M.Sc. GRADUATE PROGRAM

Graduate students must take 15-18 credits from compulsory courses, 6-9 credits from elective courses, 2 credits from seminar and 6 credits from thesis, overall 32 credits to receive M.Sc. degree.

Curriculum for the Degree of Master of Science in Civil Engineering, Major *Structural Engineering*

Semester I		
1610500	Engineering Mathematics	3
1612525	Theory of Elasticity	3
Semester II		
1612527	Dynamics of Structures	3
1612529	Finite Element Method	3
Elective Courses		
1612528	Theory of Plates and Shells	3
1612530	Stability of Structures	3
1612531	Pre-stressed Concrete	3
1612532	Design of Bridge	3
1612534	Advanced Steel Structures	3
1612537	Advanced Concrete	3
1612538	Plastics Analysis & Design of Structures	3
1612540	Reliability of Structures	3
1612603	Risk Analysis of Structures	3
1612605	Seismic Rehabilitation of Existing Buildings	3
1612612	Seismic Design of Structures	3
6612612	Seismic Design of Steel Structures	3
1612618	Strengthening Reinforced Concrete Structures	3
1612704	Advanced Concrete Technology	3
1612714	Fracture Mechanics	3
1612715	Optimization in Civil Engineering	3
1612717	Mechanics of Composite Materials	3
Semester III		
9010503	Seminar	2
9010606	M.Sc. Project	6
Semester IV		
9010606	M.Sc. Project (Continue)	0

Ph.D. GRADUATE PROGRAM

The complete Ph.D. program consists of 15 credits of coursework and 21 credits of thesis. Students must pass the written and oral comprehensive exam after completion of courses.

Curriculum for the Degree of Doctor of Philosophy in Civil Engineering, Major *Civil Engineering,* Minor *Structural Engineering*

The complete Ph.D. program consists of 15 credits of coursework and 21 credits of thesis.

A - Courses: (15 Units)

1610502	Continuum Mechanics	3
1612530	Stability of Structures	3
1612600	Earthquake Engineering	3
1612604	Random Vibration	3
1612702	Finite Element Method II	3
1612706	Advanced Reinforced Concrete Structures	3
1612708	Theory of Shells	3
1612710	Computational Plasticity	3
1612712	Theory of Boundary Elements	3
1612715	Optimization in Civil Engineering	3

At least 5 of the above courses must be taken.

B - The Ph.D. students must pass the written and oral comprehensive exam after completion of their coursework.

C – Thesis (21 Units)

9010724	Thesis	6
9010724	Thesis	6
9010724	Thesis	6
9010724	Thesis	3

COURSE DESCRIPTIONS

1610500 Engineering Mathematics
3 Cr.
Review on Basic Mathematics, Ordinary Differential Equations, Special Functions, Calculus of Variations, Vectors and Matrices Algebra, Fourier Analysis, Partial Differential Equations, Complex Analysis.

1610502 Continuum Mechanics
3 Cr.
Cartesian Tensors and differential operators on vectors, Stress analysis, Motion and deformation, Conservation laws and constitutive equation, Energy methods, Fluid mechanics, Wave propagation.

1612525 Theory of Elasticity
3 Cr.
Theory of Stress: Definition of Stress, Principal Stresses ,Mean and Deviator Stress Tensors, Differential Equation of Motion, Theory of Strain: Displacement, Rigid Body Motion, Pure Deformation, Gradient of the Displacement Vector, Principal Stresses, Strain Tensor in terms of Displacement Components, Constitutional Equations: Strain Energy, Generalized Hook"s Law, Isotropic Materials, Orthotropic Materials, Three Dimensional Equations of Elasticity: Equations of Elasticity in terms of Displacements(Navier Equations), Compatibility Equations in terms of Stresses(Michell Equations), Two-Dimensional Equations of Elasticity: Plane Strain Problems, Plane Stress Problems, Method of Solution of 2-D Problems, Two Dimensional Problems in Polar Coordinates, Special Problems: Torsion of Noncircular Prismatic Bars (Elliptic Section, Rectangular Section, Triangular Section)

1612527 Dynamics of Structures
3 Cr.
Single Degree-of-Freedom Systems: Equations of Motion: System Properties: Mass, Spring, Damper, Force - Displacement Relation, Force -Velocity Relation, Force - Acceleration Relation, Force Excitation, Earthquake Excitation, Solution of Differential Equation : Free Vibration: Un-damped Systems, Damped Systems, Forced Vibration: Un-damped Systems, Damped Systems, Response to Harmonic and Periodic Excitations, Response to Arbitrary, Step and Pulse Excitations, Numerical Evaluation of Dynamic Response: Time Stepping Methods, Newmarks Method, Generalized Single-Degree-of-Freedom Systems: Rigid Body Assemblage , Systems with Distributed Mass and Elasticity, Lumped Mass System: Shear Building, Multi Degree of Freedom Systems: Planar or Symmetric Plan Systems, Asymmetric Plan Buildings, Dynamic Analysis and Response to Linear Systems, Modal Analysis, Introduction to Nonlinear Systems

