Strengthening Design Of Reinforced Concrete With Frp Composite Materials

Strengthening Design of Reinforced Concrete with FRP establishes the art and science of strengthening design of reinforced concrete with fiber-reinforced polymer (FRP) beyond the abstract nature of the design guidelines from Canada (ISIS Canada 2001), Europe (FIB Task Group 9.3 2001), and the United States (ACI 440.2R-08). Evolved from thorough class notes used to teach a graduate course at Kansas State University, this comprehensive textbook: Addresses material characterization, flexural strengthening of beams and slabs, shear strengthening of beams, and confinement strengthening of columns Discusses the installation and inspection of FRP as externally bonded (EB) or near-surface-mounted (NSM) composite systems for concrete members Contains shear design examples and design examples for each flexural failure mode independently, with comparisons to actual experimental capacity Presents innovative design aids based on ACI 440 code provisions and hand calculations for confinement design interaction diagrams of columns Includes extensive end-of-chapter questions, references for further study, and a solutions manual with qualifying course adoption

Delivering a detailed introduction to FRP strengthening design, Strengthening Design of Reinforced Concrete with FRP offers a depth of coverage ideal for senior-level undergraduate, master's-level, and doctoral-level graduate civil engineering courses.

The first EPMESC Conference took place in 1985. It was during the Conference, recognising the success it had been, that the promoters decided to organise other EPMESC conferences, giving birth to a new series of international meetings devoted to computational methods in engineering. The variety of subjects covered by the papers submitted to the 7th Conference demonstrates how much computational methods expanded and became richer in their applications to Science and Technology. New paradigms are being cultivated as non-numerical applications started to compete with the more traditional numerical ones. The scientific and technological communities to which the EPMESC Conferences used to be addressed themselves have changed. The two-volume Proceedings that we achieved to gather represent many of the interesting developments that are taking place, not only in the Asia Pacific Region, but also in some other scientifically advanced parts of the World, and cover a vast list of subjects grouped under the following headings: Applied Mathematics; Physics and Materials Science; Solid Mechanics;

Finite Element and Boundary Element Methods; Structural Analysis; Structural Dynamics and Earthquake Engineering; Structural Engineering; Reinforced Concrete; Knowledge-Based Systems; Artificial Neural Networks and Genetic Algorithms; Computer-Aided Instruction; Computer-Aided Design and Computer-Aided Engineering; Geographic Information Systems; Environmental Applications; Road Engineering; Geotechnics; Soil Mechanics; Fluid Mechanics and Hydraulics. Two hundred and fifty one summaries were accepted, many of them with comments and restrictions, by the Programme Committee. From these, 153 papers resulted, many of them from Portuguese and Chinese origin, that were submitted to the revision of an international panel of referees from Australia, Belgium, Brazil, China, Italy, Macao, Portugal, Switzerland, United Kingdom and United States, to which we gladly acknowledge our gratitude and appreciation.

TRB's National Cooperative Highway Research Program (NCHRP) Report 655: Recommended Guide Specification for the Design of Externally Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements examines a recommended guide specification for the design of externally bonded Fiber-Reinforced Polymer (FRP) systems for the repair and strengthening of concrete bridge elements. The report addresses the design requirements for members subjected to different

loading conditions including flexure, shear and torsion, and combined axial force and flexure. The recommended guide specification is supplemented by design examples to illustrate its use for different FRP strengthening applications.

The repair of deteriorated, damaged and substandard civil infrastructures has become one of the most important issues for the civil engineer worldwide. This important book discusses the use of externally-bonded fibre-reinforced polymer (FRP) composites to strengthen, rehabilitate and retrofit civil engineering structures, covering such aspects as material behaviour, structural design and quality assurance. The first three chapters of the book review structurally-deficient civil engineering infrastructure, including concrete, metallic, masonry and timber structures. FRP composites used in rehabilitation and surface preparation of the component materials are also reviewed. The next four chapters deal with the design of FRP systems for the flexural and shear strengthening of reinforced concrete (RC) beams and the strengthening of RC columns. The following two chapters examine the strengthening of metallic and masonry structures with FRP composites. The last four chapters of the book are devoted to practical considerations in the flexural strengthening of beams with unstressed and prestressed FRP plates, durability of externally bonded FRP composite systems, quality assurance

