MASTER OF ENGINEERING IN STRUCTURAL ENGINEERING

Department of Civil Engineering
Faculty of Engineering
University of Peradeniya

Course Structure

Course code	Title	Compulsory/ Optional	Credits
CE 6501	Advanced Concrete Technology	Compulsory	3
CE 6502	Design of Steel Structures	Compulsory	3
CE 6503	Design of Reinforced Concrete Structures	Compulsory	3
CE 6504	Finite Element Methods in Structural Mechanics	Compulsory	3
CE 6505	Structural Dynamics	Compulsory	3
CE 6506	Wind Engineering	Optional	2
CE 6507	Earthquake Engineering	Optional	2
CE 6508	Engineering Materials	Optional	2
CE 6509	Advanced Foundation Engineering	Compulsory	3
CE 6510	Prestressed Concrete Design	Optional	2
CE 6511	Nonlinear Analysis of Frame Structures	Optional	2
CE 6512	Forensic Investigation, Repair and Retrofitting of Structures	Optional	2
CE 6513	Numerical Methods for Civil Engineers	Optional	2
CE 6514	Design of High-rise Buildings	Optional	2
CE 6515	Bridge Engineering	Optional	2
CE 6103	**Advanced Study**	**Compulsory**	**5**

Number of credits from compulsory courses: 18
Number of credits from optional courses: 7
Number of credits from advanced study: 5
Total number of credits: 30

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory /Optional**	**: CE 6501** **: Advanced Concrete Technology** **: 3** **: None** **: Compulsory**

Aim(s): To teach the properties of concrete and its ingredients so that the students can use this knowledge in specifying, producing, using and caring of concrete for structures.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to:

1. Identify different types of cement based on their composition and performance
2. Select most appropriate ingredients, based on their properties, for the production of concrete to suit the application
3. Specify concrete with different characteristics for diverse conditions and applications
4. Design concrete mixes to achieve specified performance requirements
5. Evaluate the properties of concrete, working life, and judge compliance
6. Propose suitable procedures for making, delivery, placing, finishing and caring of concrete, giving due consideration for the application
7. Assess structural health of concrete structures and plan appropriate rehabilitation methods

Time Allocation (Hours)	Lectures: 40 Tutorials: 03 Practicals: Assignments: 04 Independent learning: 103 (Notional hours=150)

Course Content/Course Description:

Cement production

Constituents; method of production; chemical reactions

Types of cement: Cement types; classification

Chemical and mineral admixtures: Characteristics; applications

Aggregate: Types; classifications; testing

Proportioning of concrete mixes: Mix design methods; self-compacting concrete design; zero-slump concrete design

Concept of high-performance concrete: Materials; attributes; mix design

Properties of fresh and hardened concrete

Fresh/hardened concrete properties; concrete testing

Compliance criteria, Production of concrete

Mixing; transporting; compaction; curing

Temperature effects in concrete

Temperature development; adiabatic temperature; temperature prediction; temperature control

Durability of concrete and maintenance: Carbonation; sulphate attack, ASR/ACR reactions

Assessment of working life : Carbonation assessment; half-cell potential assessment

Special types of concrete and their applications : Roller compacted concrete; fibre reinforced concrete; shotcrete

Testing of concrete in structures; Non-destructive and semi-destructive testing

Evaluation of concrete in structures, Planning and design of concrete repair , Materials and methods for repair and rehabilitation

Recommended Texts

Neville, A.M., (2012). Properties of Concrete, 5rd edition, Pearson.

Woodson, R.D., (2009). Concrete Structures, Elsevier, Oxford

Assessment		**Percentage Marks**
In-Course	Assignments/Course work Mid Semester Examination	10 30
End of Semester Examination		60

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/Optional**	**: CE 6502** **: Design of Steel Structures** **: 3** **: None** **: Compulsory**

Aim(s): The objective of this course is to develop a sound knowledge on the design of steel structures.

Intended Learning Outcomes:

At the end of this course, students should be able to,

1. Explain the holistic behaviour of steel structures
2. Design of elements subjected to axial, shear, bending and combined effects
3. Design elements using plastic theory

Time Allocation (Hours)	Lectures: 40 Tutorials: 03 Practical: - Assignments: 04 Independent learning: 103 (Notional hours = 150)

Course Content/Course Description:

Introduction:

Introduction to design of steel structures, materials behaviour, properties of structural steel, steel grades, steel sections.

