CE G 564: Structural Health Assessment and Rehabilitation

General Course Handout: Part-I

Introduction, Overview of present repair, retrofitting, and strengthening practices, Distress identification, Repair management, Causes of deterioration and durability aspects, Holistic models of Deterioration of RCC, Durability Aspects, Intrinsic and Extrinsic causes an stages of Distress, Condition Survey and Non-destructive Evaluation, Classes of Damages and Repair Classification, Structural Analysis and Design, Reserve Strength, Evaluation of Building Configuration, Repair materials and their selection, Rehabilitation and Retrofitting Methods, Analysis and Design of Externally FRP and ECC Strengthened Structures, Retrofitting using External Unbonded Post-tensioning and Near Surface Mounted FRP Rebars, Durability Based Design of FRP Reinforced/Strengthened Bridge Girders, Case Study Problems.

Course Handout-Part II

In addition to Part I (General Handout for all courses appended to the time table) this portion gives further specific details regarding the course.

Course No. : CE G564

Course Title: **Structural Health Assessment and Rehabilitation**

Civil Engineering Department, BITS Pilani, Pilani Campus

Course Description

This course deals with critical assessment of the health of structures especially reinforced concrete structures and identification of the causes of deterioration along with design of suitable repair, retrofitting, and external strengthening of deficient structural systems using conventional and high-performance materials such as polymer modified mortars and concrete, epoxy mortar and concrete, fiber reinforced polymer (FRP) systems, composite fabric wrapping sheets, composite laminate, and engineered cementitious composites. Moreover, condition survey and various non-destructive testings as well as experimental tests to assess the quality of materials used in construction for determining the reserve strength of structural members are discussed in detail. A special topic on structural health monitoring using advanced sensors will be introduced for identification, location, and severity of damage in structures. Furthermore, analysis and design of structures such as beams, bridge girders, walls, and columns reinforced and/or strengthened with high-performance FRP materials are introduced. In addition, special topics such as seismic retrofitting of columns and analysis of external FRP prestressed bridge girders with case study problems are also presented and described.

Scope and Objective of the Course

Structural health assessment and rehabilitation is an advance course for Graduate and Postgraduate students of structural and infrastructure engineering, and most important for practicing engineers associated with private as well as government organizations such as Public Works Departments and Central Public Works Department. The clear understanding of materials (steel, concrete, polymers, and FRP), mechanics of solids and RCC design is prerequisite for this course. The primary objective of the course is to make students understand the various causes of structural deficiency and durability aspects along with knowing the characteristics of conventional and advance repair materials so that a deficient structural system could be suitably rehabilitated using appropriate repair materials with optimum cost. At the end of course, students will have general awareness of the nondestructive and partial destructive

techniques, and structural health monitoring techniques along with sensors to evaluate the structural deficiency and methods of rehabilitation using appropriate repair materials. Furthermore, the student shall be capable of selecting health evaluation methods, tests, and diagnosis. Once the condition has been assessed, the student shall be able to decide upon repair strategy, the method of repair, and compatible materials. Most importantly, students will be able to analyze and design the structures reinforced, prestressed, and or externally strengthened with high-performance composite materials such as FRP and Engineered Cementitious Composites.

PREREQUISITES: (1) Course No. CE F211: Mechanics of Solids

(2) Course No. CE F 311: Design of Concrete Structures

Text Books (TB)

1. Handbook on Repairs and Rehabilitation of RCC Buildings, CPWD, Government of India, new Delhi, 2002, 498 pp.
2. Analysis and Design of FRP Reinforced Concrete Structures, Shamsher Bahadur Singh, McGraw Hill Education (India) Private Ltd., New Delhi, 2014, 323 pp.

Reference Books (RB)

1. Structural Health Monitoring of Large Civil Engineering Structures, Hua-Peng Chen, Wiley Blackwell, John Wiley and Sons Ltd., NJ, USA.
2. Guide Book on Non-Destructive Testing of Concrete Structures, Training Course Series No. 17, Report published by International Atomic Energy Agency, Vienna, 2002, 242 pp.
3. ISIS and SAMCO Educational Module 5, An Introduction to Structural Health Monitoring, SAMCO Final Report 2006, F10-Teaching Materials (Available online).
4. Mechanics of Composite Materials, Robert M. Jones, Taylor and Francis, New York, London, 1999, First Indian Reprint, 2010, 519 pp.
5. Reinforced Concrete Design with FRP Composites, Hota V.S., Gangarao, Narendra Taly, and PV Vijay, CRC Press (Taylor & Francis Group), Boca Raton, FL, USA, 2007, 382 pp.
6. FRP Strengthening of RC Structures, Teng, J. G., Chen, J. F., Smith, S. T. and Lam, L. (authors), John Wiley & Sons Ltd., West Sussex, England, 2002, 245 pp. (E-mail: cs-books@wiley.co.uk; http://www.wiley.com).
7. Strengthening of Reinforced Concrete Structures using Externally Bonded FRP Composites in Structural and Civil Engineering, L. C. Hallaway and M. B. Leeming (editors), Woodhead Publishing Ltd., Cambridge England, 2001, 327 pp.
8. Service Life Estimation and Extension of Civil Engineering Structures, V. M. Karbhari, USA.
9. Concrete Structures Repair, Rehabilitation and Retrofitting, CBS Publisher, New Delhi 2017.
10. Durability Design of Concrete Structures, A. Sarja and E. Vesikari, CRC Press, RILEM Report 14.