and control, maintenance, repair, and case studies. With its distinguished editors and international team of contributors, Strengthening and rehabilitation of civil infrastructures using fibre-reinforced polymer (FRP) composites is a valuable reference guide for engineers, scientists and technical personnel in civil and structural engineering working on the rehabilitation and strengthening of the civil infrastructure. Reviews the use of fibre-reinforced polymer (FRP) composites in structurally damaged and sub-standard civil engineering structures Examines the role and benefits of fibre-reinforced polymer (FRP) composites in different types of structures such as masonry and metallic strengthening Covers practical considerations including material behaviour, structural design and quality assurance

This book is focused on the theoretical and practical design of reinforced concrete beams, columns and frame structures. It is based on an analytical approach of designing normal reinforced concrete structural elements that are compatible with most international design rules, including for instance the European design rules – Eurocode 2 – for reinforced concrete structures. The book tries to distinguish between what belongs to the structural design philosophy of such structural elements (related to strength of materials arguments) and what belongs to the design rule aspects associated with specific

characteristic data (for the material or loading parameters). A previous book, entitled Reinforced Concrete Beams, Columns and Frames – Mechanics and Design, deals with the fundamental aspects of the mechanics and design of reinforced concrete in general, both related to the Serviceability Limit State (SLS) and the Ultimate Limit State (ULS), whereas the current book deals with more advanced ULS aspects, along with instability and second-order analysis aspects. Some recent research results including the use of non-local mechanics are also presented. This book is aimed at Masters-level students, engineers, researchers and teachers in the field of reinforced concrete design. Most of the books in this area are very practical or code-oriented, whereas this book is more theoretically based, using rigorous mathematics and mechanics tools. Contents 1. Advanced Design at Ultimate Limit State (ULS). 2. Slender Compression Members – Mechanics and Design. 3. Approximate Analysis Methods. Appendix 1. Cardano's Method. Appendix 2. Steel Reinforcement Table. About the Authors Jostein Hellesland has been Professor of Structural Mechanics at the University of Oslo, Norway since January 1988. His contribution to the field of stability has been recognized and magnified by many high-quality papers in famous international journals such as Engineering Structures, Thin-Walled Structures, Journal of Constructional Steel Research and

Journal of Structural Engineering. Noël Challamel is Professor in Civil Engineering at UBS, University of South Brittany in France and chairman of the EMI-ASCE Stability committee. His contributions mainly concern the dynamics, stability and inelastic behavior of structural components, with special emphasis on Continuum Damage Mechanics (more than 70 publications in International peer-reviewed journals). Charles Casandjian was formerly Associate Professor at INSA (French National Institute of Applied Sciences), Rennes, France and the chairman of the course on reinforced concrete design. He has published work on the mechanics of concrete and is also involved in creating a web experience for teaching reinforced concrete design – BA-CORTEX. Christophe Lanos is Professor in Civil Engineering at the University of Rennes 1 in France. He has mainly published work on the mechanics of concrete, as well as other related subjects. He is also involved in creating a web experience for teaching reinforced concrete design – BA-CORTEX. The use of fiber reinforced plastic (FRP) composites for prestressed and non-prestressed concrete reinforcement has developed into a technology with serious and substantial claims for the advancement of construction materials and methods. Research and development is now occurring worldwide. The 20 papers in this volume make a further contribution in advancing knowledge and acceptance of FRP

composites for concrete reinforcement. The articles are divided into three parts. Part I introduces FRP reinforcement for concrete structures and describes general material properties and manufacturing methods. Part II covers a three-continent perspective of current R&D, design and code implementations, and technical organizations' activities. Part III presents an in-depth description of commercially-available products, construction methods, and applications. The work is intended for engineers, researchers, and developers with the objective of presenting them with a world-wide cross-section of initiatives, representative products and significant applications.