Limit state design and code of practice:

Simple and continuous structures, limit state design, code of practice, cross section classification, section properties, holistic behaviour of structures.

Design of structural members:

Design of tension members, compression members, restrained and unrestrained beams, stocky and slender columns, special types of struts, columns in simple structures, columns under combined axial loads and moments.

Design of connections:

Connections in simple and continuous structures, design of bolted and welded connections, design of column bases.

Design of portal frames:

Plastic analysis, frame stability, local buckling, lateral distortion, torsional restraints, design of haunches.

Design of plate girders:

Sizing plate girders, section classification, moment and shear capacities, design of end panels and intermediate stiffeners.

Steel – concrete composites: Design of steel - concrete composite members.

Recommended Texts

EN 1993-1-1:2005, Design of Steel Structures – Part 1.1 General Rules and Rules for Buildings.
Brettle, M. E., Brown, D. G., 2009, "Steel Building Design: Concise Eurocodes", SCI Publication, Berkshire.
Trahair, N. S., et al., 2008, "The Behaviour and Design of Steel Structures to EC3", 4th Edition, Taylor & Francis, Oxon.
Way, A. G. J., Salter, P. R., 2003, "Introduction to Steelwork Design to BS 5950:2000", SCI Publication, Berkshire.

Assessment		Percentage Marks
In-Course	Assignments/Course work (take home) Mid Semester Examination	50 -
End of Semester Examination		50

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/Optional**	**: CE 6503** **: Design of Reinforced Concrete Structures** **: 3** **: None** **: Compulsory**

Aim(s): To provide Engineers with a thorough understanding of the design of reinforced concrete structures.

Intended Learning Outcomes:

At the end of this course, students should be able to;

1. Generalise the guiding principles of the serviceability limit state and the ultimate limit state concepts and how they relate to the design of structures.
2. Summaries the fundamental mechanics of reinforced concrete and the empirical assumptions made for analysis
3. Apply fundamental mechanics to the design of reinforced concrete beams and slabs at the serviceability limit state including determination of short and long term deflection and crack widths.
4. Apply fundamental mechanics to the design of reinforced concrete beams and slabs at the ultimate limit state including determination of member strength (flexural and shear) and ductility.
5. Apply fundamental mechanics to the design of reinforced concrete columns at the ultimate limit state including determination strength under uniaxial and biaxial bending.
6. Apply fundamental mechanics to the design of pile caps and water retaining structures

Time Allocation (Hours)	Lectures:42 Assignments:06 Independent learning:102 (Notional hours=150)

Course Content/Course Description:

Introduction: Objectives and methods of analysis and design, Properties of concrete and reinforcing steel, Design concepts
Limit State Design: Limit state of collapse, Limit state of serviceability
Design of RC beams:
Flexure -Singly/doubly RC beams, Flanged beams
Shear design
Bond, anchorage, development length and torsion
Serviceability limit state check
Curtailment
Deep beam design
Compression Members: RC Short column, RC Slender column
Reinforced Concrete Slabs: One way slab, Two way slab, Yield line theory, Serviceability limit state check, Pile cap design
Design of Water Retaining Structures

Recommended Texts

Nilson, A. H., D. Darwin, and C. W. Dolan. Design of Concrete Structures. 13th ed. McGraw-Hill, 2004.

Assessment		**Percentage Marks**
In-Course	Assignments/Course work	40
End of Semester Examination		60

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/Optional**	**: CE 6504** **: Finite Element Methods in Structural Mechanics** **: 3** **: None** **: Compulsory**

Aim(s): To reinforce the knowledge on displacement based finite element method used in analysing civil engineering problems.

Intended Learning Outcomes:

At the end of this course, students should be able to;

1. Explain the displacement based finite element methods and their limitations for analysis of civil engineering problems.
2. Apply the finite element method with specific emphasis on its applications to planer elastic problems and three dimensional problems.
3. Analyse 2D and 3D engineering problems by using commercially available Finite Element (FE) software.

Time Allocation (Hours)	Lectures: 40 Tutorials: Practical: Assignments: 10 Independent learning: 100 (Notional hours=150)

Course Content/Course Description:

Introduction to finite element method.
Review of displacement based finite element method – 1D element.
2-Dimentional plane stress/strain element formulation:
Problem differential equation, constant strain triangular (CST) element formulation, 4-node quadrilateral element formulation using isoparametric formulation, Numerical integration; Gauss Quadrature, Gauss point, Higher order elements, shear locking.

