buildings with three layers of bricks and for buildings with reinforced concrete solid-cast type walls with brickwork casing. Today fiberglass rebar has found an extensive industrial application in construction industry all over the world, e.g. it is used in construction of skyscrapers in United Arab Emirates, it is more and more used in European countries, and in Japan it is becoming the only kind of rebar to be applied when constructing earthquake-resistant structures (seismic designs).

Advantages

9 times lighter and 3 times more tensile

In comparison with steel rebar from Class A-III, its tensile strength is three times higher. Provided they have identical diameters, the specific weight of composite rebar is 4 times less. When substituted with an equal in strength rebar, composite fiberglass rebar has a specific weight, which is 9 times less in comparison with that of steel rebar.

Glass Fiber Reinforced Polymer bar (GFRP) serves long. Its working lifespan is no less than 80 years

Long service of the material accounts for its ability to preserve properties over a period of no less than 80 years (absolute performance period specified by experts). Its service life is not limited. Use of fiberglass rebar results in minimization of repair work and increases durability of the reinforced construction design.

Resistant to corrosion, alkalies, acids

Corrosion-resistant. Falls under category of materials of the 1-st group of chemical durability, which guarantees that there will occur no cracking and destruction of concrete constructions because of internal stresses that appear due to corrosion of steel rebar. Resistant to alkaliferous substances, chloride salts and acids.

It does not create electromagnetic interferences, does not conduct heat

Composite rebar is extensively used in construction of residential buildings. Popularity of the material accounts for its dielectric properties and low thermal conductivity. Fiberglass rebar is a dielectric material, that is why its use in construction industry in the future will not cause maintenance problems related to electromagnetic interference. Low thermal conductivity of fiberglass provides for additional preservation of heat indoors. Unlike metal rebar, composite rebar does not cause short circuits inside concrete constructions. In composite reinforcing bars there do not occur small currents.

Composite rebar is cheaper than its equal in strength steel counterparts

Use of the given material provides a considerable saving due to several factors: lower expenses on buying the material itself, decreasing costs on delivery, assembly, loading and unloading operations. Besides, economy is provided by lower weight and volume of rebar, and, accordingly, by decreased labour costs.

Simpler and more economic to transport

Reinforcing bars of tradable diameters up to 10 mm are supplied in coils with diameter of ~meters and weight of about 8-10 kilograms. In such form the rebar can be transported in trunk space of the passenger car, in a van or a small truck, while metal fittings are usually transported in long vehicles (more than 12 m), which is much more expensive to rent.

Flameproof

Composite rebar is non-combustible. It is manufactured of nonflammable materials. Its operation temperatures range broadly from -70°C to 400°C. The binding agent of composite rebar is destroyed by prolonged exposure to temperatures above 200°C, but concrete also loses its properties necessary for normal work if exposed to similar conditions.

It is manufactured in reinforcing bars of required length

Reinforcing bars can be delivered both in the form of rods (bars) or in coils of needed length, which saves the customer from excess payments for remaining rebar.

The same coefficient of expansion as that of concrete

When the temperature goes up, metal fittings gradually cause deformation of concrete owing to different coefficients of thermal longitudinal expansion. Fiberglass rebar has the thermal-expansion coefficient similar to that of concrete, that is why such rebar does not destroy it.

It preserves tensioning and strength when exposed to bending

It remains straight when wound in coils, which is very handy for mounting works.

Easy to mount

Joining this kind of rebar can be performed by workers with minimum use of materials and tools. Composite rebar is easy to cut; one can cut it with an angle grinder or a cross-cut, and for cutting the rebar of small diameters scissors or cutting pliers can be applied.

Scope of Applications

Use of composite construction materials made of polymer raw materials can several times increase the working lifespan of constructions in comparison with constructions where there is used metal rebar. It is especially true about building and construction work conducted in corrosive environment, which contains chloride salts and other chemically active substances. Rebar made of polymer raw materials is used for various applications according to requirements of construction designs in the following cases:

- in the course of building industrial and civil objects.
- in the course of road building.
- in the course of building and construction work aimed to create concrete constructions.
- as flexible coupling for three-layered walls of stone constructions, both civil and commercial constructions.
- in the course of work aimed to reinforcing coastlines.
- for different classes of work at ports.
- as mesh and bars in different construction designs.
- in the course of work aimed to construct sewage and irrigation engineering objects.
- in the course of layered bricking.
- when building elements of infrastructure for chemical industry.
- when working with the body of the road or road fences.
- in the course of work aimed to mount wall heat-insulation outside the building.
- for objects made of concrete with prestressed or stressed reinforcement, among which there are: power transmission line supports, products applied for constructing manifold groups, etc.
- for creating a seismic resistance belt for buildings that either have been already constructed or are still under construction.

Application Examples in Photographs


КОМПОЗИТ
ГРУПП


КОМПОЗИТ
ГРУПП


КОМПОЗИТ
ГРУПП
ЧЕЛЯБИНСК

Comparative technical characteristics of GFRP bar and steel reinforcement

Comparison characteristics of composite reinforcing bars АКП-СП and steel reinforcement A-III are shown in the following table.

Parameter	Steel Rebar	Glass Fiber Reinforced Polymer bar (GFRP)
Material	Steel	Glass roving, epoxy resin based polymer
Tensile strength, MPa	390	1000-1300
Modulus of elasticity, Mpa	200 000	50 000
Relative extension, %	25	2,2
Density, t/m3	7	1,9
Coefficient of linear expansion αx*10-5/°C	13-15	9-12
Temporary tensile strength, MPa	360	From 750
Corrosion resistance to aggressive environments	Corroding	Non-corroding material, 1st group of chemical resistance, including the alkaline environment of concrete
Thermal conductivity	Transcalent	Non- transcalent dielectric
Electroconductivity	Electroconductive	Non-electroconductive – dielectric
Available profiles, mm	6 — 80	4 — 24
Length	6-12 m rods	Any manufactured lengths of rods and hanks
Environmental friendliness	Environmentally friendly	Sanitary and epidemiological inspection report: no harmful and toxic substances emission
Lifetime	In accordance with building standards about 50 years.	Not less than 100 years (estimated)
Parameters of equally efficient reinforcing cage with a load of 25 t / m2	For 8 A-III steel rebar the cell size is 14 x 14 cm, the weight is 5,5 kg/m2	For 8 FRP the cell size is 23 x 23 cm, the weight is 0,61 kg/m2 (9 times less)

Example of computation run of economy: composite rebar versus metal rebar. Note, prices have been taken as example on average basis.

Steel Rebar	Price, $ per 1 ton	Weight of 1 linear meter, kg	Linear meters in 1 ton	Price, $ per 1 linear meter	Interchange-ability	Composite Fiberglass Rebar	Weight of 1 linear meter, kg	Linear meters in 1 ton	Price, $ per 1 linear meter
⌀8	514,7	0,395	2532		↔	⌀4	0,02	50000	
⌀10	514,7	0,617	1621		↔	⌀6	0,05	20000	
⌀12	485,2	0,888	1126		↔	⌀8	0,08	12500	
⌀14	485,2	1,21	826		↔	⌀10	0,12	83500	
⌀16	485,2	1,58	633		↔	⌀12	0,2	5000	

Length in meters of metal rebar in one ton according to GOST 5781-82.

Substitution variants: equal in strength fiberglass rebar replaces metal rebar

Concept of equal in strength substitution means that steel rebar is replaced with rebar made of composite materials, while the latter has the same strength and its other physico-mechanical parameters are similar to those of steel rebar. Equal in strength diameter of fiberglass rebar means such an outside diameter, which provides the same strength as the strength of its metal counterpart with set diameter. Substitution data are listed in the table below:

Steel Rebar A-III	Glass Fiber Reinfoced Polymer bar (GFRP)
6	4
8	5,5
10	6
12	8
14	10
16	12
18	14
20	16

Delivery Options

Composite plastic rebar versus metal rebar shows a significant advantage – it has memory, i.e. it will regain the original shape after it was changed (restitution ability). This ability of composite rebar allows to transport rebar not only in the form of bars (rods), but also wound in coils. The latter is most economical, since it allows a substantial saving of money on transportation, because then there is no need to rent big trucks and hire loading hands. After delivery the customer cuts the material into bars (rods) according to required parameters.

We make deliveries in the following formats:

— With diameters from 4 to 10 mm rebar is delivered in coils 100 meters length.

— With diameters from 12 to 20 mm rebar is delivered in rods. The length of rods is from 6 to 12 m.

Size and volume of coils depending on the diameter of reinforcing bars

Outer diameter of reinforcing bars, mm	Running meters in one coil	Sizes of the coil, m	Volume of the coil, m3
4	100	0,9*0,9*0,045	0,036
6	100	0,9*0,9*0,055	0,044
8	100	1,05*1,05*0,07	0,077
10	100	1,25*1,25*0,09	0,140

Documents and Certificates

Products are manufactured according to the state standard (GOST), there are available all necessary certificates of quality conformance and the expert opinion about compliance of our products with the norms stated in the Integrated Sanitation, Epidemiological and Hygienic Product Requirements.

/Identity of the Russian and English documents is confirmed by the South Urals Chamber of Commerce and Industry (SUCCI)/

GOST R CERTIFICATION SYSTEM

FEDERAL AGENCY ON TECHNICAL REGULATING AND METROLOGY

CERTIFICATE OF CONFORMITY

No. РОСС RU.АГ81.Н03409

Validity period from 06.04.2017 till 05.04.2020

No. 0049971

CERTIFICATION BODY Accreditation Certificate No. РОСС RU.0001.11АГ81. Product Certification Body ООО "Biryuza" (Biryuza, LLC).
Address: Block No. 526, Territory of Promzona, Town of Vidnoye, Leninskiy District, Moscow Region, 142703, Russia
Tel. +74955328497, fax +74955328497, e-mail: cs.buryuza@yandex.ru.

PRODUCTS Composite polymer reinforcement of "Composite Group" trademark
Serial production.

OK code (All-Russian Classification of Production code)
034-2014
(КПЕС (СРА) 2008)
23.14.12.190

CONFORMS WITH THE REQUIREMENTS OF NORMATIVE DOCUMENTS
GOST 31938-2012

ТН ВЭД code (CN FEA code (commodity nomenclature of foreign economic activity))
7019 90 000 9

MANUFACTURER "Composite Group", Limited Liability Company
Address: 7 Kokchetavskaya St., City of Chelyabinsk, Chelyabinsk Region, 454077, the Russian Federation.

THE CERTIFICATE IS ISSUED TO "Composite Group", Limited Liability Company
OGRN (Primary State Registration Number): 1127452006923.
Address: 7 Kokchetavskaya St., City of Chelyabinsk, Chelyabinsk Region, 454077, the Russian Federation
Tel.: +7(351) 215-22-23

ON THE BASIS OF Test Report No. 05508-392/1-1-17/БМ dated 04.04.2017 of the Testing Laboratory of "Business Market", Limited Liability Company; accreditation certificate No. ROCC RU. 0001.21 AB90; Test Report on Glass-Composite Reinforcement No. 1515/16 dated 24.05.2016 of the Testing Centre "Ural Scientific and Research Institute of the Construction Materials (UralNIIstrom)", accreditation certificate No. ROCC RU. 0001.517489 dated 24.09.2015.

ADDITIONAL INFORMATION Certification procedure: 3.

Head of the Certification Body	/signed/ (signature)	Zh.V. Ivanova (name)
Expert	/signed/ (signature)	I.M. Melsitdinova (name)

/Sealed: Certification Body
Biryuza, Limited Liability Company, Town of Vidnoye, Moscow Region, Accreditation Certificate No. РОСС RU.0001.11АГ81
For certificates and declarations/

The certificate is not applicable for mandatory certification

Seal below: The South Urals Chamber of Commerce and Industry
INN 7451016239 OGRN 1027400000649
OKPO 12580250 Chelyabinsk the Russian Federation/

СВИДЕТЕЛЬСТВО О ВЕРНОСТИ ПЕРЕВОДА
НАСТОЯЩИМ удостоверяется, что русский и английский тексты документа соответствуют друг другу.
Начальник отдела переводов ЮУТПП
А.П. Ковалева
Челябинск/
25.09.2018

AFFIDAVIT OF ACCURACY
IT IS CERTIFIED hereby that the documents in the English and Russian languages are identical.
Head of Translation Dept of the SUCCI
A.P. Kovaleva
Chelyabinsk

FEDERAL SERVICE FOR SUPERVISION OF CONSUMER RIGHTS PROTECTION AND HUMAN WELFARE (ROSPOTREBNADZOR)
DIRECTORATE OF THE ROSPOTREBNADZOR FOR THE VLADIMIR REGION

FEDERAL BUDGET HEALTHCARE INSTITUTION
SANITARY AND EPIDEMIOLOGICAL CENTER IN THE VLADIMIR REGION

Testing Laboratory Centre, GosSanEpidemNadzor certificate No. ГСЭН.RU.ЦОА.017, State Register No. РОСС RU.0001.510136
Legal address/mail address: 5 Tokareva Str., Vladimir 600005
Phone: (0942) 535828, 535836, 535835, Fax: (4922) 535828

Reg. No.: 2301
of June 1, 2012

APPROVED
by Deputy Chief Medical Officer of
the Federal Budget Healthcare Institution
'Sanitary and Epidemiological Center in the Vladimir Region'

A.N. Brychenkov

EXPERT REPORT No. 602

on product compliance with Unified Sanitary Epidemiological and Hygienic Requirements for Goods Subject to Sanitary and Epidemiological Control (Supervision)

1. **Product**: Composite Group composite reinforcement

2. **Manufacturer**: Composite Group LLC

3. **Report issued to**: Composite Group LLC

4. **Submitted materials:**

- Specification TU 2296-001-37026550-2012 "'Composite Group' composite reinforcement"
- Laboratory Examination Report of the Research Centre of Sergiev Posad Branch of Federal Budget Institution "Standartization, Metrology and Certification Center in Moscow Region" No. 425-0050 of May 4, 2012 (State Sanitary a nd Epidemiological Supervision (GosSanEpidemNadzor), Accreditation Certificates No. POCC RU.0001.516503, GOST R Accreditation Certificate No. POCC RU.0001.21AIO22);

5. **Product application**: for reinforcement of concrete, asphalt concrete and pre-tensioned structures suitable for corrosive and non-corrosive environment.

ZERTIFIKAT ■ CERTIFICATE ■ 認證證書 ■ СЕРТИФИКАТ ■ CERTIFICADO ■ CERTIFICAT

Management Service

CERTIFICATE

The Certification Body
of TÜV SÜD Management Service GmbH

certifies that

КОМПОЗИТ ГРУПП COMPOSITE GROUP

COMPOSITE GROUP CHELYABINSK, LLC
2nd Paveletskaya str. 36, office 303, Chelyabinsk Region
454047 Chelyabinsk
Russian Federation

has established and applies
a Quality Management System for

Design, development, production and sale of composite polymer products intended for reinforcement of building structures and elements in civil, industrial, road construction.

An audit was performed, Report No. **707081720**.

Proof has been furnished that the requirements according to

ISO 9001:2015

are fulfilled.

The certificate is valid from **2017-12-21** until **2020-12-20**.

Certificate Registration No.: **12 100 55054 TMS**.

Product Compliance Management
Munich, 2017-12-21

IAF DAkkS

CENTER FOR AFFORDABLE HOUSING

AND SUSTAINABLE BUILT ENVIRONMENT

N.E.D UNIVERSITY OF ENGINEERING AND TECHNOLOGY KARACHI

Department Of Civil Engineering

Phone: (92-21) 9261261-8, Ext. 2680

Ref: NED/CAHSBE/IIL/001

Date: July 29, 2020

SUBJECT – TESTING OF GFRP BARS

In Reference to the TESTING of the GFRP Bars, enclosed is the following:

1. **TEST REULTS – GFRP BARS**
2. **TESTING - PHOTOGRAPHS**

REMARKS
1) Results pertain to the GFRP BARS samples supplied to the laboratory.
2) The cross-sectional area is taken as standard numbered steel concrete reinforcing bar given in ASTM A615/A615M, Table 1.
3) Periodic slippage occurred in the end anchors of GFRP bars, thus reported elongation at Max force is the adjusted value to account for the slippage.

The test results show that the Ultimate Tensile Strength (UTS) of the GFRP basr exhibit a high value of 159 ksi and a low value of 99 ksi. The corresponding strain varies from a low of 0.013 to a high of 0.218.

Best wishes.

Shoaib Ahmad

Prof. Dr. Shoaib Ahmad
JPC Chair Professor, Department of Civil Engineering
Ph.D., PE (USA), FASCE, FACI, MPCI, PE (Pak), MIEP (PAK)
Life Time Member Pakistan Engineering Council (PEC)
Fellow of Pakistan Academy of Engineers
Ex-Chief Engineer ACI
Ex-Member Executive Council, ACEP
Email: sahmad@neduet.edu.pk

1. TEST REULTS – GFRP BARS

Name of Customer	IMS
No of Specimen	19
Reference No.	DO20-100/20-0065
Type of Specimens	GFRP Bars
Standard Test Method	ASTM D7205-06 (Reapproved 2016)
Type of Specimens	GFRP Bars
Date of Testing	24-02-2020 to 11-03-2020
Type of Testing	Tensile Properties
Notes	1) Results pertain to the samples supplied to the laboratory. 2) The cross-sectional area is taken as standard numbered steel concrete reinforcing bar given in ASTM A615/A615M, Table 1. 3) **Periodic slippage occurred in the end anchors of GFRP bars, thus reported elongation at Max force is the adjusted value to account for the slippage.