COURSE PLAN

Lecture No.	Learning Objective	Topics to be Covered	Reference Chapter/Sec. # (Book/Handbooks)
1-3	Introduction	An overview of present repair, retrofitting, and strengthening practices, Distress identification, and Repair Management	Chapter#1 (TB#1 &RB#22)
4-11	Causes of Deterioration and Durability Aspects	Holistic models of deterioration of Reinforced Cement Concrete (RCC) structures in terms of capillary porosity, air-voids, micro-cracks, macro-cracks, Aggressive deteriorating chemical agents, corrosion of reinforcing bars, Sulphate attack, Alkali-silica reaction, Durability aspects, Intrinsic and Extrinsic Causes and Stages of Distress	TB#1 (Ch. 2)
12-20	Condition Survey and Non-destructive Evaluation	Objectives, Preliminary Inspection, Planning stages, Visual Inspection, Field and laboratory testing stages, Consideration for Repair Strategy, Non-Destructive Evaluation (NDE) Tests such as Rebound Hammer Test, Ultra-sonic Pulse Velocity (UPV) test, Penetration Resistance (Windsor Probe & PNR) Test, Pull-out test, Core Sampling and Testing, Carbonation Test, Chloride Damage Assessment, Structural Integrity/Soundness Assessment using Radiography , Impact Echo, and Dynamic Tests, Interpretation, Evaluation of Results Data	TB#1 (Ch.3)

21-25	Structural Health Monitoring (SHM)	Introduction to structural health monitoring, Classification of SHM, Methodology, Sensor Technology, SHM Testing Categories, SHM System Design, Case Studies, Future of Structural Health Monitoring, Detailed example on SHM of The Golden Boy Statue mounted on the Dome of Manitoba Legislature.	RB# 1&3
26-29	Structural Analysis and Design of Existing and Rehabilitated Structures	Reserve Strength, Analysis necessary to identify critical sections, Active and Passive Repairs, Modeling of Repaired Composite Structures, Mechanical Properties of Materials, Evaluation of Damage Concrete/Reinforcements, Service Loads due to Change of Building Use, Evaluation of Building Configuration, and Load Tests for Flexural member	TB#1 (Ch.4), TB#2 (Ch3)
30-31	Selection of Repair Materials for Concrete	Materials for Repair such as Premixed Cement Concrete, Mortars, Polymer Modified Mortars and Concrete (PMM/PMC), Epoxies and Epoxy Systems including Epoxy Mortar and Concrete, Fiber Reinforced Polymer Systems, Fabric sheets, Engineered Cementitious Composites, Ferrocement	TB#2 (Ch.3), TB#1 (Ch.5)
32-35	Rehabilitation and Retrofitting Methods	Repair Options, Performance Requirements, Repair Systems, Shotcrete, Ferrocement, Plate Bonding, Fiber Wrap, Section Enlargement, and External FRP Strengthening and Prestressing	TB#2 (Ch.4 &5), TB#1 (Ch.6)
36-40	Analysis and Design of FRP and ECC External Strengthening Systems	FRP and ECC Strengthened Structural Members such as Beams, Bridge Girders, Masonry Structures, and Columns. Near Surface Mounted FRP Strengthening, Strengthening using Laminates, and Seismic Retrofitting of Columns	TB#2 (Ch.5)

41-43	Analysis Design of RC Structures Reinforced with FRP Bars	Flexural and shear Design Approach for FRP Reinforced RC Beams and FRP prestressed bridge girders, Reduction Factors, Durability Based Design	TB#2 (Ch.4 & 6)
44-45	Case Study Problems	Case study problems on Externally Strengthened and Prestressed Systems using Unbonded Tendons	TB#2 (Ch. 4 &5) and TB#1 (Ch.9)

Evaluation Scheme

EC No.	Evaluation Component	Duration	Weightage (%)	Date &Time	Remarks
1	Mid-Term Test	90 Min.	30		Partially OB
2	Assignments	Take Home	15		OB
3	Special Projects (Computer and Lab Oriented) Comprehensive Viva-Voce Examinations		25	To be announced	
4	Comp. Exam	2 Hours	30		Partially OB

Teaching Method: Teaching of the subject will be made by combination of power-point presentation. Necessary instructional materials (available and prepared by instructor) will also be supplied for ready reference.