This Special Issue presents the latest advances in the field of Textile-Reinforced Cement Composites, including Textile-Reinforced Concrete (TRC), Textile-Reinforced Mortar (TRM), Fabric-Reinforced Cementitious Matrix (FRCM), etc. These composite materials distinguish themselves from other fibre-reinforced concrete materials by their strain-hardening behaviour under tensile loading. This Special Issue is composed of 14 papers covering new insights in structural and material engineering. The papers include investigations on the level of the fibre reinforcement system as well as on the level of the composites, investigating their impact and fatigue behaviour, durability and fire behaviour. Both the strengthening of existing structures and the development of new structural systems such as lightweight sandwich systems are presented, and analysis and design

methods are discussed. This Special Issue demonstrates the broadness and intensity of the ongoing advancements in the field of Textile-Reinforced Cement composites and the importance of several future research directions.

Encouraging creative uses of reinforced concrete, Principles of Reinforced Concrete Design draws a clear distinction between fundamentals and professional consensus. This text presents a mixture of fundamentals along with practical methods. It provides the fundamental concepts required for designing reinforced concrete (RC) structures, emphasizing principles based on mechanics, experience, and experimentation, while encouraging practitioners to consult their local building codes. The book presents design choices that fall in line with the boundaries defined by professional consensus (building codes), and provides reference material outlining the design criteria contained in building codes. It includes applications for both building and bridge structural design, and it is applicable worldwide, as it is not dependent upon any particular codes. Contains concise coverage that can be taught in one semester Underscores the fundamental principles of behavior Provides students with an understanding of the principles upon which codes are based Assists in navigating the labyrinth of ever-changing codes Fosters an inherent understanding of design The text also provides a brief history of reinforced concrete. While the initial attraction for using reinforced concrete in building construction has been attributed to its fire resistance, its increase in popularity was also due to the creativity of engineers

who kept extending its limits of application. Along with height achievement, reinforced concrete gained momentum by providing convenience, plasticity, and low-cost economic appeal. Principles of Reinforced Concrete Design provides undergraduate students with the fundamentals of mechanics and direct observation, as well as the concepts required to design reinforced concrete (RC) structures, and applies to both building and bridge structural design.

The in situ rehabilitation or upgrading of reinforced concrete members using bonded steel plates is an effective, convenient, and economic method of improving structural performance. However, disadvantages inherent in the use of steel have stimulated research into using fiber reinforced polymer (FRP) material in its place, with the goal of providing a non-corrosive, more versatile strengthening system. Strengthening of Reinforced Concrete Structures presents a detailed study of the flexural strengthening of reinforced and prestressed concrete members using FRP composite plates. This book covers short and long term performance through model and full-scale experimental testing plus theoretical and numerical considerations. It discusses previous investigative and site work undertaken to strengthen concrete beams using steel bonded pates and the pros and cons of using the steel and composite plate materials. It also presents case histories of construction members upgraded or strengthened using carbon fibre/polymer matrix composite materials bonded to the structural unit. A consortium of academic and industrial researchers provided much of the data and contributed

the chapters to this volume. The research and trial tests were undertaken as part of the United Kingdom's ROBUST project. Strengthening of Reinforced Concrete Structures serves to disseminate the large amount of information that resulted from these studies. As detailed in this book, their results will serve to help generate and formulate design specifications as engineers continue to apply these important techniques to an ever-widening range of applications.

From parking garages to roads and bridges, to structural concrete, this comprehensive book describes the causes, effects and remedies for concrete wear and failure. Hundreds of clear illustrations show users how to analyze, repair, clean and maintain concrete structures for optimal performance and cost effectiveness. This book is an invaluable reference for planning jobs, selecting materials, and training employees. With information organized in all-inclusive units for easy reference, this book is ideal for concrete specialists, general contractors, facility managers, civil and structural engineers, and architects.