Plate bending element formulation:
Derivation of problem differential equation, 4-node rectangular element formulation (one of the earliest plate bending formulation), 4-node quadrilateral plate bending element formulation using Mindlin and Reissner plate theory.

Shell element formulation:

Solid element formulation:
8-node solid element formulation using isoparametric formulation, Higher order elements

Use of general purpose finite element programs: Pre-processor, mesh generation, renumbering for efficiency, post-processors, use of finite element methods in CAD/CAE, applications of general purpose finite element programs.

Recommended Texts

Logan, D 2007, *First Course in Finite Element Method*, 4th edn, Nelson Engineering.
Desai, C 2005, *Introduction to the Finite Element Method*, 1st edn, CBS Publisher.
Weaver, W and Gere, JM 2004, *Matrix Analysis of Framed Structures*, 2nd edn, Springer.

Assessment		**Percentage Marks**
In-Course	Assignments/Course work Mid Semester Examination	20 20
End of Semester Examinations		60

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/Optional**	**: CE 6505** **: Structural Dynamics** **: 3** **: None** **: Compulsory**

Aim(s): To impart fundamental knowledge on dynamic behaviour of structures.

Intended Learning Outcomes:
At the end of this course, students should be able to,
1. Describe the effect of dynamic loading on structures.
2. Analyse the responses of single/multi degree of freedom and continuous structures under various dynamic loading.
3. Analyse and design of vibration suppression systems.

Time Allocation (Hours)	Lectures: 38 Tutorials: Practicals: Assignments: 14 Independent learning: 98 (Notional hours = 150)

Course Content/Course Description:

Dynamics of Simple Structures (Single-Degree-of-Freedom systems)
Equation of motion, Free vibrations, Response to harmonic force, Response to periodic force, Response to arbitrary dynamic force.

Multi-Degree-of-Freedom Structures
Formulation of matrix equations of motion, Analysis of free vibrations, Modal analysis and forced vibrations, Steady state response.

Continuous Structures
Partial differential equations of motions (for strings, bars, beams), Modal analysis.

Random Vibrations
Probability theory, random processes, Correlation and spectral density functions, Response to stationary random excitations, Crossing, peak distributions, extreme value analysis, evaluation of fatigue life, Application to wind engineering.

Control of Dynamic Response
Overview of vibration control, Tuned Mass Dampers, Active control.

Applications of Structural Dynamics
Model validations, Vibration based structural health monitoring.

Recommended Texts
R. W. Clough, and J. Penzien, (1993), *Dynamics of Structures*, McGraw-Hill, New York, 2nd Edition.
A. K. Chopra, (1995), *Dynamics of Structures-Theory and Applications to Earthquake Engineering*, Prentice Hall, New Jersey.

Assessment		**Percentage Marks**
In-Course	Assignments/Course work	40
End of Semester Examinations		60

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/Optional**	**: CE 6506** **: Wind Engineering** **: 2** **: None** **: Optional**

Aim(s): To impart knowledge on fundamentals and the operative techniques of wind engineering with special regard for wind actions and effects on structures.

Intended Learning Outcomes:

At the end of this course, students should be able to,

1. Explain wind characteristics, wind loading and bluff-body aerodynamics.
2. Evaluate aeroelastic phenomena of structural system.
3. Design structures for wind loadings.

Time Allocation (Hours)	Lectures: 27 Tutorials: 03 Practical: Assignments: Independent learning: 70 (Notional hours = 100)

Course Content/Course Description:

Introduction to Wind Engineering:

The nature of wind from meteorological viewpoints, Wind induced damage

Wind Characteristics:

Description of wind characteristics from engineering viewpoints

Wind Loading and Bluff-Body Aerodynamics:

Introduction to bluff-body aerodynamics, Aerodynamic drag (C_D), lift (C_L), moment (C_M) and pressure (C_P), Effects of viscosity and Reynold number (Re) to flow pattern around bluff-body, Factors affect the aerodynamics coefficients (C_D, C_L, C_M and C_P), Periodic vortex induced forces, Random wind forces caused by random wind velocity fluctuations

Aeroelastic Phenomena:

Classification of wind effects on structure, Static wind load effects, Vortex induced oscillation, Galloping induced oscillation, Flutter induced oscillation

Wind Resistant Design:

Tall buildings, Long-span bridges, Wind tunnel tests, Aerodynamic and mechanical approaches to suppress wind-induced responses

Recommended Texts

Holmes, D. J. 2007, *Wind Loading of Structures*, 2ndedn, Taylor & Francis.
Clough, R. and Penzien, J. 1975, *Dynamics of Structures*, 4thedn, McGraw-Hill.
Chopra, A. K. 2011, *Dynamics of Structures*, 4thedn, Prentice Hall.