Results:

S. No	Nominal Size mm (in)	Cross Sectional Area mm^2 (in^2)	Length of Bar under test mm (in)	Max. Load kN (Kips)	Ultimate Tensile Strength N/mm^2 (ksi)	**Elongation at Max. Force (%)	Elastic Modulus GPa (ksi)
1-1	4 (0.16)	12.57 (0.02)	290 (11.42)	10.46 (2.35)	833 (121)	1.62	51.34 (7445)
1-2				12.14 (2.73)	966 (140)	1.90	50.73 (7358)
1-3				9.35 (2.10)	744 (108)	1.43	51.87 (7523)
2-1	6 (0.24)	28.27 (0.04)	290 (11.42)	20.41 (4.59)	722 (105)	1.39	52.03 (7545)
2-2				19.26 (4.33)	681 (99)	1.30	52.34 (7591)
2-3				20.77 (4.67)	735 (107)	1.41	51.93 (7532)
3-1	8 (0.31)	50.27 (0.08)	290 (11.42)	47.49 (10.68)	945 (137)	1.86	50.81 (7370)
3-2				46.81 (10.52)	931 (135)	1.83	50.87 (7378)
3-3				51.94 (11.68)	1033 (150)	2.05	50.49 (7322)
4-1	10 (0.39)	78.54 (0.12)	650 (25.59)	70.41 (15.83)	896 (130)	1.76	51.02 (7400)
4-2				64.54 (14.51)	822 (119)	1.60	51.39 (7454)
4-3				73.56 (16.54)	937 (136)	1.84	50.85 (7374)
5-1	12 (0.47)	113 (0.18)	650 (25.59)	92.94 (20.89)	822 (119)	1.60	51.39 (7454)
5-2				89.40 (20.10)	790 (115)	1.53	51.57 (7480)
5-3				97.45 (21.91)	862 (125)	1.68	51.19 (7424)
6-1	14 (0.55)	154 (0.24)	900 (35.43)	125.46 (28.20)	815 (118)	1.58	51.43 (7459)
6-2				123.10 (27.67)	800 (116)	1.55	51.52 (7472)
7-1	16 (0.63)	201 (0.31)	800 (31.50)	210.26 (47.27)	1046 (152)	2.07	50.45 (7316)
7-2				220.51 (49.57)	1097 (159)	2.18	50.29 (7293)

Prime Minister's Office
Naya Pakistan Housing & Development Authority
(NAPHDA)

No. 06/Projects/2020

Islamabad, the 9th September, 2020

Subject: **Use of Reinforced Glass Fiber Polymer Rebars in Construction Industry - GFRP**

1. Presentation on the subject submitted by I & MS Engineering (Pvt) Ltd is forwarded herewith for evaluation of material and including it in building code, if found useful. Please contact Dr. Engr Shuaib Ahmad (Member PEC) Mobile 03003383083 for any technical information or test reports etc. It is pertinent to mention that new trends in material and technologies should be adopted / encouraged for incorporating in construction industry. This office may be kept informed on the progress.

2. For necessary action, please.

Brigadier
Executive Director Administration
(Nasir Manzur Malik)

Pakistan Engineering Council Ataturk Ave, G-5/2 East, Islamabad

Copy to:

Brigadier Tariq Khalil (Retd), Consultant / Advisor
I & MS Engineering (Pvt) Ltd
H.O: IMS Centre 10-K, P.E.C.H Block 6 Karachi

ed Jaffar Abbas	03462505940		
eeq Wahaj	0302286104		
...an Riyaz	03122828466		

Available online at www.sciencedirect.com

ScienceDirect

Karbala International Journal of Modern Science 4 (2018) 216–227
http://www.journals.elsevier.com/karbala-international-journal-of-modern-science/

Replacement of steel rebars by GFRP rebars in the concrete structures

Shahad AbdulAdheem Jabbar*, Saad B.H. Farid

Department of Materials Engineering, University of Technology, Baghdad, Iraq

Received 2 August 2017; revised 19 January 2018; accepted 8 February 2018
Available online 1 March 2018

Abstract

Glass fiber reinforced polymer (GFRP) has been confirmed to be the solution as a major development in strengthened concrete technology. Synthesis of GFRP rebars by using the longitudinal glass fibers (reinforcement material) and unsaturated polyester resin with 1% MEKP (matrix material) via manual process. GFRP rebars have diameter 12.5 mm (this value is equivalent to 0.5 inch; it's most common in foundations application). GFRP surfaces are modified by the inclusion of coarse sand to increase the bond strength of rebars with concrete. Then, the mechanical characterizations of reinforced concrete with GFRP rebars are performed and compared with that of steel rebars. Preparation of concrete samples (unreinforced concrete, smooth GFRP reinforced concrete, sand coated GFRP reinforced concrete and steel reinforced concrete) with fixed ratio of ingredients (1:1.5:3) and 0.5 W/C ratio were performed at two curing ages (7 and 28) days in ambient temperature. The value of volume fraction of GFRP and steel rebars in the reinforced concrete was (5 vol. %) equally distributed with specified distances in the mold. The results show the tensile strength of GFRP rebar is 593 MPa and bend strength is 760 MPa. The compressive strength was within reasonable range of concrete is 25.67 MPa. The flexural strength of unreinforced concrete is 3 MPa and reinforced concrete with GFRP rebar, especially sand coated GFRP RC exhibit flexural strength is 13.5 MPa as a result to increase bonding with concrete and higher strain is 10.5 MPa at 28 days than that of steel reinforced concrete at the expense of flexural modulus.

Keywords: GFRP rebars; Steel rebars; Reinforced concrete; Mechanical properties

1. Introduction

The traditional strengthened concrete members such as beams are composed of concrete included Portland cement and steel rebars reinforcement. The function of concrete in these beams is the resistance to compressive loads. The tensile and shear loads will be resisted by steel rebars embedded in the concrete. Such structure is efficient where the concrete inseparable resistance to compressive loads, while the steel enhances tensile and partially shear strengths. However, the problem of corrosion associated with the steel rebars reduced its live time and the solutions such as the coating of the steel rebars are costly. Recent technologies have resulted in alternative reinforcing materials such as GFRP materials commercially available in the form of bars or sheets that can be bonded in concrete

* Corresponding author.
E-mail address: shahad1992.sh@gmail.com (S. AA. Jabbar).
Peer review under responsibility of University of Kerbala.

https://doi.org/10.1016/j.kijoms.2018.02.002

members to fulfill several desired properties. The most important is that the corrosion resistance feature of the polymer and the elongated strain to failure that give enough time to alert before failure takes place [1] (see Fig. 1).

Experimental researches on some of concrete structures reinforced with GFRP bars were done (5—8) years ago. The results have shown that GFRP rebars weren't subject to any degradation process in existence of the alkaline and corrosive environment [2].

The tensile and shear strengths of GFRP bars by using four various diameters (20, 22, 25, 28 mm) have been discussed by authors. The young's modulus of GFRP bars was equal (1—5) of young's modulus of steel. The GFRP bars exhibited brittle behavior and the relationship between stress and strain was linearly elastic up to failure. The GFRP bars were anisotropic and they were characterized by high tensile strength only in the direction of the reinforcing fibers. The cross section dimensions didn't affect the GFRP bar modulus. Variation of the shear strength of all GFRP bars diameters was little, but the higher load caused failure. The ranges of GFRP bars shear strength were 16%—20% lower than the longitudinal tensile strength [3].

Reinforced concrete beams with the Glass Fiber Reinforced Polymer (GFRP) as an alternative of traditional rebar and behavior of beam under bending were also studied. The results concluded that use of GFRP rebar in tensile loads direction of beam have displayed flexural properties similar to the steel rebar and GFRP reinforced concrete has offered high bending properties, besides acceptable shear properties [4].

Authors studied a bending method of ultra-high performance fiber-reinforced concrete beams reinforced with GFRP rebars in different ratios in the beams. The low elastic coefficient of GFRP means that high deflection and more cracks, but the presence of short fibers in concrete will improve the bending performance (less deformation, higher ductility and higher rigidity) due to strain hardening with multiple micro cracks and increased bending strength with the increased reinforcement ratio. All of the test results showed a lower deflection due to strain hardening at a certain level of service [5].

Other authors presented a properties of reinforcing bars (steel and GFRP) in the concrete beams were used. The GFRP surface finish was different (sand coating and helically grooved surface). The concrete beams were normal and high strength reinforced with steel and GFRP rebars. Steel reinforced concrete beam represents the reference sample. Bending test variables were type and reinforcement ratio, surface finish and rebar diameter. The results of the test showed that the cracks width in concrete was affected by the diameter of the reinforcement and the surface finish while the deflection was not affected by these parameters. All GFRP reinforced beams showed linear relation between stress and strain until failure. Normal strength concrete beams reinforced with GFRP have low strains compared with high strength concrete at the same level

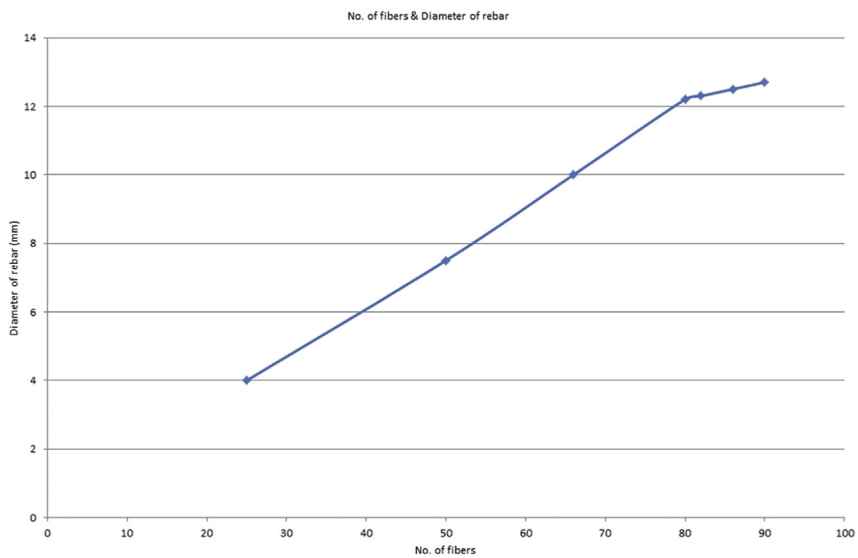


Fig. 1. Relationship between number of fibers and diameter of rebar.

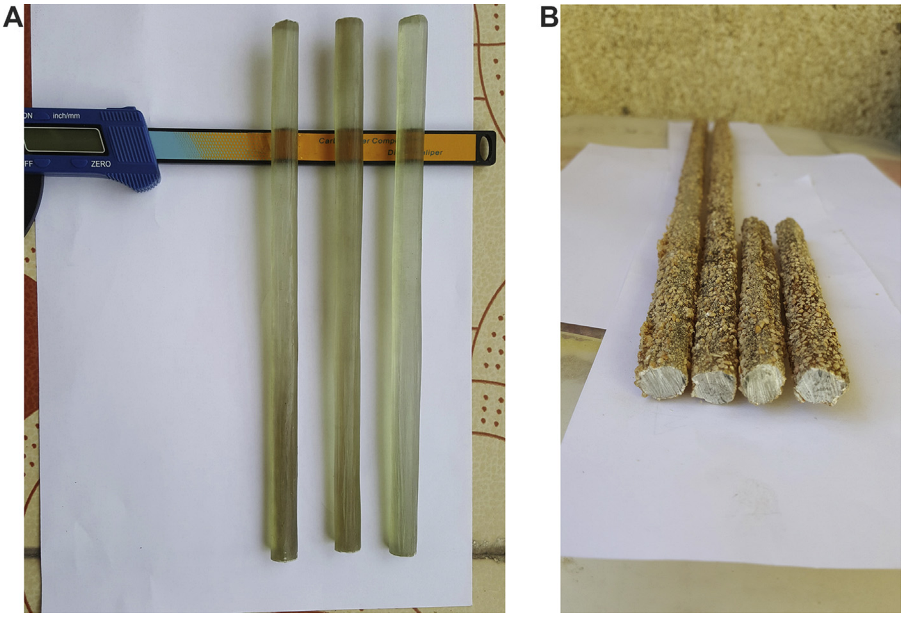


Fig. 2. GFRP specimens. (A) GFRP only, (B) Sand coated GFRP.

of load. Sand coated GFRP reinforced beams showed smaller cracks and reduced cracks width compared with helically grooved GFRP reinforced beams, which indicated better bond properties between concrete and GFRP [6].

The hybrid reinforcement (steel and GFRP) was discussed by authors for ultra-high performance fiber-reinforced concrete to improve the ductility and elasticity of FRP reinforced concrete. Bending test for high strength fiber-reinforced concrete reinforced with GFRP rebars (3 beams) and ultra-high performance fiber-reinforced concrete reinforced with steel (4 beams) at different reinforcement ratios was performed. Due to the strain hardening, all samples showed high stiffness after initial cracking. Increased GFRP ratio improved performance under bending test (ductility and stiffness). The hybrid reinforcement was by replacing part of the GFRP with steel rebars to improve stiffness before steel yielding which leads to less deformability [7].

A study simulates the flexural behavior of ultra-high performance fiber reinforced concrete beams reinforced with steel and GFRP was performed by authors. Finite element model was first carried out on the basis of single fiber pull-out method. Two different tension-softening curves (TSCs) with the assumptions of 2-dimensional (2D) and 3-dimensional (3D) random fiber orientations were obtained from the micromechanics-based modeling, and linear elastic compressive and tensile models before the occurrence of cracks were obtained from the mechanical tests and rule of mixture. Analytical results showed 2D random fiber orientation was suitable for ultra-high performance concrete beams non reinforced with rebar and 3D random fiber orientation was suitable for ultra-high performance concrete beams reinforced with steel and GFRP due to disorder alignment as a result of internal reinforcement [8].

The surface characteristics of FRP rebars were already discussed by authors. The rates of smooth FRP bond strength can be approximately comparable to that of steel distorted rebars. Modified FRP rebars with coarse sand can offer better bonding than smooth rebars. This is because the flexural modulus of the FRP bars are always less than steel reinforcing bars hence, the bond strength is extended at more slips [9].

The bond strength of fibers reinforced polymer (FRP) rebars in concrete with simple strength was studied. The pullout test was performed to measure the four various types of reinforcing bar: aramid FRP (AFRP), carbon FRP (CFRP), glass FRP (GFRP) and steel. The total samples were 151 including rebars with diameters (6, 8, 10, 16 and 19 mm) embedded in the concrete samples (203 mm cube). The results concluded that the effective mean of surface deformation applied to improve the bond between concrete and bars were similar to the ones on steel, other means of surface deformation were by making an external helicoid strand and deep dents (groves) which are acceptable means of bond improvement. One of the easier means of surface deformation was by sand coating for obtaining bond strength better than that of those with smooth surface [10].

2. Aims of the work

Glass fiber reinforced polymer (GFRP) was used as an alternative material to the steel rebar. It is light-weight, no-corrosion, superior tensile strength, and high mechanical performance. Installation of the GFRP rebar is similar to steel rebar, but with less handling, transporting and storage problems. In this work, the unsaturated polyester resin and E-glass fibers are used to synthesis GFRP rebars of 1.25 cm diameter to simulate the dimensions of steel rebars. Their surfaces are modified by the inclusion of coarse sand to avoid slipping in stress conditions. Then, the mechanical characterizations of reinforced concrete with GFRP rebars are applied and compared with that of steel rebars.

3. Materials and methods

3.1. Materials used

The Materials used in this research and their characteristics are: Glass fibers in the form of a mat "JIASHAN FIBERGLASS WEAVING FACTORY ZHEJIANG, China" Weighing 600 g$\setminus$m^2 and a length of 1250 mm. The fibers are pulled from the mat and utilized to synthesis rebars. It is found that 86 fibers and the added resin are required to produce a rebar of 1.25 cm diameter. Unsaturated polyester resin "FARAPOL Company, Iran" and Hardener (Methyl ethyl ketone peroxide) "akpakimya company, Turkey". Ordinary Portland cement manufactured by (Mass-Bazian) was used, conformed to the Iraqi standard [11]. Al-Ukhaydir natural sand as fine aggregate and the gradation and selected chemical and physical properties were within limits of the Iraqi standard [12]. Gravel of (5–19 mm) gradation was utilized as a coarse aggregate from north of Baghdad (Al-Nabaai) and the sieve analysis, specific gravity, density and sulfate contents are within Iraqi standard No.45/1984 [12]. Tap water was used.

3.2. GFRP rebar

Synthesis of GFRP rebar from glass fibers and unsaturated polyester resin was produced by immersing the fibers longitudinally in the unsaturated polyester resin with (1%) of its hardener and then the excess polymer is removed. That was without the utilization of a mold, because in case of using a mold, the matrix will fail before fibers resistance when subjected to the forces of tension. Several efforts were made to fulfill the required diameter of bar by using different number of fibers and measuring diameter every time as shown in Fig (1). Finally a bar of diameter 12.5 mm was obtained which is common in construction applications. The resulting bar has fibers volume fraction of 80% and polyester volume fraction of 20%.