TRB's National Cooperative Highway Research Program (NCHRP) Report 678: Design of FRP Systems for Strengthening Concrete Girders in Shear offers suggested design guidelines for concrete girders strengthened in shear using externally bonded Fiber-Reinforced Polymer (FRP) systems. The guidelines address the strengthening schemes and application of the FRP systems and their contribution to shear capacity of reinforced and prestressed concrete girders. The guidelines are supplemented by design examples to

illustrate their use for concrete beams strengthened with different FRP systems. Appendix A of NCHRP Report 678, which contains the research agency's final report, provides further elaboration on the work performed in this project. Appendix A: Research Description and Findings, is only available online.

High strength fibre composites (FRPs) have been used with civil structures since the 1980s, mostly in the repair, strengthening and retrofitting of concrete structures. This has attracted considerable research, and the industry has expanded exponentially in the last decade. Design guidelines have been developed by professional organizations in a number of countries including USA, Japan, Europe and China, but until now designers have had no publication which provides practical guidance or accessible coverage of the fundamentals. This book fills this void. It deals with the fundamentals of composites, and basic design principles, and provides step-by-step guidelines for design. Its main theme is the repair and retrofit of un-reinforced, reinforced and prestressed concrete structures using carbon, glass and other high strength fibre composites. In the case of beams, the focus is on their strengthening for flexure and shear or their stiffening. The main interest with columns is the improvement of their ductility; and both strengthening and ductility improvement of un-reinforced structures are covered. Methods for evaluating the strengthened structures are presented. Step by step procedures are set out, including flow charts, for the various structural components, and design examples and practice problems are used to illustrate. As infrastructure ages

worldwide, and its demolition and replacement becomes less of an option, the need for repair and retrofit of existing facilities will increase. Besides its audience of design professionals, this book suits graduate and advanced undergraduate students.

The in situ rehabilitation or upgrading of reinforced concrete members using bonded steel plates is an effective, convenient and economic method of improving structural performance. However, disadvantages inherent in the use of steel have stimulated research into the possibility of using fibre reinforced polymer (FRP) materials in its place, providing a non-corrosive, more versatile strengthening system. This book presents a detailed study of the flexural strengthening of reinforced and prestressed concrete members using fibre reinforces polymer composite plates. It is based to a large extent on material developed or provided by the consortium which studied the technology of plate bonding to upgrade structural units using carbon fibre / polymer composite materials. The research and trial tests were undertaken as part of the ROBUST project, one of several ventures in the UK Government's DTI-LINK Structural Composites Programme. The book has been designed for practising structural and civil engineers seeking to understand the principles and design technology of plate bonding, and for final year undergraduate and postgraduate engineers studying the principles of

highway and bridge engineering and structural engineering. Detailed study of the flexural strengthening of reinforced and prestressed concrete members using fibre reinforced polymer composites Contains in-depth case histories

Although the use of composites has increased in many industrial, commercial, medical, and defense applications, there is a lack of technical literature that examines composites in conjunction with concrete construction. Fulfilling the need for a comprehensive, explicit guide, Reinforced Concrete Design with FRP Composites presents specific informat

Strengthening of Concrete Structures Using Fiber Reinforced Polymers (FRP): Design, Construction and Practical Applications presents a best practice guide on the structural design and strengthening of bridge structures using advanced Fiber Reinforced Polymer (FRP) composites. The book briefly covers the basic concepts of FRP materials and composite mechanics, while focusing on practical design and construction issues, including inspection and quality control, paying special attention to the differences in various design codes (US, Japan, and Europe) and recommendations. At present, several design guides from the US, Japan, and Europe are available. These guidelines are often inconsistent and do not cover all necessary design and inspection issues to the same degree of detail. This book provides a critical review and comparison of these guidelines,

and then puts forward best practice recommendations, filling a significant gap in the literature, and serving as an important resource for engineers, architects, academics, and students interested in FRP materials and their structural applications. Written from a practitioner's point-of-view, it is a valuable design book for structural engineers all over the world. Includes a large quantity of design examples and structural software to facilitate learning and help readers perform routine design Provides recommendations for best practices in design and construction for the strengthening of bridge structures using advanced fiber-reinforced polymer (FRP) composites Presents comprehensive guidelines on design, inspection, and quality control, including laboratory and field testing information This book describes the application of nonlinear static and dynamic analysis for the design, maintenance and seismic strengthening of reinforced concrete structures. The latest structural and RC constitutive modelling techniques are described in detail, with particular attention given to multi-dimensional cracking and damage assessment, and their practical applications for performance-based design. Other subjects covered include 2D/3D analysis techniques, bond and tension stiffness, shear transfer, compression and confinement. It can be used in conjunction with WCOMD and COM3 software Nonlinear Mechanics of Reinforced