Assessment		**Percentage Marks**
In-Course	Assignments:	20
	Mid Semester Examination:	30
End of Semester Examinations		50

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/Optional**	**: CE 6507** **: Earthquake Engineering** **: 2** **: None** **: Optional**

Aim(s): To impart knowledge on Earthquake Engineering aspects.

Intended Learning Outcomes:
At the end of this course, students should be able to,

1. Explain the fundamental concepts, principles and application of earthquake engineering in seismic analysis.
2. Analysis of structures for earthquake loadings.
3. Design of structures for earthquake loadings.

Time Allocation (Hours)	Lectures: 28 Assignments: 04 Independent learning: 68 (Notional hours = 100)

Course Content/Course Description:

Nature of Earthquakes; Sources of earthquake ground motions**,** measures of earthquake intensity and damage potential**, s**eismicity in and around Sri Lanka, effects of earthquakes on structures: lesson learned from past earthquakes.

Response of Simple Structures to Earthquake Ground Motions; equation of motion for base excitation, solution of the SDOF system**, e**arthquake response spectra.

Seismic Analysis Procedures (Force-based procedure); linear elastic design spectrum and inelastic design spectrum**,** analysis procedures for building structures**, b**asic design principles and performance requirements.

Seismic Design Principles for RC Structures; structural systems/ types of buildings**,** capacity design principles**,** ductility in reinforced concrete**,** capacity design procedure.

Force-Based vs. Direct Displacement-Based Design

Damage Avoidance Design; base isolation**, r**ocking precast structural systems

Recommended Texts
Priestley, M.J.N., Calvi, G.M. and Kowalsky, M.J. (2007). Direct displacement based design of structures, IUSS Press, Pavia, Italy
Chopra, A. K. (2017), "Dynamics of structures: theory and application to earthquake engineering", 5th Edition, Prentice Hall International, Inc. Englewood Cliff

Assessment		**Percentage Marks**
In-Course	Assignments/Course work	40
End of Semester Examinations		60

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/ Optional**	**: CE 6508** **: Engineering Materials** **: 2** **: None** **: Optional**

Aim(s): The objective of this course is to provide a sound knowledge in structure and properties of engineering materials, advanced materials, material selection and design

Intended Learning Outcomes:
At the end of this course, students should be able to;

1. Identify different classes of materials based on structure – property and process relationships
2. Select appropriate materials for intended purposes
3. Carryout lifelong learning on new materials and their applications

Time Allocation (Hours)	Lectures: 26 Tutorials: 03 Practical: Assignments: 02 Independent learning: 69 (Notional hours=100)

Course Content/Course Description:

Introduction:
Introduction to materials, material classes and properties, price and availability of materials, material efficient designs.
Polymers:
Generic polymers, GFRP, CFRP and KFRP, mechanical behaviour of polymers, polymer composites, advance engineering applications of polymers and polymer composites.
Ceramics and glasses: Classes of ceramics and glasses, cement and concrete, rocks and minerals, mechanical properties, high performance ceramics, ceramic composites, ceramic matrix composites (CMC), advanced engineering applications of ceramics, glasses and composites.
Metals: Ferrous and non-ferrous metals, alloys, light alloys, mechanical properties of metals and alloys, metal matrix composites (MMC), selection of metals and alloys for designs.
Materials and energy: Energy economy, material contents in products, alternative materials, production process.
Advanced Materials: Carbon-carbon composites, cellular solids and foams, micro-composites, Nano-materials.
Construction Materials: Sustainability of construction materials Local and regional materials, Alternative materials for construction.

Recommended Texts
Ashby, M. F., and Jones, D. R. H., (1996). "Engineering Materials I", 2nd Edition, Butterworth – Heinemann (or any edition from the 2nd edition).
Ashby, M. F., and Jones, D. R. H., (1998). "Engineering Materials II", 2nd Edition, Butterworth – Heinemann (or any edition from the 2nd edition).
Ashby, M. F., (2005). "Materials Selection in Mechanical Design", 3rd Edition, Elsevier (or any edition from the 3rd edition).