After obtaining GFRP as shown in Fig (2A), tensile and bend strengths were measured and compared with normal reinforcement bar. There are many ways to increase bonding between reinforcement and the concrete such as coating of GFRP bars with coarse sand of above 300 μm as shown in Fig (2B).

3.3. Mixing method

The used mixing proportion was (1:1.5:3). The dry materials (cement and sand) were thoroughly mixed per ASTMC-192 in a pan and then the gravel was combined and mixed with the entire batch by shovel until the gravel is uniformly distributed throughout the batch. Then the water was poured and blended with the dry materials for specific duration until the concrete is homogenous in appearance and has the desired consistency. The mixing process was paused and then returned for a few minutes and the open end or top of the pan was covered to prevent evaporation during the rest period. This step was repeated in two cycles to insure the homogeneity for mixture. The total mixing time was about 15 min [13] (see Fig. 2).

3.4. Molds used

Wooden mold for compressive strength and flexural strength was used throughout this investigation. Cubic shapes (edge length of 100 mm) of molds were used to prepare specimens for compressive strength and prismatic specimens of 100 × 100 × 400 mm for flexural strength. The molds were softly coated with Vaseline oil before use, per ASTMC-192 concrete casting was performed in different layers, each layer of 50 mm. Each layer was compacted by using Tamping Rods until no air bubbles emerged in the concrete, and the surface of concrete was leveled off fully to the upper of the molds by using steel trowel. Concrete is reinforced by 5 vol. % GFRP and steel bars evenly distributed with specific distance in the mold. Polyethylene sheets are utilized as

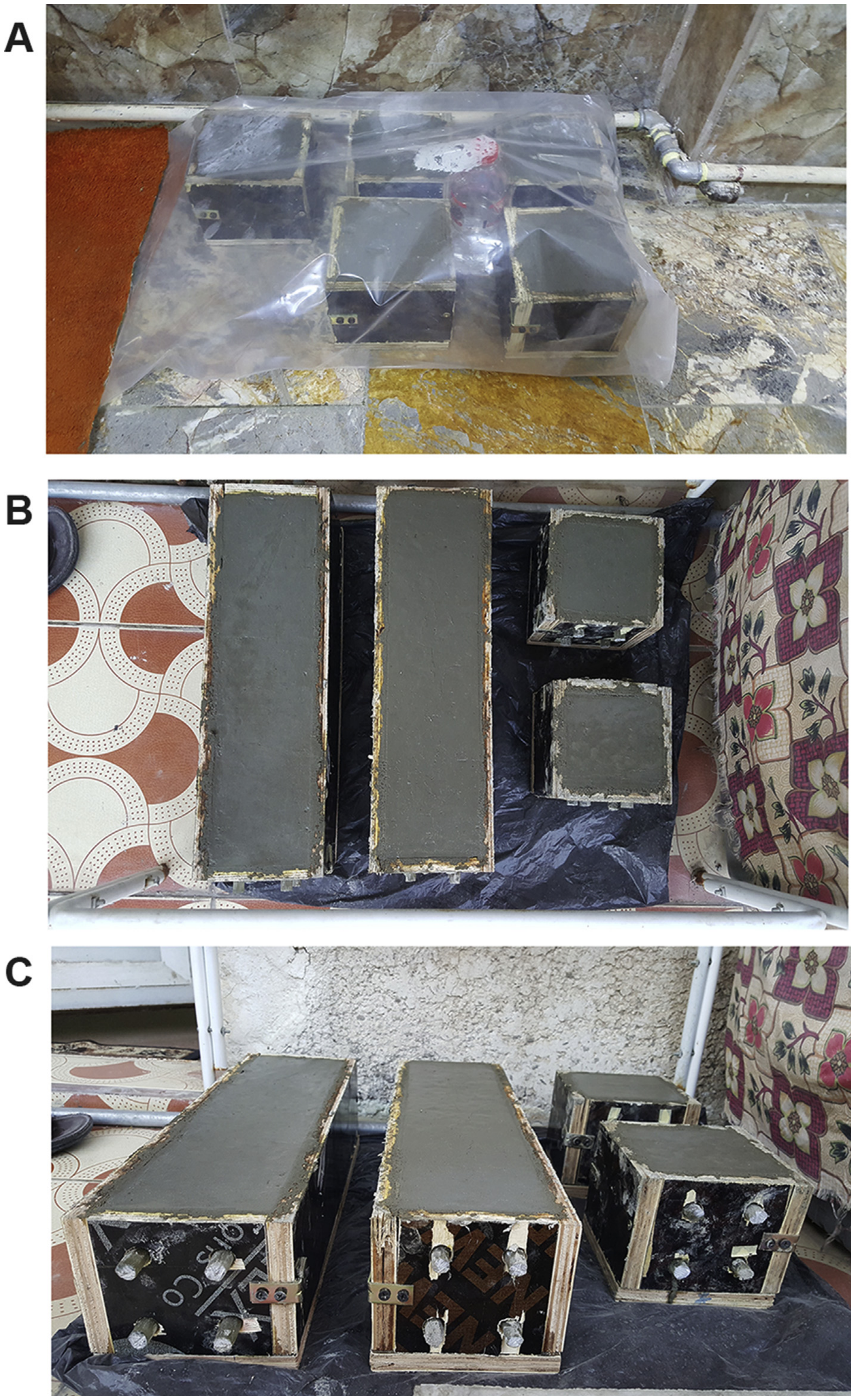


Fig. 3. (A−C): Casting of specimens.

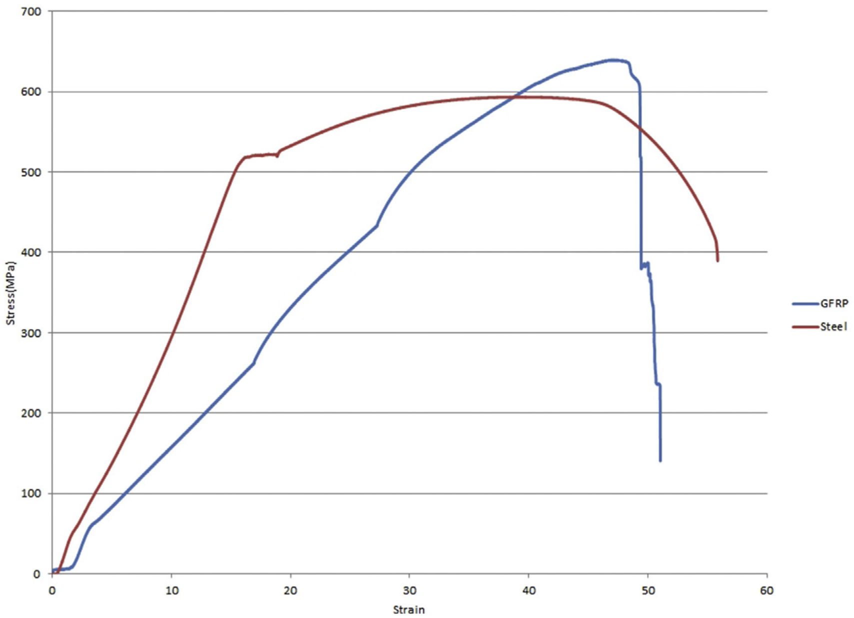


Fig. 4. Tensile curves of rebars.

covers for specimens after their casted for 24 h in room temperature (24 ± 2) °C to inhibit moisture content from evaporation as shown in Fig. 3 [13].

3.5. The effective curing in first ages is essential for the gain of durability, strength and stability of volume

The basic conditions that must be supplied to continue a reaction is the appropriate temperature, and adequate moisture. The green concrete contains enough water to complete the hydration process of cement, but in most conditions a large quantity of water is evaporated by heat. Moisture curing method was utilized to compensate for the water that evaporates during the casting process [14]. Specimens were completely submersed in water tanks at 21 ± 2 °C until the time of measurements (7 or 28 days) as a curing age.

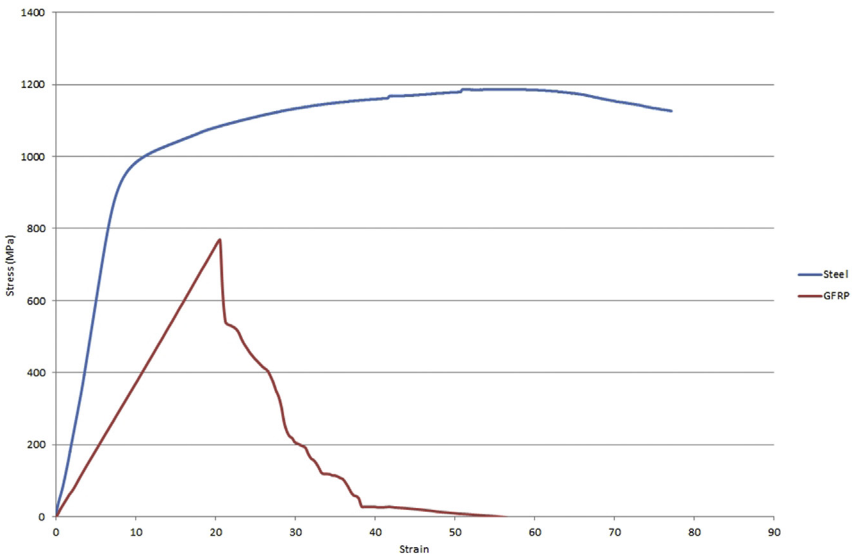


Fig. 5. Bending curves of GFRP and steel.

Table 1
Tensile strength of rebars.

Property	Samples	
	Steel	GFRP
Yield strength (MPa)	520	593
Yield strain	17	40

Table 2
Results of bending measurement of rebars.

Property	Samples	
	Steel	GFRP
Yield strength (MPa)	1050	760
Yield strain	16	20

Table 3
Compressive strength results of concrete.

Sample type	Compressive strength (MPa)	
	7 days	28 days
Unreinforced concrete	20.41	25.67

4. Results and discussion

4.1. Characterization of rebar

4.1.1. Tensile strength

The tensile strength was measured according to ASTM D7205-06 for GFRP rebar and ASTM A496-02 for steel rebars using specimen of 25 ± 5 cm length, 1.25 cm diameter [15,15a].

The concrete will be bonded with reinforcing bars, so that the extra tensile stresses, which can't be resisted by concrete, will be transported to the reinforcing bars therefore, the rebars must have a relatively high tensile strength (see Fig. 5).

Tensile measurement results are offered in Fig. 4 and Table 1).

The curves have shown that GFRP has higher yield strength than traditional steel rebar due to unique anisotropic property of composites makes them strong in tension. The yield strain of GFRP is higher than steel rebar; this will give the engineer premature warning of the failure Table 2.

4.1.2. Bending strength

Bending strength is measured per ASTM D790 for GFRP and steel rebar using specimen of 25 ± 5 cm length, 1.25 cm diameter [16]. This measurement is performed to determine an approximate values of the bending (strength and strain) of a bare GFRP reinforcing bar and it's compared with bare steel reinforcing bar. The results of bending measurements are shown in Fig (5) and Table (2).

The curves have shown the basic difference between GFRP and steel rebars. The results for the bending strength of GFRP showed that highest point of stress involve the stress which creates at the crack, after that the stress will decrease but the crack will grow until the failure. The initial failure of the steel rebar at strain 16.21%, while the initial failure of the GFRP starts at strain 20.23%. Thus, the use of the

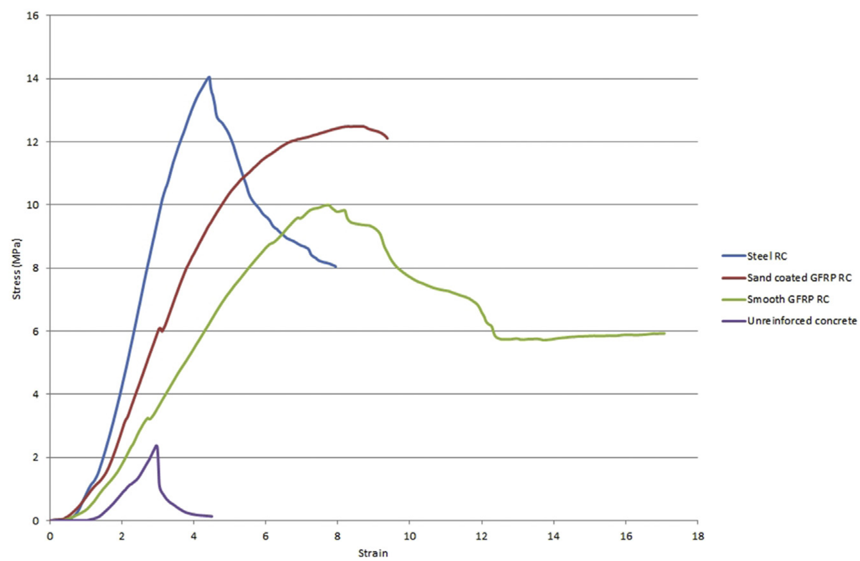


Fig. 6. Flexural curves of unreinforced and reinforced concrete at 7 curing age.

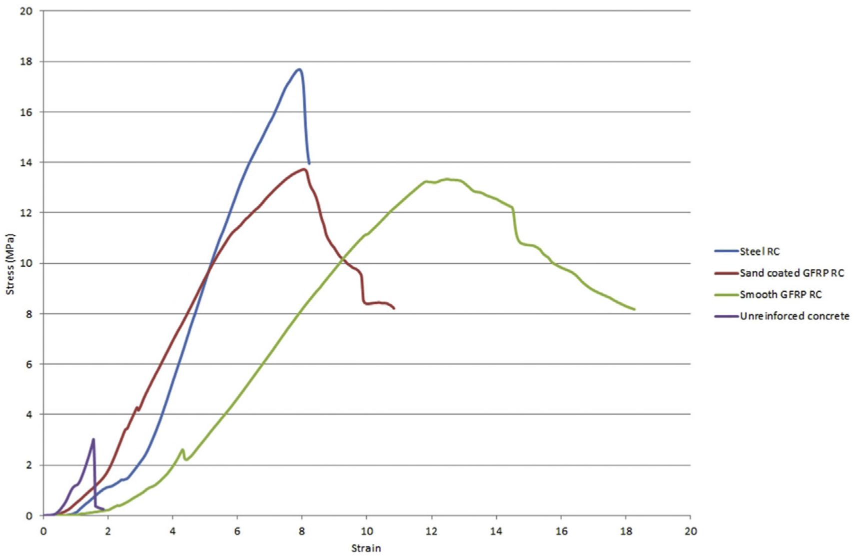


Fig. 7. Flexural curves of unreinforced and reinforced concrete at 28 curing age.

GFRP rebars shows more deflection before starting to fail. This can give more chance to be alerted before failure takes place.

4.2. Characterization of reinforced concrete

4.2.1. Compressive strength

The compressive strength is measured BS1881: part 116 [17]. The test samples were 100 mm cubes and the results are shown in Table 3. The sufficient compressive strength will be provided by concrete. The foundation is example of construction applications that require compressive strength according to mixing proportions used.

The results showed the compressive strength of unreinforced samples at 28 days is good for foundations application. The compressive loads will resist by concrete only as a result powdered ingredients of concrete.

4.2.2. Flexural strength

Measurement of flexural properties was done according to ASTMC-293 [18]. The test samples were 100 × 100 × 400 mm prisms and tested via three points loading. The specimens were measured after (7, 28) days of immersion in water.

Table 4
Average flexural characteristics values of samples (7 days curing).

Property	Samples			
	Unreinforced concrete	Smooth GFRP reinforced concrete	Sand coated GFRP reinforced concrete	Steel reinforced concrete
Flexural strength (MPa)	2	10.5	11.5	14
Strain	4.5	17	11	8
Modulus of elasticity (MPa)	500	500	1000	2000

Table 5
Average flexural characteristics values of samples (28 days curing).

Property	Samples			
	Unreinforced concrete	Smooth GFRP reinforced concrete	Sand coated GFRP reinforced concrete	Steel reinforced concrete
Flexural strength (MPa)	3	12.5	13.5	17.5
Strain	2	16	10.5	9
Modulus of elasticity (MPa)	1000	500	1000	1500

Fig. 8. (A, B): typical fracture of unreinforced concrete.

Fig. 9. (A, B): typical fracture of smooth GFRP RC.

This measurement was performed to determine ability of sand coated GFRP reinforced concrete to withstand flexural loads and to compare it with unreinforced concrete and other reinforced concrete samples.

The results of flexural tests are shown in Figs 6 and 7 and Tables 4 and 5.

The curves showed ductile behavior of GFRP reinforced concrete at 7&28 curing ages which gives more chance to alert before the failure. The results showed flexural strength of the unreinforced concrete is low and it's significantly improved by reinforcement. The flexural strength of the sand coated GFRP reinforced concrete is high and it's close to steel reinforced concrete. This is because it has higher strain than the steel reinforced concrete at the expense of the flexural modulus.