Concrete presents a practical methodology for structural engineers, graduate students and researchers concerned with the design and maintenance of concrete structures.

Externally-bonded fiber reinforced polymer (FRP) composites are an increasingly adopted technology for the renewal of existing concrete structures. In order to encourage the further use of these materials, a design code is needed that consi ders the inherent material variability of the composite, as well as the variatio ns introduced during field manufacture and environmental exposure while in servi ce. Load and Resistance Factor Design (LRFD) is a reliability-based design metho dology that provides an ideal framework for these considerations and is compatib le with existing trends in civil engineering design codes. This investigation st udies the application of LRFD to FRP strengthening schemes, with an emphasis on wet layup, carbon-fiber composites applied to reinforced concrete T-beam bridge girders. Models to describe variation in the existing structural materials and t he structural loading are drawn from the literature. Techniques for reliability analysis are discussed and existing work on externally bonded FRP reliability is surveyed. Stochastic variation in the FRP is characterized based on tensile tes ting of several sets of field manufactured wet layup composites. A General desig n procedure applicable to many different

situations is proposed using a composit e specific resistance factor to consider material variability, a set of Applicat ion Factors to account for deviations introduced through field manufacture and a n environment and service-life specific factor for FRP degradation. Preliminary resistance factors for design of FRP strengthening are calibrated over a range o f design scenarios. FRP degradation is considered based on existing durability m odels, and continued degradation of the structure due to general corrosion of th e reinforcing steel is included. The girders used for calibration are selected a s representative examples from a sample of California bridge plans. The reliabil ity has been evaluated using simulation and first-order methods. An example of t he proposed design procedure, using the calibrated resistance factors, is provid ed.
Fiber-reinforced polymer (FRP) composites have become an integral part of the construction industry because of their versatility, enhanced durability and resistance to fatigue and corrosion, high strength-to-weight ratio, accelerated construction, and lower maintenance and life-cycle costs. Advanced FRP composite materials are also emerging for a wide range of civil infrastructure applications. These include everything from bridge decks, bridge strengthening and repairs, and seismic retrofit to marine waterfront structures and sustainable, energy-efficient housing. The International Handbook of

FRP Composites in Civil Engineering brings together a wealth of information on advances in materials, techniques, practices, nondestructive testing, and structural health monitoring of FRP composites, specifically for civil infrastructure. With a focus on professional applications, the handbook supplies design guidelines and standards of practice from around the world. It also includes helpful design formulas, tables, and charts to provide immediate answers to common questions. Organized into seven parts, the handbook covers: FRP fundamentals, including history, codes and standards, manufacturing, materials, mechanics, and life-cycle costs Bridge deck applications and the critical topic of connection design for FRP structural members External reinforcement for rehabilitation, including the strengthening of reinforced concrete, masonry, wood, and metallic structures FRP composites for the reinforcement of concrete structures, including material characteristics, design procedures, and quality assurance–quality control (QA/QC) issues Hybrid FRP composite systems, with an emphasis on design, construction, QA/QC, and repair Quality control, quality assurance, and evaluation using nondestructive testing, and in-service monitoring using structural health monitoring of FRP composites, including smart composites that can actively sense and respond to the environment and internal states FRP-related books, journals,

conference proceedings, organizations, and research sources Comprehensive yet concise, this is an invaluable reference for practicing engineers and construction professionals, as well as researchers and students. It offers ready-to-use information on how FRP composites can be more effectively utilized in new construction, repair and reconstruction, and architectural engineering.