Assessment		**Percentage Marks**
In-Course	Assignments/Course work (take home)	40
End of Semester Examinations		60

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/Optional**	**: CE 6509** **: Advanced Foundation Engineering** **: 3** **: None** **: Compulsory**

Aim(s): To impart knowledge and understanding of fundamental concepts of bearing capacity theory, to analyse and design different types of shallow foundations subjected to static and dynamic loads and deep foundations subjected to axial/lateral loads and uplift using Eurocode 7.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to,

1. Analyse and design different types of shallow foundations including spread, strap, combined and raft foundations subjected to static and dynamic loads.
2. Analyse and design axially loaded single and group piles and caisson foundations in granular and cohesive soils.
3. Analyse and design laterally loaded piles and piles subjected to uplift.
4. Carry out a comprehensive design of foundations of a proposed building considering the soil stratigraphy at the site and loading conditions

Time Allocation (Hours)	Lectures: 40 Tutorials: Assignments: 20 Independent learning: 90 (Notional hours=150)

Course Content/Course Description:

Shallow foundations:

Bearing capacity theories, Shallow foundation design using Eurocode 7, eccentric and inclined loads, bearing capacity on slopes, Bearing capacity of layered soils, foundation settlements

Design of combined and raft foundations:

flexible and rigid design of combined footings and raft foundations

Machine foundations:

Types of machines, design criteria, elements of vibration theory, governing equations

Deep foundations:

Introduction, bearing capacity of group piles, Quality Control and Quality assurance of pile foundation, Design of deep foundations using Eurocode 7, Negative skin friction, Pile group settlement, Rock socketed piles, Laterally loaded piles, Piles subjected to uplift, Design of Caissons in sand and clay

Design Exercise:

Design of foundation of a building

Recommended Texts

Das B.M., (2011).“Principles of Foundation Engineering”, 7th edition, PWS Publishers.

Coduto D.P., (2001). “Foundation design principles and practices”, 2nd edition, Prentice Hall.

Smith I., (2014). “Smith’s Element of Soil Mechanics (Design to Eurocode)”, 9th edition, Blackwell publishing.

Tomlinson M., Woodward J., (2007). “Pile design and construction practice”, 5th edition, Taylor and Francis.

Frank R., (2004). “Designers' guide to EN 1997-1 Eurocode 7: Geotechnical design-General rules”, Thomas Telford.

Orr T.L.L., Eric R.F.,(2012). “Geotechnical design to Eurocode 7”, Springer Science & Business Media.

PLAXIS 2D, (2015). “Scientific Manual”.

STN E., (2004). “Eurocode 7: “Geotechnical design. Part 1: General rules, BS EN 1997-1: 2004”, Bratislava: Slovak Standards Institute, Slovak Republic.

Assessment		Percentage Marks
In-Course	Assignments/Course work	20
	Mid Semester Examination	30
End of Semester Examinations		50

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/Optional**	**: CE 6510** **: Prestressed Concrete Design** **: 2** **: None** **: Optional**

Aim(s): To impart knowledge on prestressed concrete (PC) design concepts so that the students can use this knowledge when they design/construct PC structures.

Intended Learning Outcomes:

At the end of this course, students should be able to,

1. Describe prestressed concrete design concepts.
2. Design simply supported prestressed concrete beams, composite and continuous prestressed concrete beams and prestressed concrete slabs.
3. Produce design information in the form of detailed drawings and specifications.

Time Allocation (Hours)	Lectures: 29 Tutorials: Practicals: Assignments: 02 Independent learning: 69 (Notional hours = 100)

Course Content/Course Description:

History of prestressed concrete

Use of prestress in non-concrete structures; application on concrete structures; characteristics; attributes

Prestressing systems

Pre-tensioning systems; post-tensioning systems; anchoring systems

Principles of prestrssed concrete design

Stress calculation; stress limits

SLS and ULS design

Magnel diagram; tendon profile; deflection; ULS

Composite section design

Prestress loss assessment

Short-term losses; long-term losses

Continuous beam design

Parasitic forces; concordant profile

Prestressed concrete slab design

New materials Fibre reinforced polymer

Recommended Texts

EN 1992-1-1:2004, Design of Concrete Structures – Part 1-1: General rules and rules for buildings

EN 1992-2:2005, Design of Concrete Structures – Part 2: Concrete Bridges – Design and Detailing Rules