The strength of Smooth GFRP reinforced concrete is lower than the sand coated GFRP reinforced concrete, as a result of low flexural modulus. Sand grains cause an increase in brittleness of the GFRP rebars, this lead to increased strength at the expense of the flexural strain.

4.2.3. Comparison between the fractures of the different samples

In the case of the unreinforced concrete, the brittle fracture is very clear as shown in Fig. 8A, B. While, the smooth GFRP reinforced concrete also show multiple fracture line, but without complete fragmentation as shown in Fig. 9A, B. On the other hand, the sand coated GFRP reinforced concrete is shown in Fig. 10A, B. The fragmentation after fracture is lower than that

A

B

Fig. 10. (A, B): typical fracture of sand coated GFRP RC.

Fig. 11. (A, B): typical fracture of steel RC.

of the smooth GFRP reinforcement. The concrete is still in one piece which may be helpful in reducing damaged after failure. The appearance of the fractures of the sand coated GFRP reinforced concrete is comparable to that of the steel reinforced concrete Fig. 11A, B.

5. Conclusions

From this work, the following conclusions are withdrawn:

1. In general: GFRP reinforcing bar has higher tensile strength and higher corrosion resistance than steel rebar in addition, moderate flexural strength, these properties make GFRP is good alternative of steel in foundations application.
2. According to the results, the mechanical characteristics can be concluded as the following:
   a. Tensile strength of bare GFRP bar is high, because they are anisotropic composite materials, GFRP rebar achieved yield tensile strength about 13% higher than that the steel rebar, while yield strain of GFRP is higher than steel about 58%.
   b. Bend strength of bare GFRP bar is good; where yield strength of GFRP rebar achieved 72% of steel rebar strength while yield strain of GFRP is higher than steel about 20%.
   c. Compressive strength of unreinforced concrete is 25.67 MPa; this value is acceptable according to British Standard specification.
   d. Flexural strength is good of sand coated GFRP RC at all curing ages. Increase of smooth GFRP

RC flexural strength was about 76–81% and sand coated GFRP RC about 78–83% as compared with unreinforced concrete strength. However, strength of smooth GFRP achieved 71–75%, while sand coated strength achieved 77–82% of steel RC flexural strength. Decrease of flexural modulus of smooth GFRP RC around 66% and sand coated GFRP RC around 33% compared with steel RC. The flexural strain of Smooth GFRP RC is increased around 44% and sand coated GFRP around 14% as compared with steel RC at 28 day curing age.

References

[1] H.V. GangaRao, N. Taly, P.V. Vijay, Reinforced Concrete Design with FRP Composites, CRC Press, 2006.
[2] M. Kemp, D. Blowes, Concrete Reinforcement and Glass Fibre Reinforced Polymer, Queensland Roads Edition, no. 11, 2011, pp. 40–48.
[3] L.I.U. Jun, Z. Hong, Y.H. Jun, L.J. Fan, Experimental research on strength of GFRP bars in shield engineering, Adv. Mater. Res. (1020) (2014).
[4] V.R. Patil, Experimental Study of Behavior of RCC Beam by Replacing Steel Bars with Glass Fiber Reinforced Polymer and Carbon Reinforced Fiber Polymer (GFRP), 2014.
[5] D.Y. Yoo, N. Banthia, Y.S. Yoon, Predicting service deflection of ultra-high performance fiber-reinforced concrete beams reinforced with GFRP bars, Compos. Part B Eng. 99 (2016) 381–397.
[6] A. El-Nemr, E.A. Ahmed, B. Benmokrane, Flexural behavior and serviceability of normal-and high-strength concrete beams reinforced with glass fiber-reinforced polymer bars, ACI Struct. J. 110 (6) (2013) 1077.
[7] D.Y. Yoo, N. Banthia, Y.S. Yoon, Flexural behavior of ultra-high-performance fiber-reinforced concrete beams reinforced with GFRP and steel rebars, Eng. Struct. 111 (2016) 246–262.
[8] D.Y. Yoo, N. Banthia, Numerical simulation on structural behavior of UHPFRC beams with steel and GFRP bars, Comput. Concr. 16 (5) (2015) 759–774.
[9] S. Sólyom, G.L. Balázs, A. Borosnyói, Bond behaviour of FRP rebars—parameter study, in: SMAR 2015—Third Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures, Antalya, Turkey, September, 2015, pp. 7–9.
[10] R. Okelo, R.L. Yuan, Bond strength of fiber reinforced polymer rebars in normal strength concrete, J. Compos. Constr. 9 (3) (2005) 203–213.
[11] ASTM C150-02, Standard Specification for Portland Cement, ASTM International, West Conshohocken, PA, 2002.
[12] ASTM C33-02a, Standard Specification for Concrete Aggregates, ASTM International, West Conshohocken, PA, 2002.
[13] ASTM C192, "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory", Animal Book of ASTM Standard, Philadelphia, 04-02, 2006, pp. 112–118.
[14] ACI Committee 308R-01, Guide to Curing Concrete, Reported by ACI Committee 308, ACI Manual of Concrete Practice, 2009, p. 2.
[15] ASTM D7205-06, Standard Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars, ASTM International, 2003.
[15a] ASTM A496-02, Standard Specification for Steel Wire, Deformed for Concrete Reinforcement, 2002.
[16] ASTM D790, Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials, 1997.
[17] B.S. 1881: Part 116, Method for Determination of Compressive Strength of Concrete Cubes, British Standards Institution, 1989.
[18] ASTM C293, Annual Book of ASTM Standards, Standard Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading), 04.02, 2002.

GOVERNMENT OF PAKISTAN
MINISTRY OF SCIENCE AND TECHNOLOGY
COUNCIL FOR WORKS AND HOUSING RESEARCH
F-40, SITE, Hub River Road, Karachi-75730, Tel: (021) 99238159, 32577236; Fax: (021) 32577235
E-mail: cwhr@khi.comsats.net.pk; website: www.cwhr.gov.pk

No.CWHR/CRO, CWHR/1056/2019

Dated:17.12.2019

TEST REPORT

1. NAME OF CLIENT : Dr. Javeria Sheikh, Voice Chanceller, Indus Valley Karachi.
2. DESCRIPTION OF SAMPLE (S) : Lightweight Structural Concrete designed at Strength level 2500-3000 PSI as per ASTM C-330, C-333-1995
3. TEST DESCRIPTION : COMPRESSIVE STRENGTH
4. R&D PROJECT/Lab. Analysis : For comparative analysis of both lightweight aggregate concrete using polymer bars as a simple reinforcement with PUMICE lightweight aggregate instead of crushed lime stone aggregate.
5. STANDARD : ASTM C-330, C-333-1995TEST RESULTS

COMPRATIVE ANALYSIS USING CONCRETE MIX DESIGN DOE METHOD AT STRENGHT LEVEL 2500-3000 PSI

DESCRIPTION OF CONCRETE	COMPRESSIVE STRENGTH (PSI)
1. Using especially selected PUMICE as a naturally bloated lightweight aggregate of size ¾" down with washed silica sand and OPC as a dry binding agent, lightweight aggregate concrete with nominal ratio 1:2:4 was selected for developing typically designed RCC lightweight aggregate concrete. Instead of steel bars reinfovemenet used polymer bars to replace steel bars and weight of concrete with polymer bars and PUMICE lightweight aggregate instead of crushed lime stone aggregate mostly used in conventional RCC concrete at water cement ratio 0.65 and 50 mm slump. 2. Dry concrete unit weight: ranging from 115-117 lb/cft with especially selected lightweight concrete for structural purposes. 3. **Properties of PUMICE:** Hardness ranging from 6-7 Mohs Scale, Specific Gravity: 2.6-2.8, Water Absorption: 0.9-1.2%, loss of Ignition: ranging from 3.75-4.4%, silica as $SiO2$: 68-72%, $Al2O3$: 21.93%, $TiO2$: Nil, CaO: Nil, MgO: 2.1%; $Na2O$: 0.01%, $K2O$: 0.83%. 4. **ALTERNATIVE BUILDING COMPONENTS:** Bricks, blocks, tiles, RCC slabs, RCC lintel, Column, floors, roofing system with pre cast building elements etc. these are substitute highly advanced building products can be used at arid, tropical and humid climatic environment, especially coast line	2700 **using typically designed concrete cubes of size 8"X8" with specified thickness using 4 No. polymer bars with center to center using polymer bar square rings etc. complete.** Testing period upto 10 days curing using normally sprinkling 03 days and 03 days pounding just to see behavior of the concrete, extremely found very good by both hydration process therefore again recommended to cast small medium

of Balochistan. These products are chemically sound, can be resisted aggressive chemical ions viz. chloride, sulfate, carbonate and bicarbonate etc. because PUMICE as a substitute naturally bloated lightweight aggregate with dry unit weight ranging from 32-42 lb/cft and polymer rebar instead of steel/Iron bar etc. 5. **RECOMMENDATION:** By using concrete strength level starting from 2500-3500 P.S.I, alternative especially selected lightweight structural concrete can be used for construction of alternative cheaper, durable and structurally viable reinforced cement concrete with good corrosion resistant properties.	to large size alternative RCC lightweight concrete keeping in view of building components viz. lintel, columns, RCC slabs and pre cast RCC roofing system alongwith floor low cost panels.

Tested by

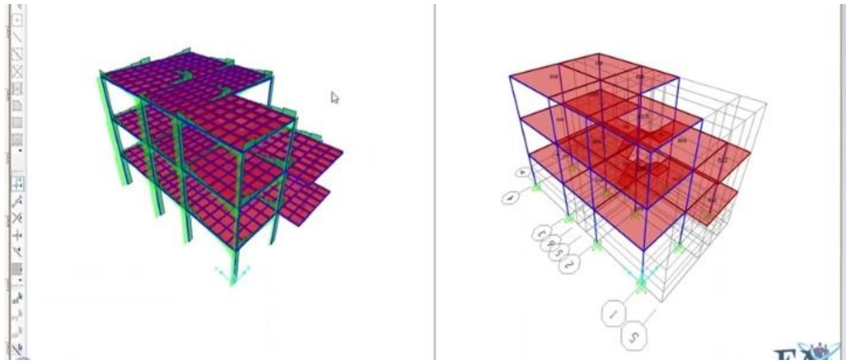
(Dr. Javeria Sheikh)
Focal Research Coordinator

(Muhammad Ghaffar)
Technician, Structural Concrete Testing Lab., CWHR

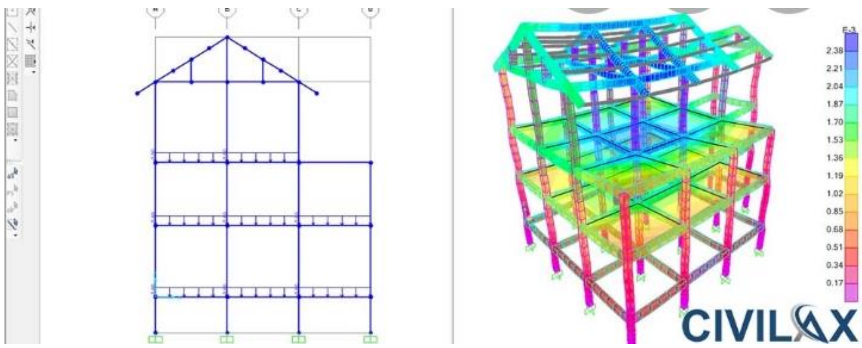
Checked & Verified by

(Abdul Bari Mangi)
Chief Research Officer
Head of Structural Concrete Testing Lab., CWHR
Cell No.: 0334-3927948

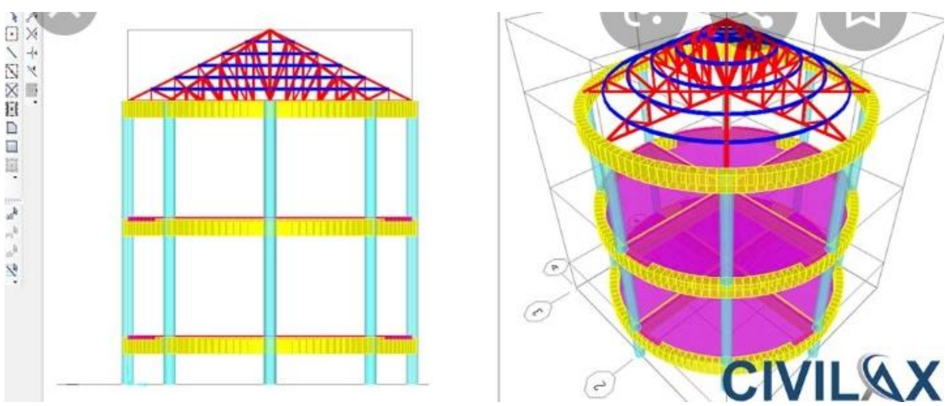
Comparative Analysis of the reinforcement conventional with rebar for both the Maga projects



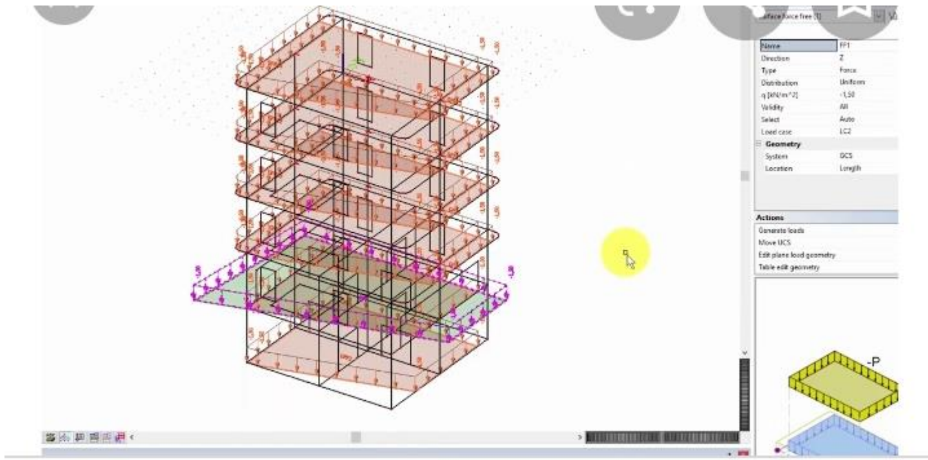
A typical two floor building design comparison of conventional steel vs rebar reinforcement



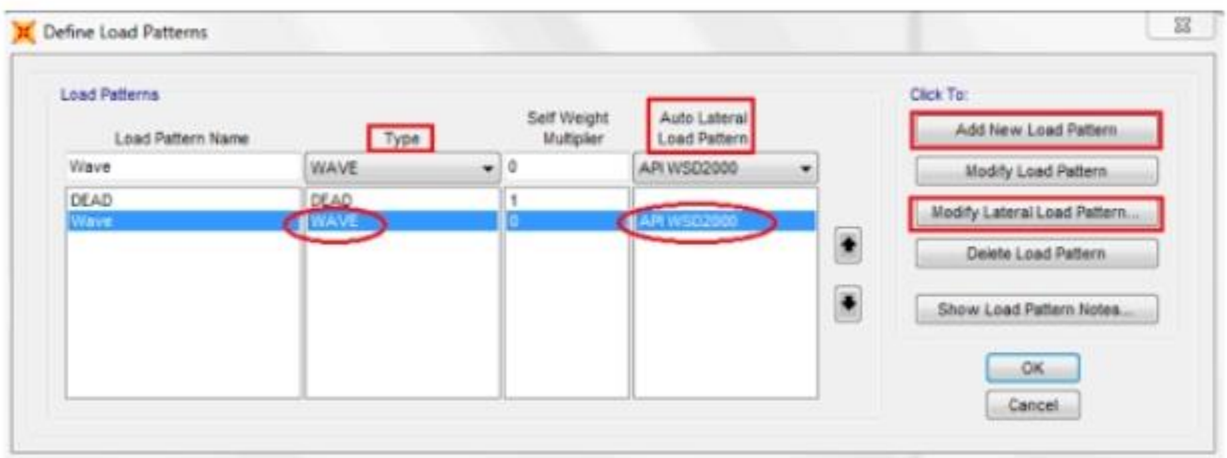
Deflection system in circular hut at Baluchistan cost



Stresses in the circular planning

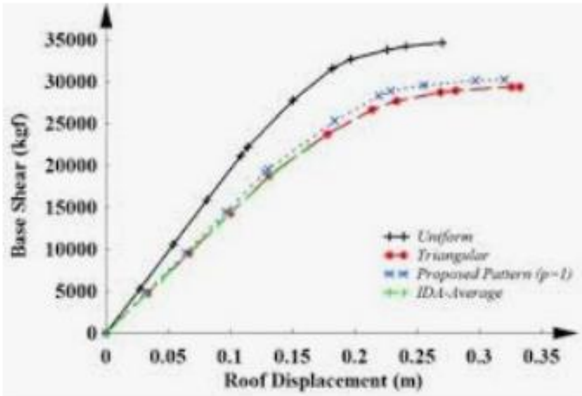


Multi story floor building housing society typo-morphology 3 for Naya Pakistan



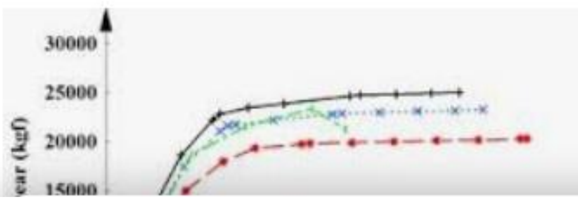
Modification of lateral forces wind pressure

The **knot** is a unit of speed equal to one nautical mile per hour, exactly 1.852 km/h (approximately 1.15078 mph or 0.514 m/s). The ISO standard symbol for the knot is **kn**. The same symbol is preferred by the Institute of Electrical and Electronics Engineers; **kt** is also common, especially in aviation, where it is the form recommended by the International Civil Aviation Organization (ICAO)..



pattern for pushover analysis ...

jvejournals.com



This section describes how to define automatic wave loads. The automatic wave load is a special type of load pattern. It generates loads on the structure resulting from waves, current flow, buoyancy and wind.