1612528 Theory of Plates and Shells
3 Cr.
Introduction, Elements of Plates Bending Theory, Circular Plates, Rectangular Plates, Plates of Various Geometrical Forms, Plate Bending by Numerical Methods: Energy Methods, Finite Differences, Finite Elements, Finite Strips, Stability of Plates

1612529 Finite Element Method
3 Cr.
Introduction to the Use of Finite Elements: Physical Problems and Mathematical Models, Formulation: Mathematical Fundamentals, Weighted Residual Approximations, Weak Formulation and Galerkin Method, Approximation in Solution of Differential Equations , Approximate Solution to Systems of Differential Equations, Differential Equations in Engineering Problems (Solid Mechanics, Heat Conduction), Virtual Work for Solid Problems, Variational Principles in FE Formulation, Continuity Requirements, Piecewise Trial Functions, The Concepts of Element and Shape-Function: One Dimensional Lagrange Shape-Functions (Linear and Higher Order Elements), Hermite Polynomials for Shape-Functions with Higher Continuity, Two Dimensional Quadrilateral Elements with Lagrange Polynomials, The Concept of Mapping, Iso-Parametric, Sub-Parametric and Super-Parametric 2D/3D Elements, Triangular and Tetrahedral Elements, Numerical Integration, Plate Formulation and Elements, Axisymmetric Solid/Shell Problems and the Associated Elements .

1612530 Stability of Structures
3 Cr.
Introduction: What is buckling?, Importance of Buckling Load, Historical Review, Buckling and Post Buckling of Bars with Finite Degrees of Freedom, Buckling and Post Buckling of Columns, Buckling of Beams Columns, Inelastic Buckling of Plates, Slope Deflection and Moment Distribution Methods for Buckling Analysis of Frame, Finite Element Method for Frame Buckling, Exact Finite Element Method for Frame Buckling, Lateral Torsional Buckling of Beams, Local and Post Local Buckling of Plates, Finite Element Method for Plate Buckling, Finite Strip Method for Plate Buckling

1612531 Pre-stressed Concrete
3 Cr.
Principle and Methods of Pre-stressing, Pre-stressing Materials, Flexure: working stress analysis and design, Flexure: Ultimate strength analysis and design, Design for shear and Torsion, Computation of Pre-stress Losses, Deflection Computation, Analysis and design of composite beams, Continuous Beams

1612532 Design of Bridge
3 Cr.
Criteria for Bridge Design, Highway Bridges Loading, Design Traffic Lanes, Live loads on Highway Bridges, Impact on Highway Bridges, Longitudinal Forces on Highway Bridges, Centrifugal Force on Highway Bridges, Sidewalk Loading, Wind Loading, Thermal Forces on Highway Bridges, Uplift on Highway Bridges, Forces of stream Current, and Ice on Highway Bridges, Earth Pressure on Highway Bridges, Earthquake Pressure on Highway Bridges, Loading Combinations on Highway Bridges, Load-Factor Design Loadings, Influence Lines and Design Forces, Design of Bridge Decks, Design of Reinforced Concrete Decks, Design of Precast Concrete Decks, Design of Pre-stressed/Post-tensioned Concrete Decks, Design of Composite I-Girder Decks, Design of Composite Box-Girder Decks, Design of Orthotropic-Plate Girder Decks, Design of Elastomeric Supports, Design of Abutments and Piers , Bridge Project

1612534 Advanced Steel Structures
3 Cr.
Stability of Columns, Stability of Frames, Torsional Analysis and Design of I Beams, Lateral – Torsional Buckling of Beams, Moment Magnification Factors in Beam – Columns, Plastic Analysis and Design of Continuous Beams, Design of Composite Beams

1612537 Advanced Concrete
3 Cr.
Constitutive Laws of Reinforced Concrete Materials, Analysis and Design of Concrete Tanks and Reservoirs , Analysis and Design of Concrete Silos and Bunkers , Analysis and Design of Concrete Shells, Ductility in Reinforced Concrete Structures

1612538 Plastic Analysis and Design of Structures
3 Cr.
Basic concept, plastic bending, ultimate loads of beams and frames, plastic design of beams and columns, beam-columns, deflections.

1612540 Reliability of Structures
3 Cr.
Events, probability of events, probability of failure of determinate structures, faults & probability of failure of indeterminate structures, application of normal & lognormal and extreme value probability laws for the calculation of safety of structures.

1612600 Earthquake Engineering
3 Cr.
Earthquake Ground Motion, Seismic Behavior of Structures, Ductility and Modeling of Load Bearing Systems, Elastic and Inelastic Earthquake Analyses of Structures, Introduction to Performance Based Design, Structural Control, Soil-Structure Interaction.