Hurst, M.K., 1998, *Prestressed Concrete Design*, 2nd Edition, Taylor and Francis, Oxon

Lin, T.Y. and Burns, N.H., 1982, Design of Prestressed Concrete Structures – 3rd Edition, John Wiley & Sons

Mosley, B., Bungey, J. and Hulse, R., 2007, *Reinforced Concrete Design to Eurocode 2*, 7th Edition, Palgrave Macmillan

Assessment		**Percentage Marks**
In-Course	Assignments/Course work	20
	Mid Semester Examination	30
End of Semester Examinations		50

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/Optional**	**: CE 6511** **: Nonlinear Analysis of Frame Structures** **: 2** **: None** **: Optional**

Aim(s): To reinforce the knowledge on analysis of frame structures for nonlinear response incorporating the material and geometric nonlinearity.

Intended Learning Outcomes:
At the end of this course, students should be able to,
1. Explain the different approaches for modelling of frame structures for nonlinear analysis.
2. Explain different incremental iterative solution methods.
3. Analyse frame structures for static and dynamic loadings.
4. Evaluate the difference between displacement-based and force-based frame elements.

Time Allocation (Hours)	Lectures: 25 Tutorials: Practical: Assignments: 10 Independent learning: 65 (Notional hours = 100)

Course Content/Course Description:

Introduction to nonlinear frame analysis:
Failure modes observed in reinforced concrete and steel frame structures; plastic hinge development due to moment-axial interaction, shear failure of short element, large displacement induced by torsional response.

Nonlinear frame models:
Frame element with lumped plasticity; plastic hinge~~,~~
Frame element with distributed plasticity; Displacement based formulation, force based formulation,
Numerical integration; Gauss Quadrature and Gauss Lobatto, Section models,
Uni-axial material constitutive models for nonlinear hysteretic response

Incremental-Iterative solution strategies:
Load control method,
Displacement control method; Newton Raphson, Modified Newton Raphson, Krylow Newton Raphson, Arc length method;
Convergence criteria.

Analysis of nonlinear geometry:
Co-rotational formulation.

Recommended Texts
Nonlinear Finite Element Analysis of Solids and Structures, M. A. Crisfield, Wiley and Sons, 1991
Computational Inelasticity, J.C. Simo and T. J.R Hughes, Springer-Verlag, 1998.
Practical Programming in Tcl and Tk, B.B. Welch, Prentice-Hall, 2000
OpenSees Manual

Assessment		Percentage Marks
In-Course	Assignments/Course work	40
	Mid Semester Examination	-
End of Semester Examinations		60

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/Optional**	**: CE 6512** **: Forensic Investigation, Repair and Retrofitting of Structures** **: 2** **: None** **: Optional**
Aim(s): The objective of this course is to develop a sound knowledge on forensic investigation, damage assessment, repair and retrofitting of steel and concrete structures.	
Intended Learning Outcomes: At the end of this course, students should be able to; 1. Describe the failure mechanisms of structures 2. Analyse the present condition and strength of existing concrete and steel structures 3. Design repairing and retrofitting methods for damaged structures	
Time Allocation (Hours)	Lectures: 26 Tutorials: 03 Practicals: - Assignments: 02 Independent learning: 69 (Notional hours=100)

Course Content/Course Description:

Introduction:

Role of expert witness, forensic investigation, damage assessment techniques.

Failures in Civil Engineering Structures:

Technical, structural and non-structural failures. Natural hazards and unusual loads: effects on the built environment.

Failure Mechanisms and Guidelines:

Failure mechanisms in concrete and steel elements and structures. Guidelines for Failure Investigation.

Forensic Investigation and Damage Assessment:

Investigation of damaged or failed structures, assessment of damage, case studies.

Strength Evaluation of Existing Concrete and Steel Structures:

Preliminary investigation (review of existing information and condition survey and evaluation). Assessment of loading conditions and selection of evaluation method.

Methods for Assessing Properties of Concrete and Steel:

Visual inspection. Detailed investigation: Stress-wave propagation methods, Infrared thermography, Ground-penetrating radar (GPR), Electrical and magnetic methods for reinforcement, Surface hardness test and coring for concrete, tensile, impact and hardness testing for steel, microstructure and crack investigation of steel, corrosion, fatigue testing.

Repair of Concrete and Steel Elements:

Causes, control and evaluation of cracking of concrete, methods of crack repair. Fatigue assessments, evaluation of crack initiation and propagation of steel, repair methods.