Wave Load Pattern Definition

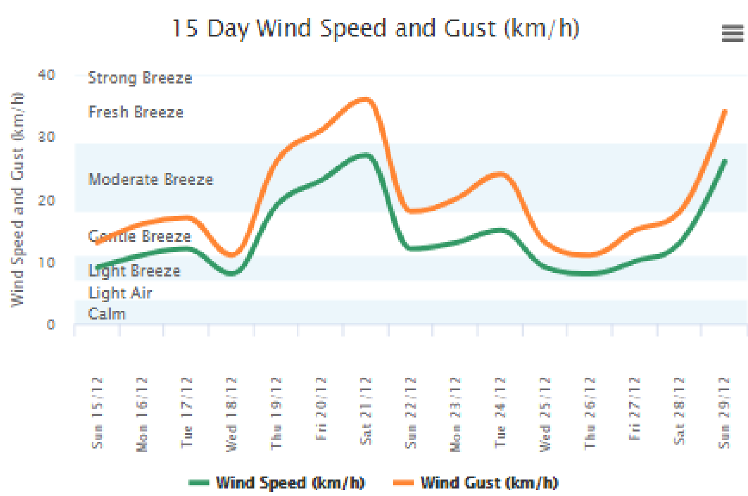
Define the automatic wave load as follows:

1. Click the **Define menu > Load Patterns** command in SAP2000 or the **Loads > Load Patterns** command in CSiBridge to open the Define Load Patterns form, as shown in Figure 1.
2. Type in the load name (e.g., W1), type (i.e., WAVE), and self-weight multiplier (e.g., 0) and select an Auto Lateral Load (i.e., API WSD2000).
3. Click the **Add New Load Pattern** button to add the W1 wave load pattern definition to the DEAD load pattern definition or click the **Modify Load Pattern** button to replace the DEAD load pattern definition with the W1 wave load pattern definition.

Figure 1: Defining a Wave Load Pattern

15 Day Wind Speed and Gust Chart

Wind speed chart displays the changes in wind speed and gust over next 15 days.



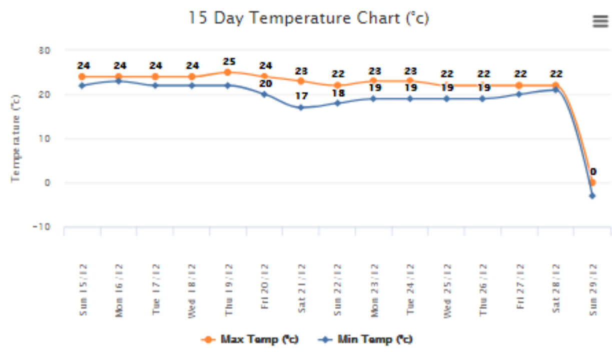
Gwadar Weather Charts

Balochistan, PK

Weather 1 hr 3 hr

15 Day Temperature Chart

Temperature chart displays the maximum and minimum temperature over next 15 days.



Using the requirements of ACI 318-19 Clause 5.3.1, evaluate all applicable load combinations and find the maximum required strength (factored design moment) at Section A and Section B at the strength limit state (check positive and negative sense). Show your work. If you decide not to consider one or more load combinations, provide a brief explanation of why you chose to exclude the combination(s) in question.

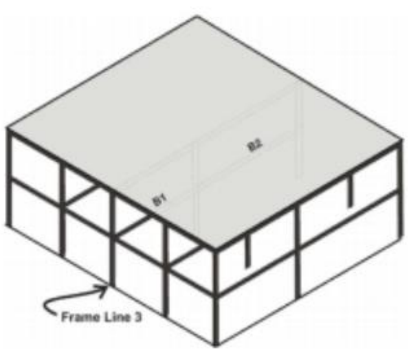


Figure 5 - Two-Storey Building - Isometric

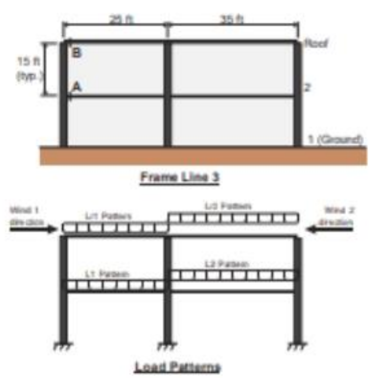
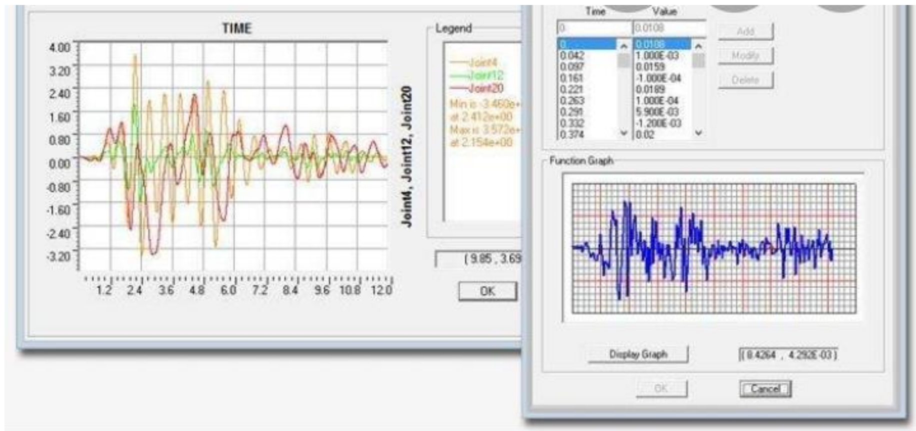


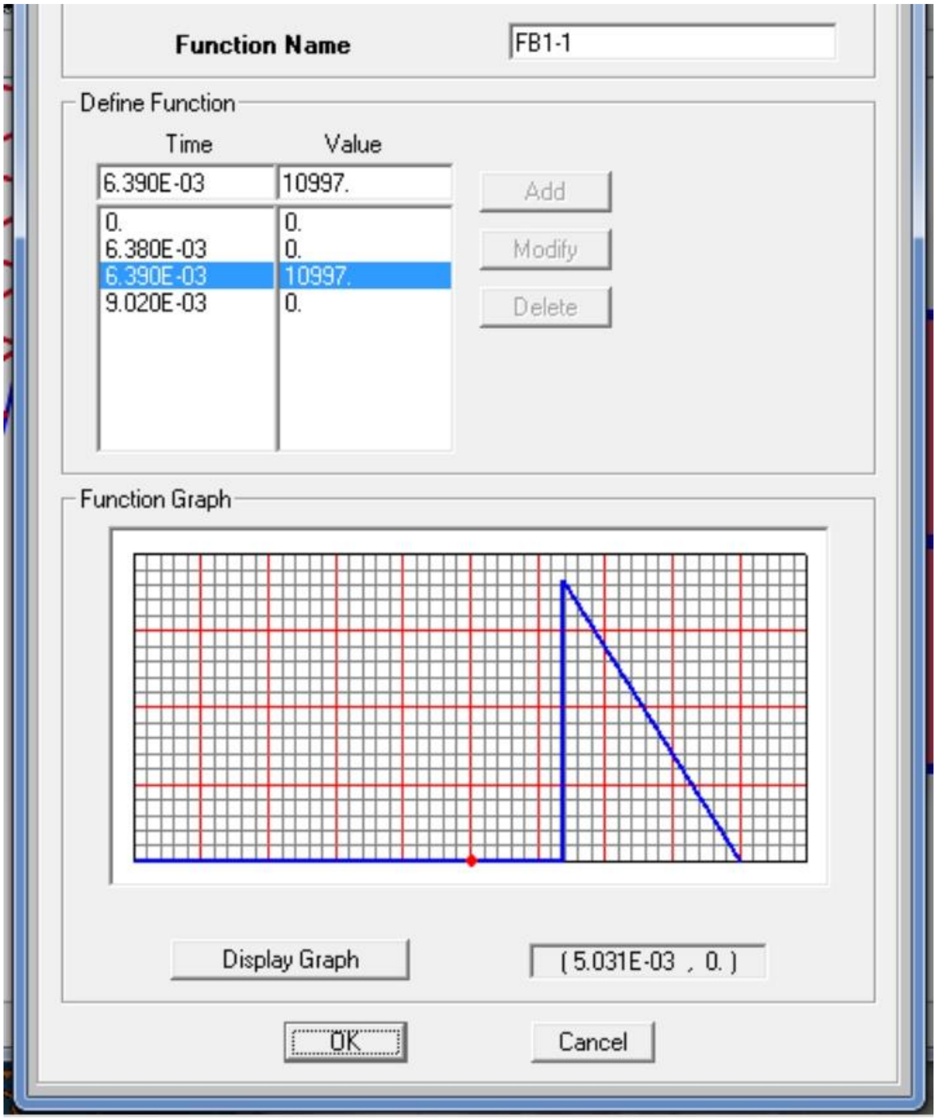
Figure 6 - Frame Line 3 - Elevation

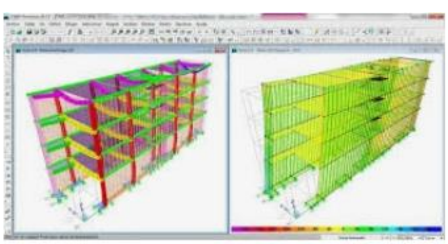
Structural Analysis Results – Moments at Sections A and B

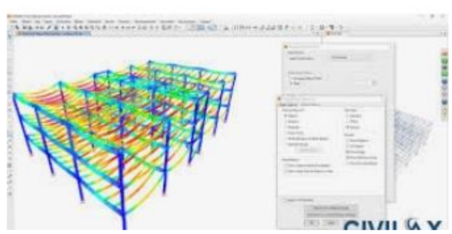
Load Case	Moment at Section A (k-ft)	Moment at Section B (k-ft)
Dead Load (D)	-100.8	-74.4
Live Load Pattern 1 (L1)	-24.8	-2.6
Live Load Pattern 2 (L2)	3.3	-1.4
Roof Live Load Pattern 1 (Lr1)	-1.2	-9.6
Roof Live Load Pattern 2 (Lr2)	1.2	1.7
Snow Load (S)	-4.5	-15.0
Wind Load Pattern 1 (W1)	15.3	11.1
Wind Load Pattern 2 (W2)	-11.8	-0.4



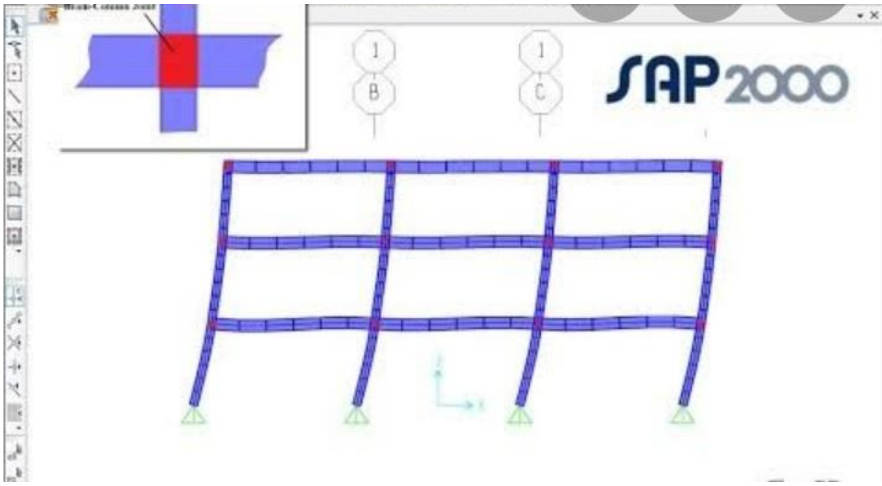
The structure is designed such that it takes the pressure of the wind loads



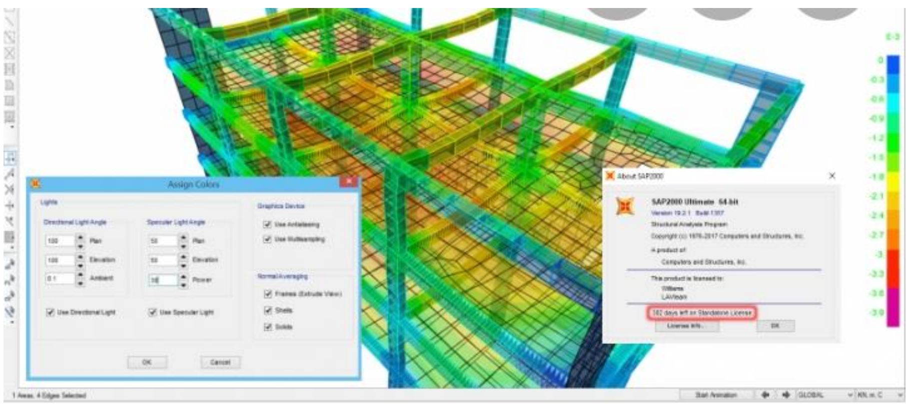


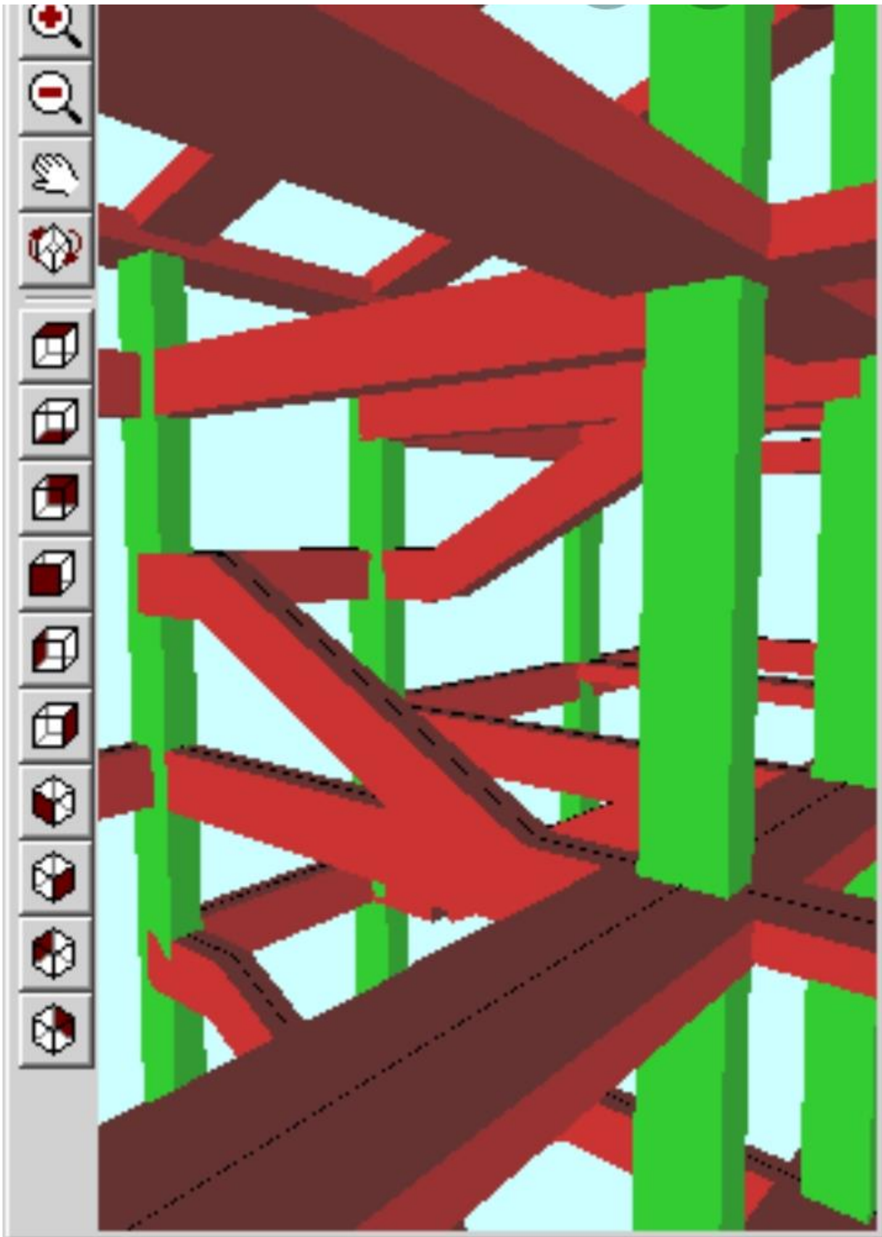


Analysis of the structure with loads

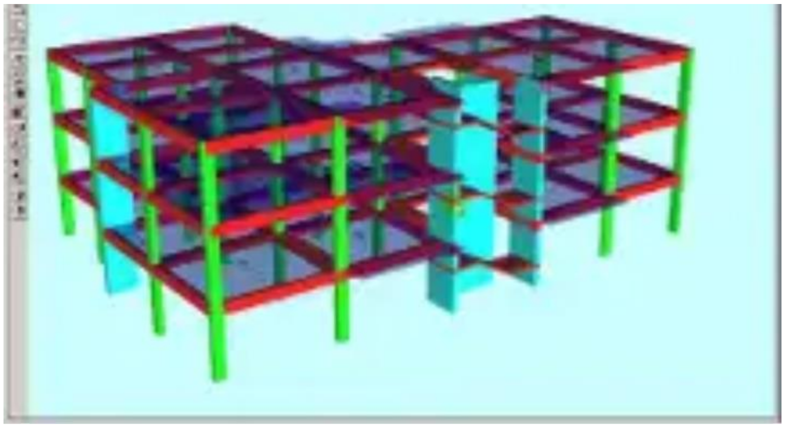


The deflection in Fly Ash brick and Re-Bar for the Naya Pakistan housing morphology 2 according to the urban planning