Design and construction in existing contexts is becoming increasingly important, and often the structures - sometimes of historical interest - can be preserved easily and at minimum cost by employing strengthening measures. Existing concrete members can be strengthened by using adhesives to bond additional reinforcing elements onto or into those members. This book explains the design rules, together with their background, and uses examples to illustrate their use, specifically for slabs, beams and columns. Concrete member strengthening measures can take the form of, for example, flexural strengthening with externally bonded (surface-mounted) CFRP strips, CF sheets and steel plates, flexural strengthening with CFRP strips bonded in slits (near-surface-mounted reinforcement), shear strengthening with externally bonded CF sheets and steel plates, and column strengthening with CF sheets as confining reinforcement. The explanations and background information provided are mainly based on the new German guideline "Strengthening of Concrete Members with Adhesively Bonded Reinforcement" by the German Committee for Structural Concrete (DAfStb). This is the first European guideline to regulate this topic in the form of a supplement to the Eurocode. As it is planned to produce a document in a future Eurocode 2, the DAfStb guideline serves as a starting point. The authors are

extensively involved in the planning, design, operation and inspection of buildings for preservation and reconstruction, and in the updating of European Technical Approval Guidelines (ETAGs) and design rules. Selected chapters from the German concrete yearbook are now being published in the new English "Beton-Kalender Series" for the benefit of an international audience. Since it was founded in 1906, the Ernst & Sohn "Beton-Kalender" has been supporting developments in reinforced and prestressed concrete. The aim was to publish a yearbook to reflect progress in "ferro-concrete" structures until - as the book's first editor, Fritz von Emperger (1862-1942), expressed it - the "tempestuous development" in this form of construction came to an end. However, the "Beton-Kalender" quickly became the chosen work of reference for civil and structural engineers, and apart from the years 1945-1950 has been published annually ever since.

Corrosion-resistant, electromagnetic transparent and lightweight fiber-reinforced polymers (FRPs) are accepted as valid alternatives to steel in concrete reinforcement. Reinforced Concrete with FRP Bars: Mechanics and Design, a technical guide based on the authors' more than 30 years of collective experience, provides principles, algorithms, and practical examples. Well-illustrated with case studies on flexural and column-type members, the book covers internal, non-prestressed FRP reinforcement. It assumes some familiarity with reinforced concrete, and excludes prestressing and near-surface mounted reinforcement applications. The text discusses FRP materials properties, and addresses testing and quality control, durability, and serviceability. It provides a historical overview, and emphasizes the ACI technical literature along with other research worldwide. Includes an explanation of the key physical mechanical properties of FRP bars and their production methods

Provides algorithms that govern design and detailing, including a new formulation for the use of FRP bars in columns Offers a justification for the development of strength reduction factors based on reliability considerations Uses a two –story building solved in Mathcad® that can become a template for real projects This book is mainly intended for practitioners and focuses on the fundamentals of performance and design of concrete members with FRP reinforcement and reinforcement detailing. Graduate students and researchers can use it as a valuable resource. Antonio Nanni is a professor at the University of Miami and the University of Naples Federico II. Antonio De Luca and Hany Zadeh are consultant design engineers.

Two different strengthening methods for reinforced concrete beam were reviewed and studied in this project. Methods were externally bonded fiber reinforced polymer (FRP) and steel plate method glued in the soffit of reinforced concrete beam. This study made comparisons for different parameters effecting, design approach, design assumption and some advantages and disadvantages to the above method. Besides that evaluation of the different design approach and comparisons with the existing experimental results was also made. From the comparison and the evaluation made, it was concluded that for shear strengthening using FRP, the approach based on bond mechanism is the best to use for design and analysis. For shear strengthening using steel plate bonding, the approach either base on load evaluation on plate separation or shear strength method are the best for design and analysis. For flexural strengthening using FRP, the approach based on ACI 440 guideline is the best to use for design and analysis and for flexural strengthening using steel, the approach based on serviceability strength moment is the best for design and analysis. Besides that, it was also observed that the current design methods in BS8110 are not