Strengthening and Stabilization of Concrete and Steel Structures:

Techniques consideration, beam shear capacity strengthening, shear transfer strengthening, stress reduction techniques, column strengthening, flexural strengthening, connection stabilization and strengthening, design and construction of externally bonded FRP systems.

Recommended Texts

Robert, T. R., (2010), "Forensic Structural Engineering Handbook", 2nd Edition, McGraw-Hill.
Henry, P., (1994), "Design Paradigms: Case Histories of Error and Judgment in Engineering", Cambridge University Press.

Assessment		Percentage Marks
In-Course	Assignments/Course work (take home)	50
End of Semester Examinations		50

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/Optional**	**: CE 6513** **: Numerical Methods for Civil Engineers** **: 2** **: -** **: Optional**

Aim(s): To introduce numerical methods for solving mathematical models of Civil Engineering problems.

Intended Learning Outcomes:

On successful completion of the course, the students should be able to;

1. Explain numerical methods for solving simultaneous equations, finding roots of equations, interpolation and curve fitting.
2. Apply numerical methods for solving ordinary and partial differential equations.
3. Develop suitable algorithms for solving partial differential equations.

Time Allocation (Hours):	Lectures: 26 Tutorials: 02 Practicals: Assignments: 04 Independent learning: 68 (Notional hours=100)

Course content/Course description:

- **Solutions to nonlinear equations:** bisection method; method of false position; fixed-point iteration; Newton-Raphson's method; secant method.
- **Numerical solutions to systems of linear equations:**
  Gaussian elimination; Jacobi method; Gauss Seidel method
- **Interpolation:** Linear interpolation; Newton interpolation; Lagrange interpolation; Spline interpolation.
- **Approximation and curve fitting:** Linear regression; polynomial regression;
- **Numerical solutions to ordinary differential equations:**
  Initial value problems: Eular method, Runge-Kutta methods;
  Boundary value problem: Finite difference method
- **Numerical solutions for partial differential equations:**
  Finite difference method: Elliptic equations:1D and multi-dimensional problems; parabolic problems;
  Integral Equation Methods: Collocation method, Galerkin method and Weighted Residual method ; Numerical Quadrature: Gaussian Quadrature.

Recommended Texts :

C. Chapra and R.P.Canale, (2000). *Numerical Methods for Engineers*, 5th edition, McGraw-Hill.

Assessment		**Percentage Mark**
In-course	Tutorials/Quizzes	40
End of Semester Examinations		60

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/Optional**	**: CE 6514** **: Design of High-Rise Buildings** **: 2** **: Structural Dynamics** **: Optional**

Aim(s): To train graduate students with advanced knowledge of multi-disciplinary aspects on modelling, analysis, design and construction of High-Rise buildings.

Intended Learning Outcomes:

At the end of this course, students should be able to;

1. Explain the basic structural configurations for vertical and lateral load resistance system of high-rise buildings
2. Describe building services and design philosophy for high-rise buildings
3. Evaluate the behaviour of high-rise buildings against wind and earthquake loadings
4. Analyse and design structural systems of high-rise buildings

Time Allocation (Hours)	Lectures: 24 Tutorials: - Practical: - Assignments: 12 Independent learning: 64 (Notional hours =100)

Course Content/Course Description:

Introduction to High-Rise Building:
What is "High-Rise building"?, Different High-Rise building systems, Function of service core, Required professional skills, Special consideration of High-Rise building design

Design Process and Philosophy:
Structural design considerations, Overall design process, Structure design process, Design philosophy and process, Proportioning for safety, Philosophies in current use, From serviceability to performance

Building Systems:
Knowledge model for system selection, Determining system suitability, Evaluating system suitability, Assigning suitability values, Selection of structural system, Typical characteristics of residential buildings and commercial buildings, The building structural system (physical and conceptual)

Structural Load Resisting Systems:
Vertical load resisting systems, Lateral Load Resisting Systems, Selection of Lateral Load Resisting Systems

Performance based Concept for High-Rise Buildings:
Performance based design of new High-Rise buildings, Performance based evaluation of existing High-Rise buildings

Modeling, Analysis and Design for Lateral Loads:
Computer modeling for accurate analysis (SAP 2000), Analysis and design of shear walls, Analysis and design of transfer girders and deep beams, Analysis and design of High-Rise building for wind loading, Analysis and design of High-Rise building for seismic loading

Recommended Texts

Smith, B. S. and Coull, A. 1991, *Tall building structures*, John Wiley (or any new edition).