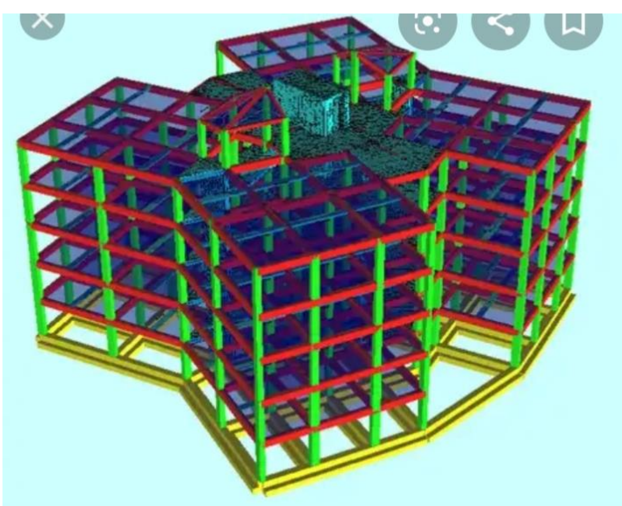


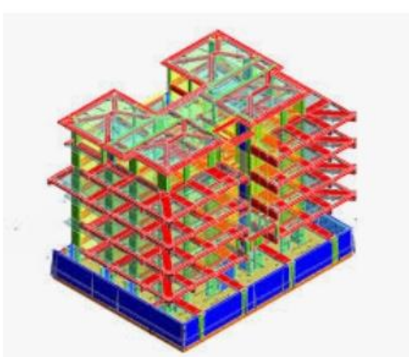


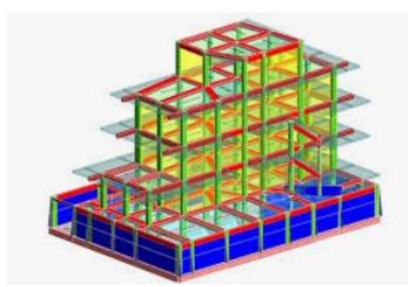
The structure system designed on SAP for the Naya Pakistan Building for the structure for Re-Bar



Typology 1 and 2 for Lahore Architecture planning and Urban Planning

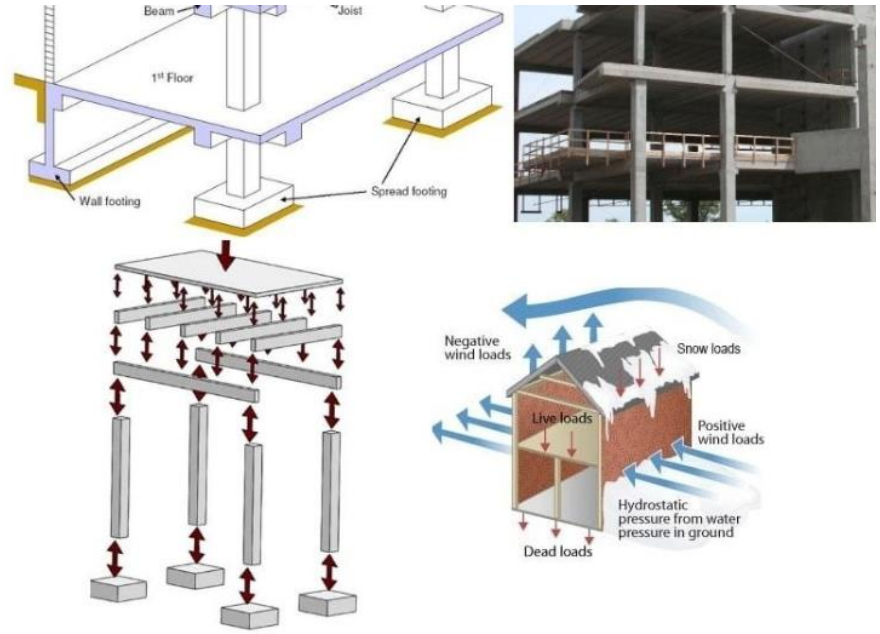




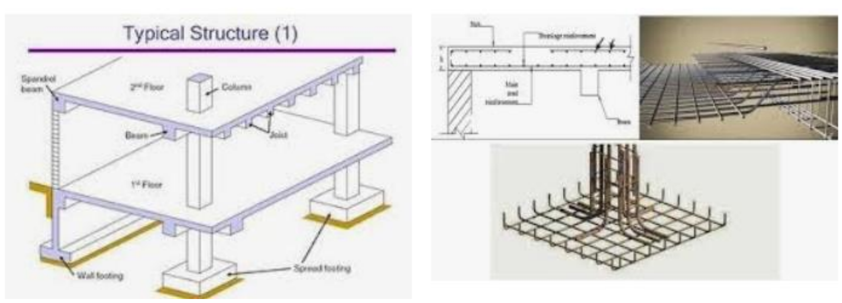


Nostri Lavori - ProgettazioneS...
progettazionestrutturale.it

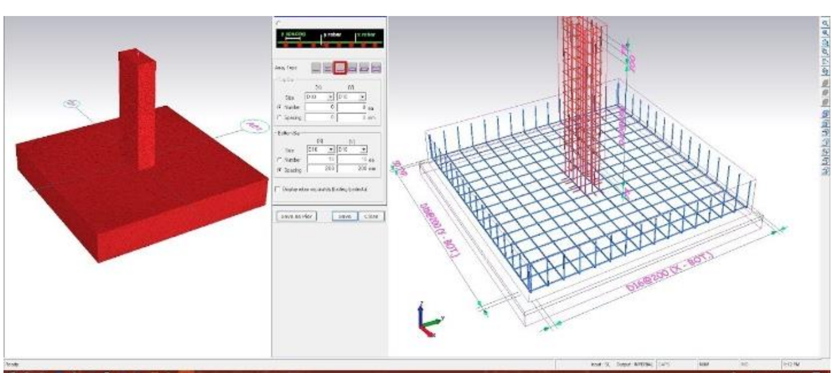
Morphology and tower type 4-5 for the Housing Scheme design Naya Pakistan



Special Structural Systems for Re-Bar Typo morphology



The structure detail of the foundation systems



240 yard used approximately 13 tons of steel singe stories

500 yards uses approximately 27 tons story single

80 yards used approximately 7 tons at Sea Shore

260,000 tons for Naya Pakistan scheme

70,000 tons for the Chalet Design at Baluchistan

RECOMMENDATION FOR INCLUSION OF USE OF GFRP BARS In Building Code of Pakistan (BCP) SP-2007

1. BACKGROUND

Glass fiber-reinforced polymer (GFRP) has demonstrated great potential in civil engineering. It offers several advantageous properties comparing with other traditional reinforcing materials. One of the distinguishing properties of GFRP bars is the unprecedented durability when subjected to aggressive environment. Corrosion is probably the biggest civil engineering issue that forces builders, governments, and contractors to spend billions of dollars on the rehabilitation of steel-reinforced concrete structures. The leading advantage of using fiberglass bars as an internal reinforcement is that it enables concrete structures to achieve long service life without any major maintenance.

The field of applications include:

Residential construction and civil engineering:

- Foundations of buildings and structures;
- Frame construction etc.
- Walls
- Rafts
- UG Tanks. OH tanks
- Repair & reinforcement of bearing capacity in brick and reinforcement concrete structures;

Industrial engineering:

- Reinforcement of concrete tanks, storages of treatment facilities, sewage well's covers;
- Elements of chemical manufacturing facilities;
- Reinforcement of concrete floors;
- Hydro technical facilities.

Highway construction:

- Highway applications (bridges, overpasses, etc.)
- Reinforcement of roads;
- Catenary poles;
- Road, airfield slabs & sulfur concrete slabs.

Bridge building & reconstruction:

- Bridge deck slabs;
- Bridge enclosures;
- Footways;
- Reinforcement of onshore facilities.

Railway construction:

- Elements of railway sleepers for high-speed trains and underground railroads.

Marine Structures:

- Marine applications (seawalls, retaining walls, etc.)

Mining and Tunneling

- Mining and tunneling lining

Transport Structures

- Bus stops, Airport runways, etc.

2. GLOBAL FRP MANUFACTURERS

The global market of FRP Rebars is growing and could reach $ 91.0 million by 2021 (Markets and Markets, 2016), based on a predicted Compound Annual Growth Rate (CAGR) of 11.4 % between 2016 and 2021 (Markets and Markets, 2016).

Figure 1 Distribution of global FRP rebar manufacturers

Figure 1 visualizes that the FRP rebar manufacturer density is highest in America with nine manufacturers (nine in USA and three in Canada); a total of seven FRP rebar producers are located in Europe (two in Germany, two in Italy, one in Switzerland, one in Ukraine, and one in the Czech Republic); while an additional six are located in Asia (two in India, one in Thailand, one in Russia, one in China, and one in Saudi Arabia); finally, two Oceanian manufacturers produce in South Australia and New Zealand. The Evolution of FRP market share in USA is show in **Figure 2**.

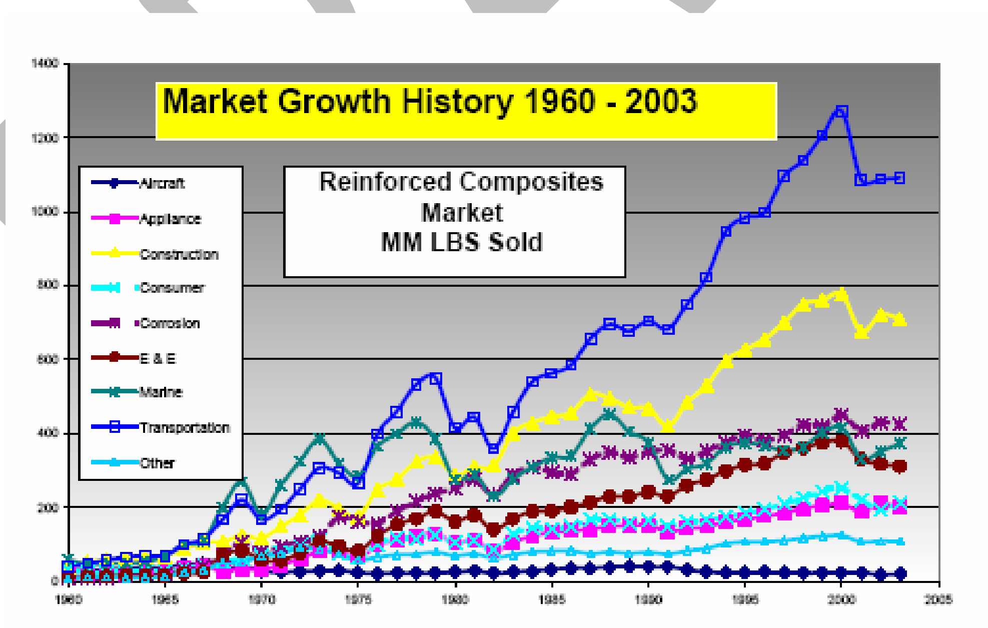


Figure 2 Evolution of FRP market share (*source American Composites Manufacturing Association)*

The Design Manuals and Specifications for Composite FRP reinforcement bars are listed in **Table 1**. As seen in **Table 1,** the listed documents contain numerous design guidelines that target the structural design of concrete elements (columns, beams, slabs, etc.) reinforced with FRP bars.

Table 1 Design Manuals and Specifications for Composite FRP reinforcement bars

Design Guidelines	Title
AASHTO	
GFRP-1	AASHTO LRFD Bridge Design Guide Specifications for GFRP- Reinforced Concrete Bridge Decks and Traffic Railings
FDOT	
DEV932	Nonmetallic Accessory Materials for Concrete Pavement and Concrete Structures
ACI	
440.1R-15	Guide for the Design and Construction of Structural Concrete Reinforced with Fiber-Reinforced Polymer Bars
440.3R-12	Guide Test Methods for Fiber-Reinforced Polymers (FRPs) for Reinforcing or Strengthening Concrete Structures
440.5-08	Specification for Construction with Fiber-Reinforced Polymer Reinforcing Bars
440.6-08	Specification for Carbon and Glass Fiber-Reinforced Polymer Bar Materials for Concrete Reinforcement
440.9R-15	Guide to Accelerated Conditioning Protocols for Durability Assessment of Internal and External Fiber-Reinforcement
CSA	
CAN/CSA-S06-15	Fiber Reinforced Structures, Canadian Highway Bridge Design Code, Page 693-728
CAN/CSA-CSA-S806-12	Design and Construction of Building Components with Fiber-Reinforced Polymers
CAN/CSA-S807-10	Specification for Fiber-Reinforced Polymers
Design Manual No. 3	Reinforcing Concrete Structures with Fiber Reinforced Polymers
Design Manual No. 4	FRP Rehabilitation of Reinforced Concrete Structures
Design Manual No. 5	Prestressing Concrete Structures with FRPs
ISO	
14484:2013 ED1	Performance guidelines for design of concrete structures using fiber reinforced polymer(FRP) materials.
ICC-Evaluation Service	
AC454	International Code Council, Evaluation Service, Acceptance Criteria for Fiber Reinforced Polymner (FRP) bars for Internal Reinforcmenet of concrete members, June 2016.

3. PROPOSED CORRIGENDUM TO THE - Building Code of Pakistan (BCP) SP-2007

The proposed additions are in red font. The deletions are in strike out format.

Page iv (Building Code of Pakistan (BCP) SP-2007

d) CHAPTER 7 Structural Concrete

ACI (2005), *Building Code Requirements for Structural Concrete,*
ACI 318-05, American Concrete Institute,
Farmington Hills, MI.
Portions copyrighted © American Concrete Institute. All rights reserved.
ACI 440.1R-15, Guide for Design and Construction of Structural Concrete Reinforced with Fiber Reinforced Polymer (FRP) Bars
American Concrete Institute, Farmington Hills, MI.

____

7.3 General Requirements

7.3.1

Scope

7.3.1.1 This section contains special requirements for design and construction of cast-in-place reinforced concrete members of a structure for which the design forces, related to earthquake motions, have been determined on the basis of energy dissipation in the nonlinear range of response as specified in Chapter 5. For applicable specified concrete compressive strengths see Section 1.1.1 of ACI 318-05 and Section 7.3.4.1. For explanation of provisions, see Chapter 21, Commentary of ACI 318-05 and for design and construction of structural concrete reinforced with Fiber Reinforced Polymer (FRP) bars, see ACI 440.1R-15. All equations are in SI units whereas equations given in parenthesis are in FPS units.

7.3.1.2 In regions of low seismic risk (Seismic Zone 1) or for structures assigned to low seismic performance or design categories, the provisions of Chapters 1 through 18 and 22 of ACI 318-05 shall apply and for Fiber Reinforced Polymer (FRP) bars, ACI 440.1R-15 shall be applicable. Where the design seismic loads are computed using provisions for intermediate or special concrete systems, the requirements of Chapter 7 for intermediate, or special system shall be satisfied.

7.3.1.3 In regions of moderate seismic risk (Seismic Zones 2A, 2B) or for structures assigned to intermediate seismic performance or design categories, intermediate or special moment frames, or ordinary, intermediate, or special structural walls, shall be used to resist forces induced by earthquake motions. The provisions of Chapter 21 of ACI 318-05 shall apply and for Fiber Reinforced Polymer (FRP) bars, ACI 440.1R-15 shall be applicable. Where the design seismic loads are computed using provisions for special concrete system, the requirements of Chapter 7 for special system shall be satisfied.

7.3.1.4 In regions of high seismic risk (Seismic Zones 3, 4) or for structures assigned to high seismic performance or design categories, special moment frames, special structural walls, and diaphragms and trusses complying with 7.3.2 through 7.3.6 and 7.4 through 7.11, the provisions of Chapter 21 of ACI 318-05 shall apply and shall be used to resist forces induced by earthquake motions. Member not proportioned to resist earthquake forces shall comply with 7.12.