suitable for strengthening design because in FRP strengthening, the ultimate limit state assumes that at least one of the materials attains its maximum allowable strain and the cross sectional area of external reinforcement and the position of neutral axis is determined by equilibrium of normal and bending forces over the concrete section but for current design method BS8110 the strains in the concrete and the reinforcing steel are directly proportional to the distance from the neutral axis, at which the strain is zero. Furthermore in the serviceability limit state in FRP strengthening, plastic deformations are not allowed and nominal values of loads are used to prevent large deflections and wide crack openings but for current design method B S 8110 deflection are controlled by simply limiting the span / depth ratios and crack are controlled by simply limiting the maximum spacing of the tension reinforcement. Therefore current design code cannot be used for structural strengthening design and it should be modified.

Rehabilitation of Concrete Structures with Fiber Reinforced Polymer is a complete guide to the use of FRP in flexural, shear and axial strengthening of concrete structures. Through worked design examples, the authors guide readers through the details of usage, including anchorage systems, different materials and methods of repairing concrete structures using these techniques. Topics include the usage of FRP in concrete structure repair, concrete structural deterioration and rehabilitation, methods of structural rehabilitation and strengthening, a review of the design basis for FRP systems, including strengthening limits, fire endurance, and environmental considerations. In addition, readers will find sections on the strengthening of members under flexural stress, including failure modes, design procedures, examples and anchorage detailing, and sections on shear and torsion stress, axial strengthening, the installation of FRP systems,

and strengthening against extreme loads, such as earthquakes and fire, amongst other important topics. Presents worked design examples covering flexural, shear, and axial strengthening Includes complete coverage of FRP in Concrete Repair Explores the most recent guidelines (ACI440.2, 2017; AS5100.8, 2017 and Concrete society technical report no. 55, 2012)

In December 1996, the then CEB established a Task Group with the main objective to elaborate design guidelines for the use of FRP reinforcement in accordance with the design format of the CEB-FIP Model Code and Eurocode2. With the merger of CEB and FIP into fib in 1998, this Task Group became fib TG 9.3 FRP Reinforcement for concrete structures in Commission 9 Reinforcing and Prestressing Materials and Systems. The Task Group consists of about 60 members, representing most European universities, research institutes and industrial companies working in the field of advanced composite reinforcement for concrete structures, as well as corresponding members from Canada, Japan and USA. Meetings are held twice a year and on the research level its work is supported by the EU TMR (European Union Training and Mobility of Researchers) Network "ConFibreCrete". The work of fib TG 9.3 is performed by five working parties (WP): Material Testing and Characterization (MT&C) Reinforced Concrete (RC) Prestressed Concrete (PC) Externally Bonded Reinforcement (EBR) Marketing and Applications (M&A) This technical report constitutes the work conducted as of to date by the EBR party. This bulletin gives detailed design guidelines on the use of FRP EBR, the practical execution and the quality control, based on the current expertise and state-of-the-art knowledge of the task group members. It is regarded as a progress report since it is not the aim of this report to cover all aspects of RC strengthening with composites. Instead, it focuses on those

aspects that form the majority of the design problems. several of the topics presented are subject of ongoing research and development, and the details of some modelling approaches may be subject to future revisions. as knowledge in this field is advancing rapidly, the work of the EBR WP will continue. Inspite of this limit in scope, considerable effort has been made to present a bulletin that is today's state-of-art in the area of strengthening of concrete structures by means of externally bonded FRP reinforcement.

This guide to good practice focuses on the techniques for the repair and strengthening of reinforced and prestressed concrete structures - covering the planning, design, implementation and monitoring of repair and strengthening projects.