Assessment		**Percentage Marks**
In-Course	Mini project:	40
End of Semester Examinations		60

Course Code **Course Title** **No. of Credits** **Pre-requisites** **Compulsory/Optional**	**: CE 6515** **: Bridge Engineering** **: 2** **: Design of reinforced concrete structures** **: Optional**

Aim(s): To improve the professional exposure towards Bridge Engineering aspects.

Intended Learning Outcomes:

At the end of this course, students should be able to;

1. Explain different structural configurations of bridges and select suitable bridge type for a given project by reviewing techno economic feasibilities of different alternatives.
2. Analyse the bridge decks for code defined traffic and other loadings.
3. Design substructure elements, superstructure elements bearings and expansion joints.
4. Evaluate the performance of existing bridges through monitoring practices and suggest appropriate maintenance, repair and rehabilitation schemes.

Time Allocation (Hours)	Lectures: 27 Tutorials: Practicals: Assignments:06 Independent learning: 67 (Notional hours =100)

Course Content/Course Description:

Design considerations

Economical consideration; site selection; aesthetics; geotechnical investigations; hydrological and hydraulic considerations; safety considerations

Alternative structural configurations and systems

Use of different materials, Constructability, Modern concepts, FEM applications, Construction methods

Bridge deck loading and analysis

Guidelines and Codes of Practices in highway and railway bridge design including Sri Lankan practices

Design of superstructure:

Reinforced concrete bridges; Pre-stressed concrete bridges: Steel bridges; Steel-concrete composite bridges

Design exercise is based on a selected bridge type

Design of substructure:

Abutments; piers; piles and other foundations

Design of bearings and joints

Design of Elastomeric bearing, Bridge expansion joints

Dynamic Analysis of Bridges

Structural dynamics for bridges, seismic effects, wind effects

Maintenance of bridges:

Scheme of inspection; identification of defects and repair methods

Recommended Texts

RDA Bridge Design Manual

Essentials of Bridge Engineering, 4^{th} Ed, D.J. Victor, Oxford & IBH Publishing, 1973

Bridge Engineering, S. Ponnuswamy, Tata McGraw-Hill Publishing, 1986

Bridge & Structure Estimating, J.D.Nardon, McGraw-Hill Publishing, 1995

Eurocode specifications: EN 1990 – EN 1994, EN 1997

Assessment		**Percentage Marks**
In-Course	Assignments/Course work	40
End of Semester Examinations		60

Course Code	: CE 6103
Course Title	: Advanced Study
No. of Credits	: 5
Pre-requisites	: None
Compulsory/Optional	: Compulsory

Aim(s): To train the students to carry out literature review, identify a knowledge gap/complex engineering problem, formulate a methodology, execute the methodology and present the findings.

Intended Learning Outcomes:

On successful completion of the course, the student should be able to;

1. search for technical literature, formulate a research problem based on the identified knowledge gap/complex engineering problem and develop appropriate methodology.
2. carry out a comprehensive analysis to solve the identified research problem/complex engineering problem.
3. write the report and present the research findings/solution to the complex engineering problem in a precise and coherent manner.

Time Allocation (Hours)	Notional hours = 500

Course Content/Course Description:

Self-studies:

Search of technical literature, identify the knowledge gap/complex engineering problem, formulate aim, objectives and scope, develop a methodology, collect data, comprehensive analysis of the research problem/complex engineering problem and present the findings in the form of presentations and a report.

Meetings with supervisor:

Conduct progress meetings with the supervisor, discuss the progress, and receive feedback from the supervisor for the presentation and report.

Recommended Texts

Geoffrey R.M., David D., David F., (2005). "Essentials of Research Design and Methodology", John Wiley & Sons.

Creswell J. W., David J. C., (2017). "Research Design: Qualitative, Quantitative, and Mixed Methods", John SAGE Publications.

Assessment	**Percentage Mark**
In-Course **Progress evaluations:** **Four progress evaluations:** Progress evaluation 1: Oral presentation 1 Progress evaluation 2: Oral presentation 2 Progress evaluation 3: Oral presentation 3 Progress evaluation 4: Oral presentation 4 (After submission of detailed proposal)	40
Detailed Proposal: Detailed Proposal (after three progress presentations) defended before continuing with the advanced study	10
Final Evaluation:	
Final report	30
Presentation	20