~~**7.3.1.5** A reinforced concrete structural system not satisfying the requirements of this chapter shall be permitted if it is demonstrated by experimental evidence and analysis that the proposed system will have strength and toughness equal to or exceeding those provided by a comparable monolithic reinforced concrete structure satisfying this chapter.~~

7.3.1.5 Sponsor of any reinforced concrete structural system of design, construction, or alternate construction materials within the scope of this chapter, the adequacy of which has been shown by successful use or by analysis or test, but which does not conform to or is not covered by this Chapter, shall have the right to present the data on which their design is based to the building official or to the board of examiners appointed by the building official. This board shall be composed of competent engineers and shall have the authority to investigate the data so submitted, require tests, and formulate rules governing design and construction of such systems to meet the intent of this chapter. These rules, when approved by the building official and promulgated, shall be the same force and effect as the provisions of this Chapter.

Respectfully Submitted
Chair Prof. Dr. Engr. Shuaib Ahmad
Ph.D., PE (USA), FASCE, FACI, MPCI, PE (Pak), MIEP (PAK)
Fellow of Pakistan Academy of Engineers (FPAE)
Life Time Member Pakistan Engineering Council (PEC)
Ex-Chief Engineer American Concrete Institute (ACI)
Ex Member Executive Council, ACEP

SUMMARY OF QUALIFICATION

Dr. Engr. Shuaib Ahmad is a world recognized Specialist Civil and Environmental Engineer with over 44 years of experience in Design and Condition Assessment of Civil Infrastructure Systems that includes Marine Structures, Environmental Structures including hydraulic (Water) and other Urban Structures; Building Facilities, Transportation Systems including Bridges and Mass Transit Systems), Highways (Pavements) and, Railways. He has performed condition assessment studies of facilities and provided the designs for retrofitting/strengthening using Fiber Reinforced Polymer (FRP) materials. Using GFRP bars, he has designed a Demonstration Residential (G+1) unit on 120 sq. yds.

He has published over 175 technical research publications on variety of topics and has authored number of books. A fellow of American Society of Civil Engineers (ASCE), a fellow of American Concrete Institute (ACI) and senior member of number of professional societies including PCI, ASTM, AASHTO. He has been recipient of number of awards and recognitions for his contribution to the profession including the ASCE Walter Huber Award.

- ***Advisor / Consultant to the Code Writing Bodies - International***

For over 10 years, he served as Chief Engineer of ACI, administered the secretariat, and served as Secretary of International Standards Organization (ISO) technical Committee - ISO/TC71, that develops International Codes for Reinforced, Pre cast and Prestressed Concrete. His services include participation in Code writing committees such as ACI 318 "Building Code Requirements for Structural Concrete", ACI 350 "Code Requirements for Environmental Engineering Concrete Structures", ACI 357 "Design and Construction of Fixed Offshore Construction". Dr. S. Ahmad is one of the founding members of the ACI Committee 440 "Fiber Reinforced Polymer Reinforcement" that develops codes, guides for the use of Fiber Reinforced Polymers for Structural Concrete.

Dr. Ahmad was involved in the development of the ISO 19338 code. Dr. Ahmad is knowledgeable about International Standards including the ISO standards, ICC codes, UBC codes, ACI Codes, Euro Code, and ASHTO Code for Bridges.

Other Consultancies in Code development includes the following:

- Consultant – African Concrete Code (ACC), SOUTH AFRICA and LYBIA.
- Consultant - Saudi Building Code (SBC), SAUDI ARABIA

On Behalf of ACI, his contribution in the development of the Building Code of Pakistan –Seismic Provisions-2007 is acknowledged in the acknowledgement section of the Code.

GFRP

(Glass Fiber Reinforced Polymer)

Rebar

The Alternate Solution!

Reinforce safely without Steel Rebars.

Dr. Engr. Shuaib Ahmad,

Ph.D., PE (USA), FASCE, FACI, MPCI, PE (Pak), MIEP (PAK)

Fellow of Pakistan Academy of Engineers (FPAE)

Life Time Member Pakistan Engineering Council (PEC)

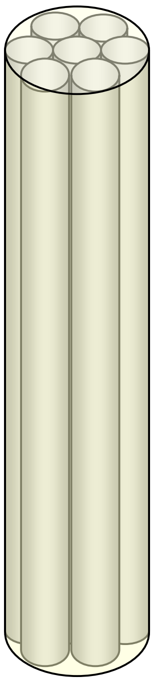
Ex Chief Engineer American Concrete Institute (ACI)

Ex Member Executive Council, ACEP

FRP Materials

Constituents

What is FRP?



Fiber Composites Matrix

Fibers

Provide strength and stiffness

Carbon, Glass, Aramid

Matrix

Protects and transfers load between fibers

Polyester, Epoxy, Vinyl Ester, Urethane

Creates a material with attributes superior to either component alone!
fibers **and** matrix both play critical roles in the composites material...

What is GFRP?

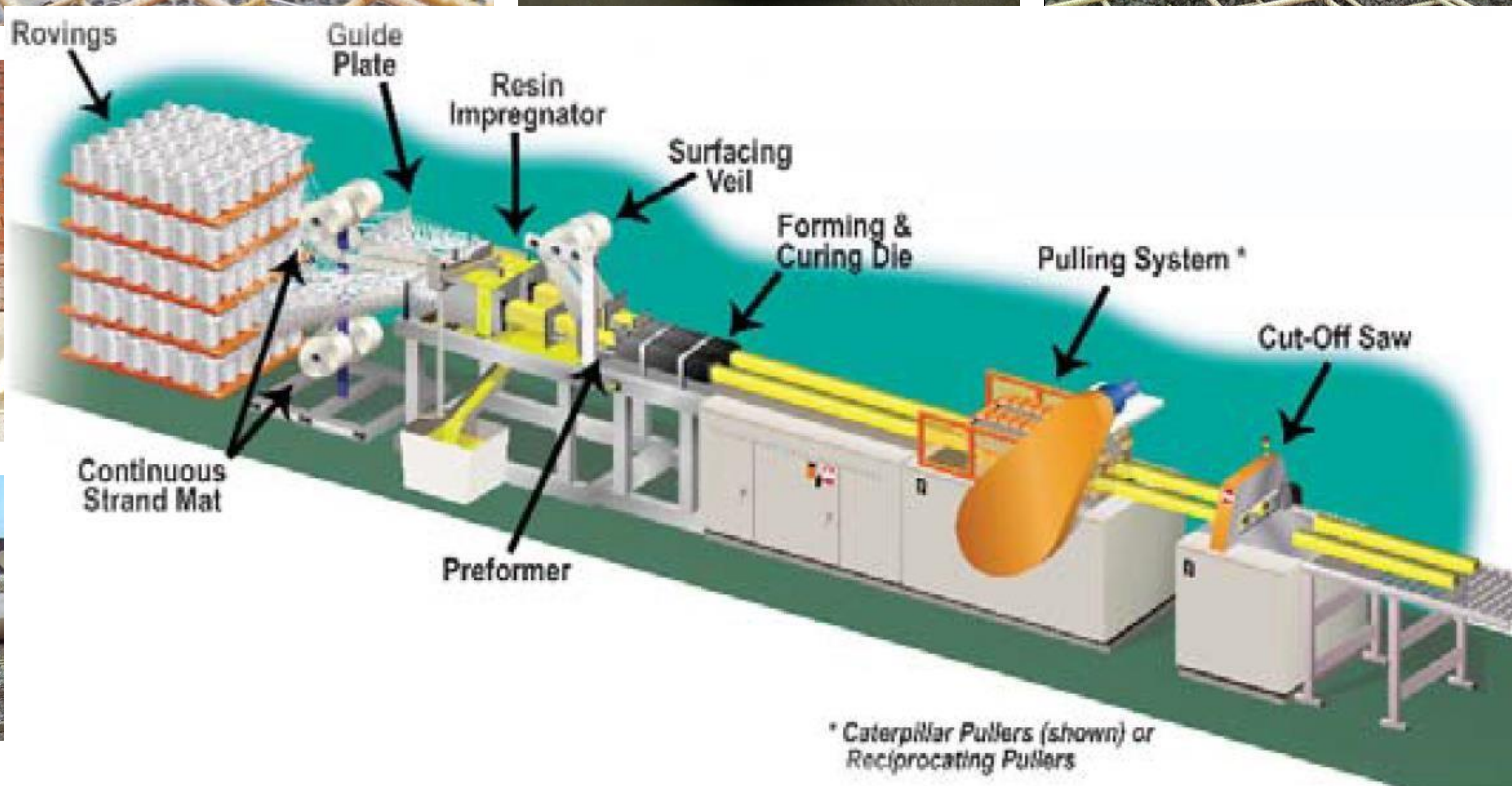
- The GFRP (GLASS FIBER REINFORCED POLYMER REBAR) rebar is a structural ribbed reinforcing bar made of **high strength and corrosion resistant glass fibres** that are impregnated and bound by an extremely durable polymeric epoxy resin.

- This combination equals an engineered material system resulting in unique attributes that replace and supersede typical materials such as galvanized, epoxy coated and stainless steel rebar.

- Its characteristic properties are ideal for any harsh and corrosive environments.

FRP Overview: Processes

- Pultrusion Processing:



Advantages of using GFRP

- 100+ years of lifespan and corrosion resistance
- **4 x lighter** in weight than steel Rebar
- **2 x tensile strength** of steel rebar

- Non-Conductive to heat and electricity
- Non-Magnetic (transparent to electrical fields)
- High Fatigue endurance and Impact Resistance
- Non-Existent corrosion, rust free
- Transparent to radio frequencies
- Cost effective vs. epoxy coated, galvanized and stainless steel rebar

Advantages of using GFRP

- Impervious to chloride ion, low pH chemical attack and bacteriological growth
- Resistant to chemical acids and alkaline bases, therefore extra concrete cover, anti-shrink additives, and even cathodic protection are not required.
- Significantly improves the longevity of engineering structures where corrosion is a major factor.
- Low carbon footprint
- Non Toxic
- Easy and Rapid Installation
- Reduced lie cycle cost of the project, Maintenance free

Corrosion Resistant.
GFRP will not rust, even in the harshest environments. It does not react to salt ions, chemicals or the alkaline present in concrete.

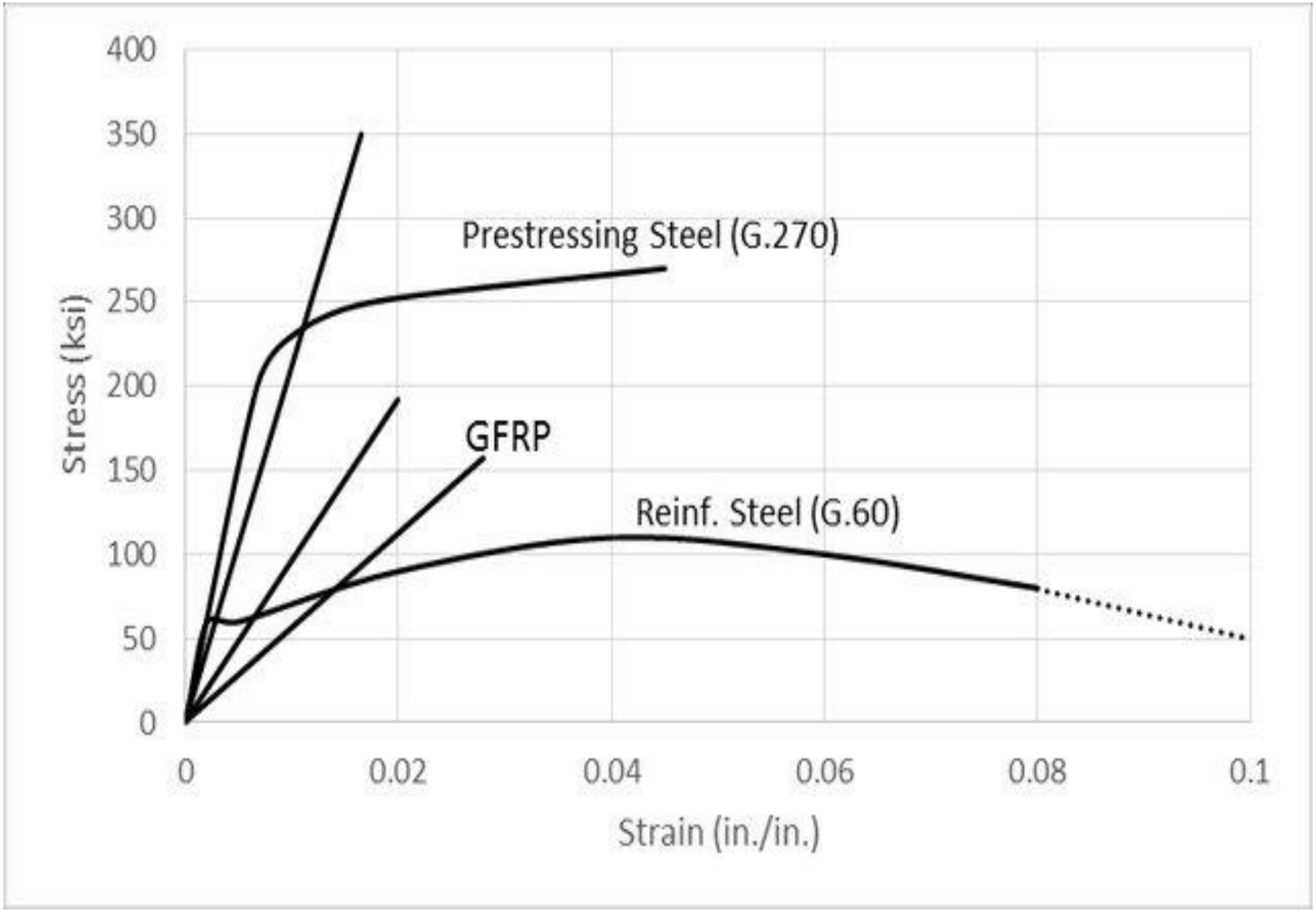
Superior Tensile Strength.
GFRP rebar offers a tensile strength up to 2 times that of steel.

Thermal Insulation.
GFRP is highly efficient to resisting heat transfer applications and does not create a thermal bridge within structures.

Electrical and Magnetic Neutrality.
GFRP rebar does not contain any metal; it will not cause any interference in contact with strong magnetic fields or when operating sensitive electronic instruments such as MRI units and rooms, Communications, Airports, Transformers, Aluminium and Copper Smelting Plants, Tele-Communications towers, Airport control towers, Hospitals and Rail roads.

Lightweight.
GFRP rebar is 4 times lighter in weight than the equivalent strength of Steel rebar. It is much easier to handle, and in most cases, only one truck load will be sufficient to supply the rebar even for an entire project.