Strengthening Design of Reinforced Concrete with FRPCRC Press

The strengthening of reinforced concrete (RC) structures using advanced fibre-reinforced polymer (FRP) composites, and in particular the behaviour of FRP-strengthened RC structures is a topic which has become very popular in recent years. This popularity has arisen due to the need to maintain and upgrade essential infrastructure in all parts of the world, combined with the well-known advantages of FRP composites, such as good corrosion resistance and ease for site handling due to their light weight. The continuous reduction in the material cost of FRP composites has also contributed to their popularity. While a great amount of research now exists in the published literature on this topic, it is scattered in various journals and conference

proceedings. This book therefore provides the first ever comprehensive, state-of-the-art summary of the existing research on FRP strengthening of RC structures, with the emphasis being on structural behaviour and strength models. The main topics covered include: * bond behaviour * flexural and shear strengthening of beams * column strengthening * flexural strengthening of slabs. For each area, the methods of strengthening are discussed, followed by a description of behaviour and failure modes and then the presentation of rational design recommendations, for direct use in practical design of FRP strengthening measures. Researchers, practicing engineers, code writers and postgraduate students in structural engineering and construction materials, as well as consulting firms, government departments, professional bodies, contracting firms and FRP material suppliers will find this an invaluable resource.

This book analyses the current knowledge on structural behaviour of RC elements and structures strengthened with composite materials (experimental, analytical and numerical approaches for EBR and NSM), particularly in relation to the above topics, and the comparison of the predictions of the current available codes/recommendations/guidelines with selected experimental results. The book shows possible critical issues (discrepancies, lacunae, relevant

parameters, test procedures, etc.) related to current code predictions or to evaluate their reliability, in order to develop more uniform methods and basic rules for design and control of FRP strengthened RC structures. General problems/critical issues are clarified on the basis of the actual experiences, detect discrepancies in existing codes, lacunae in knowledge and, concerning these identified subjects, provide proposals for improvements. The book will help to contribute to promote and consolidate a more qualified and conscious approach towards rehabilitation and strengthening existing RC structures with composites and their possible monitoring.

Over the past two decades Fiber-Reinforced Polymer (FRP) composites has gained acceptance in civil engineering industry as a result of the urgent need to retrofit exiting constructed facilities and structures. This book focuses on the shear strengthening of reinforced concrete (RC) beams using FRP composites. Several research problems related to shear strengthening still linger and therefore require further research studies to be entirely solved. The main objective of this book is to experimentally and analytically study the FRP strengthening methods of full-scale RC beams in shear.

The Most Complete FRP Reinforced Concrete Structure Analysis and Design Guide This

comprehensive reference provides proven design procedures for the use of fiber-reinforced polymer (FRP) materials for reinforcement, prestressing, and strengthening of reinforced concrete structures. The characteristics of FRP composite materials as well as the latest manufacturing techniques are discussed. Detailed illustrations and tables, design equations, end-of-chapter problems, and real-world case studies are included in this authoritative resource. Analysis and Design of FRP Reinforced Concrete Structures covers: Material characteristics of FRP bars History and uses of FRP technology Design of RC structures reinforced with FRP bars Design philosophy for FRP external strengthening systems Durability-based design approach for external FRP strengthening of RC beams

?With the advent of advanced composite materials in the form of fiber reinforced polymer (FRP), these innovative FRP materials have been utilized across the world as internal reinforcements, external reinforcements, and prestressing tendons/strands. The research carried out on FRP materials have revealed their potential as efficient construction materials requiring least maintenance and minimal life cycle cost. In addition, FRP also finds usage as external strengthening material in deficient structures and for upgrading the strength of structures to meet new requirements. This book presents various aspects of FRP composite materials, their

characteristics, manufacturing techniques, real-life projects, different forms of FRP products and, most importantly, detailed procedures for designing new structures using FRP as internal reinforcements, external strengthening materials, and prestressing materials. The main topics covered: introduction of FRP composites? material characteristics? history and uses of FRP technology? design of RC structures using FRP bars? design philosophy for FRP external strengthening systems? durability-based design approach for external FRP strengthening of RC beams Alongside case study problems, for example, on FRP prestressed concrete bridges, this book comes equipped with ample exercise problems and design examples. As a consolidated source of design guidelines and design examples on FRP reinforced and/or prestressed concrete structures, this book will be of prime interest to a wide range of readers including researchers, academicians in general, consultants, practitioners, designers, writers of design codes, structural engineers, and senior undergraduate and graduate students.