STRESS-STRAIN CURVES

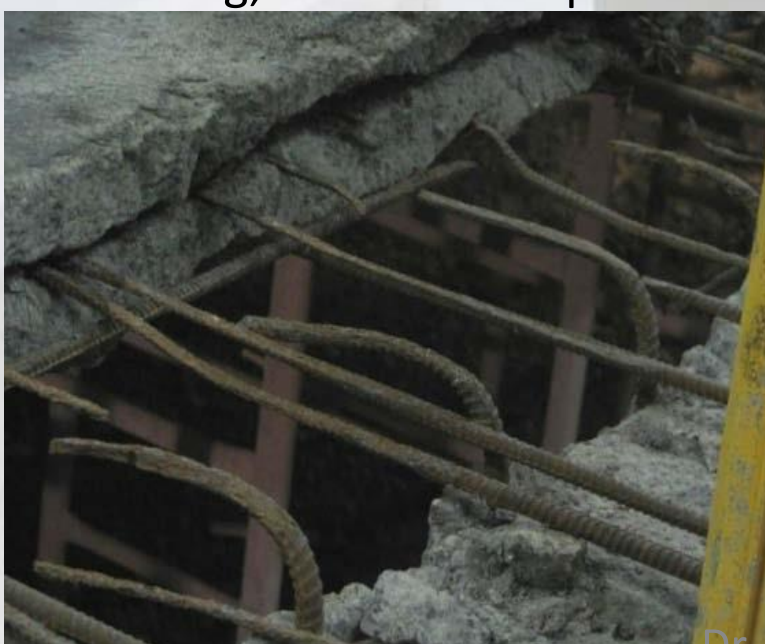


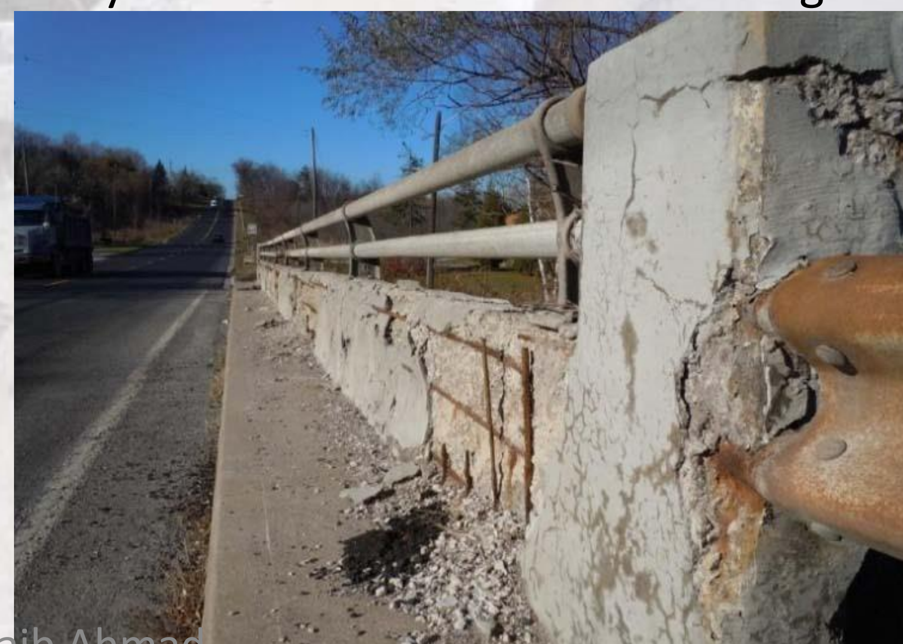
The Issues

- **Corrosion** of steel is a major cause of infrastructure degradation. Solving this problem is a major challenge for the engineering community.
- Use of **Non Potable water**

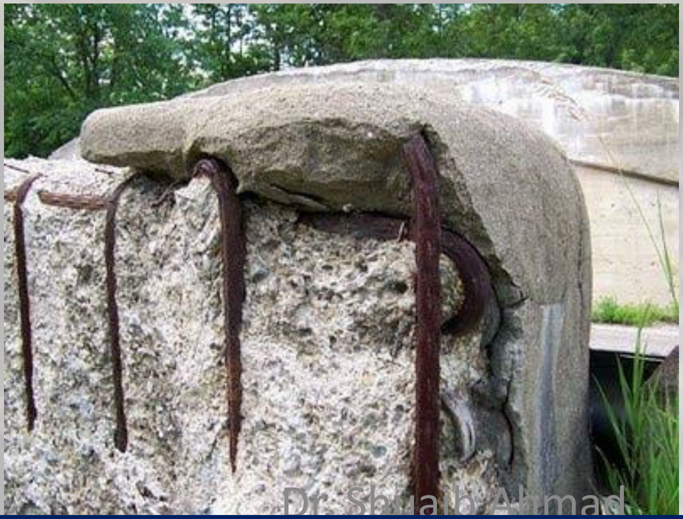
High porosity and Micro cracking in concrete allows water and corrosive agents such as salt to penetrate and reach reinforcing steel. Once exposed to those corrosive agents, steel will begin corroding.

When rusting, steel rebar expands and thereby cracks the concrete surrounding it.





The Consequences of Corrosion and Non Potable Water



The Consequences of Corrosion and Non Potable Water

- High rehabilitation cost
- Health and Safety-hazard
- Shutdown due to corrosion failure
- Contamination
- Loss of efficiency

The Solution !

Several options have been explored, most notably the use of galvanized steel rebar, epoxy coated or stainless steel. The results, however, have been disappointing as these solutions have turned out to be less than effective or cost prohibitive.

Glass Fiber Reinforced Polymer (GFRP) bars has the answer to variety of problems faced by the Conventional Reinforced Concrete Construction.

Non Potable water can be used in Construction with GFRP bars.

Lightweight, non-existent corrosion, that offers excellent tensile strength and high mechanical performance.

GFRP rebar is installed much like steel rebar, but with fewer handling, transportation and storage problems.

Market Applications for GFRP Bars

- Reinforced Concrete Exposed to De-Icing Chlorides
- High Voltages & Electromagnetic Fields
- Applications Subjected to Corrosive Environments
- Structures Built in or Close to Sea Water
- Thermally Sensitive Applications
- Weight Sensitive Structures
- Applications Requiring Low Electric Conductivity or Electromagnetic Neutrality
- Masonry Strengthening
- Long-Term Durability required

Reinforced Concrete Exposed to De-Icing Chlorides

Bridge Decks & Railings • Median Barriers • Roads and Slabs on grade • Salt Storage Facilities • Continuously Reinforced Concrete Paving • Precast Elements - Manhole Covers, Culverts • Rail Grade Crossings • Curbs • Parking Structures • Retaining Walls and Foundations

High Voltages & Electromagnetic Fields

Light & Heavy Rail Tracks • Hospital MRI Areas • High Voltage Substations • Cable Ducts & Banks • Aluminium Smelters & Steel Mills • Radio Frequency Sensitive Areas • High Speed Highway Tolling Zones

Applications Subjected to Other Corrosive Agents

Waste Water Treatment plants • Architectural Concrete Elements • Historic Preservation • Petrochemical plants • Pulp/Paper mills • Cooling Towers • Nuclear Power and Dump plants • Chemical plants • Liquid Gas plants • Pipelines/tanks for fossil fuel

Structures Built in or Close to Sea Water

Sea Walls • Wharf, Quays and Dry Docks • Floating Structures • Piers • Jetties • Canals • Dams • Offshore Platforms • Aquariums • Roads and Buildings • Port Aprons • Coastal Construction exposed to Salt Fog • Barrier Walls • Desalinization Intakes

Thermally Sensitive Applications

Apartment patio decks; thermally insulated concrete housing and basements including ICF construction; thermally heated floors and conditioning rooms

Weight Sensitive Structures

Concrete construction in areas of poor load bearing soil conditions, remote geographical locations, sensitive environmental areas, or active seismic sites posing special issues that the use of lightweight reinforcement will solve.

Applications Requiring Low Electric Conductivity or Electromagnetic Neutrality

Aluminium and copper smelting plants; manholes for electrical and telephone communication equipment; bases for transmission / telecommunication towers; airport control towers; magnetic resonance imaging in hospitals; toll road sensing arrays and collection booths, railroad crossing sites, and specialized military structures.

Masonry Strengthening

Flexural and shear strengthening of existing unreinforced masonry for seismic, wind or blast loading events. Rehabilitate existing masonry with step cracks and other bed joint issues.

Long-Term Durability required

Reservoirs, Tunnels, Infrastructure, Industrial plants

Where should GFRP REBARS be used?

- Any concrete member **susceptible to corrosion** by chloride ions or chemicals
- Any concrete member requiring non-ferrous reinforcement due to **Electro-magnetic considerations**
- Applications requiring **Thermal non-conductivity**
- As an alternative to Epoxy, Galvanized or Stainless Steel rebars
- Where machinery will "consume" the reinforced member (i.e. Mining and tunneling)

Potential Use of GFRP BARS-

- BUILDINGS (Residential and Commercial)
- WATER TANKS (Underground and Overhead)
- SWIMMING POOLS
- HOSPITALS
- SCHOOLS
- ELECTRIC LIGHT POLES (Non Conductive, Life safety issue in Rains)
- UNDERGROUND CONCRETE PIPES
- MAN HOLE COVERS
- GRAIN SILOS
- PILING FOUNDATIONS

Potential Use of GFRP BARS

- OFF SHORE STRUCTURES
- WATER FRONT STRUCTURES
- JETTYS & DOLPHINS
- COASTAL STRUCTURES
- WORKS PROJECTS (hydraulic Structures)
- DE-SALINATION PLANTS
- WATER WAYS
- CANALS (IRRIGATION NETWORK)
- LAKE (PONDS)

Potential Use of GFRP BARS

- BRIDGES (Overhead and Underpasses)
- INTERCHANGES
- CULVERTS
- RETAINING WALLS
- JERSEY BARRIER & MEDIAN DIVIDERS
- RAILWAY TRACKS (Sleepers)





16.08.2012 16:36




COST/BENEFIT ANALYSIS

- 4 TIMES LIGHTER THAN TRADITIONAL STEEL BAR
- 2 TIMES HIGHER TENSILE STRENGTH
- HIGH STRENGTH TO WEIGHT RATIO
- COST EFFECTIVE CONCRETE-REINFORCEMENT RATIO

- LOGISTICS/SHIPMENT COST REDUCTION
- LABOR PRODUCTIVITY RATIO

- DRASTIC REDUCTION IN O&M COSTS
- HUGE AMOUNT COST SAVING ON CORROSION TREATMENT

Storage - Space Efficiency

International Standards

ACI - Committee 440	ACI - 117 - 06	ASTM D 3916	CAN / CSA S 806 - 02
ACI - 440.1R - 01	ACI - 301 - 05	ASTM D 638	CAN / CSA S 6 - 06
ACI - 440.1R - 06	ACI - Committee 318	ASTM B 769 - 94	
ACI - 440.3R - 04	ACI - ASCE Committee 445	ASTM D 695	DIN 1045 - 1

Comparative Characteristics

	Steel Reinforcement	GFRP Reinforcement
GFRP equivalents for replacement steel rebar	6 mm	4 mm
	8 mm	6 mm
	10 mm	7 mm
	12 mm	8 mm
	14 mm	10 mm
	16 mm	12 mm
	18 mm	14 mm
	20 mm	16 mm
Weight (equal to strength) kg	6 mm – 0.222	4 mm – 0.02
	8 mm – 0.395	6 mm – 0.05
	10 mm – 0.67	7 mm – 0.07
	12 mm – 0.92	8 mm – 0.08
	14 mm – 1.28	10 mm – 0.10
	16 mm – 1.58	12 mm – 0.20
	18 mm – 2.00	14 mm – 0.35
	20 mm – 2.47	16 mm – 0.35

PRICE COMPARISON

- Globally GFRP bar is 1.5 times more expensive than traditional steel rebars.
- On per meter length basis

Factory Cost of GFRP bar = Factory Cost of STEEL rebar

- Savings in Shipment cost, due to reduced weight of GFRP bar.
- Factory fabrication of GFRP bar cages (when required) further reduces fabrication cost at site and labor cost

Some Examples of Applications

BUILDINGS

- GFRP rebar is an excellent product to build sustainable and corrosion-free buildings.
- Steel rebar, on the other hand, does not provide an effective mechanism against salt ions and chemicals.
- Therefore, use our supreme quality fiberglass rebar which is manufactured using the highest quality corrosion resistant vinyl ester resin and fiberglass materials.
- Whether you are building a single family home, duplexes, or a high-rise condominium complex, GFRP rebar will guarantee a strong and rust- free construction solution.

GFRP BARS bars - Buildings

BRIDGES AND INTERCHANGES

Bridge	Main span	Location	Year	Pultrusion	Infusion	Case study
A19 Tees viaduct	cladding	Teeside	1989	ACCS		Composites UK
Aberfeldy Footbridge	64 m	Scotland	1993	ACCS		
Andel bridge		Netherlands	1995			
Błaźowa road bridge	21 m	Poland	2015		✓	video 19'12"
Bonds Mill Lift Bridge	8.23 m	Gloucestershire	1995	ACCS		
Bradkirk (Blackpool) footbridge over railway (NGCC page)		Lancashire	2009		✓	
(Autovia del) Cantabrico	13 m	Spain				
Cuenca Parque de los Moralejos		Spain	2011			
Cueva de Oñati-Arrikrutz walkway		Spain	2008	✓		
Dawlish railway station	18 m	Devon	2012			Composites UK
Den Dungen draw bridge		Netherlands				
Earlsdon reservoir		Scotland	2013	✓		
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

BRIDGES AND INTERCHANGES

Bridge	Main span	Location	Year	Pultrusion	Infusion	Case study
A19 Tees viaduct	cladding	Teeside	1989	ACCS		Composites UK
Aberfeldy Footbridge	64 m	Scotland	1993	ACCS		
Andel bridge		Netherlands	1995			
Błażowa road bridge	21 m	Poland	2015		✓	video 19'12"
Bonds Mill Lift Bridge	8.23 m	Gloucestershire	1995	ACCS		
Bradkirk (Blackpool) footbridge over railway (NGCC page)		Lancashire	2009		✓	
(Autovia del) Cantabrico	13 m	Spain				
Cuenca Parque de los Moralejos		Spain	2011			
Cueva de Oñati-Arrikrutz walkway		Spain	2008	✓		
Dawlish railway station	18 m	Devon	2012			Composites UK
Den Dungen draw bridge		Netherlands				
Earlsdon reservoir		Scotland	2013	✓		
Eindhoven University of Technology	14 m	Netherlands	2016		✓	hemp/flax

BRIDGES AND INTERCHANGES TESTIMONIALS

Cueva de Oñati-Arrikrutz walkway		Spain	2008	✓		
Dawlish railway station	18 m	Devon	2012			Composites UK
Den Dungen draw bridge		Netherlands				
Earlsdon reservoir		Scotland	2013	✓		
Eindhoven University of Technology	14 m	Netherlands	2016		✓	hemp/flax
Friedberg B3 highway bridge	deck	Germany	2008	ASSET		
Friesland bridge		Netherlands	2002			
Garstang Mount Pleasant M6 bridge		Lancashire	2006	ASSET		Composites UK
Halgavor bridge	47 m	Cornwall	2001	✓	✓	
Holländerbrücke (Reinbek near Hamburg)		Germany	2009	FBD450		
Kolding bridge	40 m	Denmark	1997			
Lleida pedestrian footbridge 1	38 m	Spain	2004			
Lleida pedestrian footbridge 2		Spain	2010			
Lunetten bicycle/pedestrian bridge	12 m	Utrecht	2010			
Madrid footbridge		Spain	2011		✓	
Mapledurham	13 m	Oxfordshire	2016			Infracore Inside
Moscow arched footbridge		Russia	2008		✓	
Nazeing Marsh (Broxbourne)	21 m	Hertfordshire	2017			
Nørre Aaby		Denmark	2008	✓		

Fig. 12. SIP FRP deck panels, FRP rebars, and bi-directional FRP grid during placement.

Fig. 13. Pouring and vibration of concrete at FRP reinforced bridge deck.

GFRP

(Glass Fiber Reinforced Polymer)

Rebar

The Alternate Solution!

Reinforce safely without Steel Rebars.

Dr. Engr. Shuaib Ahmad,

Ph.D., PE (USA), FASCE, FACI, MPCI, PE (Pak), MIEP (PAK)

Fellow of Pakistan Academy of Engineers (FPAE)

Life Time Member Pakistan Engineering Council (PEC)

Ex Chief Engineer American Concrete Institute (ACI)

Ex Member Executive Council, ACEP

Nonmetallic composite reinforcement bars demonstrate several undeniable advantages as compared to traditional steel bars. Those advantages include high strength, lightness, resistance to corrosion, electro- and magnetic transparency, and low conductivity.

It should be noted, that in the last 25 years composite reinforcement bars have gained widespread acceptance in construction of various facilities and road infrastructure elements both in Russia and abroad, including countries located in the high seismicity zones (e.g. Japan, Italy, Canada, the USA, and China). More than that, the applicable design regulations of those countries allow using composite reinforcement bars in the structures of buildings and other facilities. So, for example, since 1997 in Japan the regulations for structural design using composite reinforcement bars JSCE "Recommendation for Design and Construction of Concrete Structures using Continuous Fiber Reinforcing Materials" are applied, which allow design of concrete structures using composite reinforcement bars in the seismic zone. Italian standards CNR-DT 203/2006 2007 "Guide for the Design and Construction of Concrete Structures Reinforced with Fiber Reinforced Polymer Bars" also do not limit the application of composite reinforcement bars in high seismicity zones, with the allowance for operating peculiarities of concrete structures reinforced with composite bars.

In comparison with other countries located in high seismicity zones Russia on the whole is characterized by moderate seismicity. Nevertheless, in the RF there are some regions where seismic activity is rather high (the Baikal rift zone, the Kuril-Kamchatka zone, the Sakhalin island, etc.)

In our country structural analysis of building and facilities designed to be constructed in high seismic zones is conducted for basic and special load combinations with allowance for estimated seismic load. Seismic forces are included into special loads and forces combinations according to construction regulations СП 58.13330. Seismic forces are taken into account only when seismic activity in the area of construction amounts to 7 points and more.

In the process of structural analysis for strength and stability, apart from basic rates of operating conditions taken in accordance with other applicable regulations, extra rates of operating conditions are introduced.

One of the peculiarities in the process of design of buildings and facilities in high seismic zones involves providing conditions to facilitate the development of plastic strains (the so-called plastic hinges) ensuring the stability of construction in structural elements and their compounds.

The design of concrete structures reinforced with composite bars in high seismic zones is somewhat different from usual conditions of construction without any regard to seismicity. Fiberglass composite reinforcement bars are characterized by low relative elongation at fracture (ca. 2 - 2.5%). Besides, at fracture fiberglass composite reinforcement bars are brittle, that is the material is considered to be elastic up to its fracture. Steel bars, on the contrary, demonstrate explicit or implicit yield segment on the stress-strain diagram. This segment predetermines plastic properties of steel. Therefore conventional concrete structures reinforced with steel bars have elasto-plastic properties. Structures reinforced with fiberglass composite bars, on the other hand, demonstrate elastic properties. Thus, when designing structures reinforced with fiberglass composite bars in high seismic areas one should keep in mind elastic behavior and lack of possibility of plastic strain of such structures.

Structures reinforced with fiberglass composite bars designed in the RF must be calculated and satisfy the provisions of construction regulations СП 14.13330.2014 “Construction in seismic areas”, СП 63.13330.2012 “Reinforced concrete structures”, as well as of other applicable regulations.