1612603 Risk Analysis of Structures
3 Cr.
An introduction to engineering statistics and probabilities, A review of earthquake and seismology, A survey of seismic properties in Iran, Analytic and probabilistic risk assessment of earthquake, Design spectrum, Risk analysis of structures: Damage criteria, Analytical and experimental methods of damage estimation, Damage analysis using fragility curve; Engineering decision making: Estimated annual damage costs, Life cycle analysis.

1612605 Seismic Rehabilitation of Existing Buildings
3 Cr.
Concepts of seismic rehabilitation, Understanding the status quo, Building modeling, Earthquake structural analysis, Seismic evaluation and retrofitting.

1612612 Seismic Design of Structures
3 Cr.

6612612 Seismic Design of Steel Structures
3 Cr.
Introduction to seismic behavior of structures, Earthquakes and related issues, Determination of earthquake forces, Plastic behavior of steel structures and ductility concepts, Lateral displacement of structures, Seismic design of diaphragm, Capacity design, Seismic design of moment frames (OMF, IMF and SMF), Design of laterally braced frames (CBF, EBF and BRBF) and Steel plate shear wall.

1612618 Strengthening Reinforced Concrete Structures
3 Cr.
Introduction to engineering concepts of strengthening and rehabilitation, strengthening methods, steel and concrete jackets, strengthening with FRP composites, materials characteristics and constitutive laws, time dependent materials properties, durability of strengthening materials, repair and maintenance, flexural strengthening, flexural failure modes in strengthened beam, effects of existing loads on flexurally strengthened beam, flexural strengthening design, shear strengthening and its types, shear strengthening design, types of torsional strengthening, torsional strengthening design, column strengthening, column confinement with strengthening, confinement effects on column behavior, types of column strengthening, models for ductility and strength enhancement in strengthened column, strengthening design of column in compression, strengthening design of column in compression and flexure, bond between strengthening system and structural members, performance evaluation of strengthened system, seismic strengthening in flexure and shear, seismic strengthening of beam-column joints. seismic strengthening of shear walls.

1612702 Finite Element Method II
3 Cr.
Introduction to Nonlinear Analysis, Kinematics of the Body, The basic problem, the deformation gradient, strain and stress tensors, Total Lagrangian, updated Lagrangian formulation, Eulerian formulation, Displacement – based finite elements, Linearization of the principal of virtual work with respect to finite element variables, Truss and cable elements, Two dimensional plane stress and plane strain problems, Axisymmetric problems, Three – Dimensional solid elements, Structural elements, Beam element, Axisymmetric shell element, Plate and general shell element, Solution of nonlinear equations, Tangent and secant method, Iteration, Newton – Raphson, Arc- length method

1612704 Advanced Concrete Technology
3 Cr.
Cement hydration, Strength of concrete, Time-dependent deformation in concrete, Additives in concrete, Concrete rheology, Concrete durability, Assessment of structural concrete, New types of concrete, Massive concrete issues

1612706 Advanced Reinforced Concrete Structures
3 Cr.

1612708 Theory of Shells
3 Cr.
Shell geometry, Reference coordinate system, Shell curvature, Kinematics of shells, Strain relations, Constitutive equations, Love assumptions, Shear deformable shells, Stress resultants, Boundary conditions, Membrane and bending behavior, Popular shell geometries (Cylindrical, Spherical, Conical, Elliptic-Parabolic, etc.), Loading of shells, Axisymmetric shells, Buckling, Vibration, Shallow shells, Composite shells, Finite Element and generalized Methods for the analysis of shell structures,

1612710 Computational Plasticity
3 Cr.
An Overview of Plasticity Theory: Mathematical Fundamentals, The Physics of Plasticity (Metals, Soils, Rocks, Concrete), Highlights of Continuum Mechanics, Yield Criteria, Flow Rules and Hardening Rules, Drucker's Stability Postulate, Maximum-Dissipation Postulate, Normality and Uniqueness, Incremental Stress-Strain Relations Using Stress-Space and Strain-Space, Hardening Models, Computational Techniques: Finite-Element Formulation for Nonlinear Problems, Numerical Algorithms for Solving Nonlinear Problems (Time Marching Algorithms), Elastic-Plastic Operator Split (Elastic Predictor and Plastic Corrector), Return Mapping Algorithms, Cutting Plane and Closest Point (and Linearization), Return Mapping Algorithm for J2 Plasticity with Mixed Isotropic/Kinematic Hardening (and Linearization), Return Mapping Algorithm for General Plasticity Models with General Linear/Non-Linear Mixed Hardening Involving Linear/Non-Linear Elastic Behavior (and Linearization), Multi-Surface Plasticity (Non-Smooth Surfaces), Return Mapping Algorithm for Problems with Non-Smooth Yield Surfaces (and Linearization), Mixed Formulations in the Finite Element Method (Problems with Incompressible Material), Formulation in Elasto-Plasticity Problems with Yield Surface Independent of the Mean Stress, The B-bar Method, Highlights of Visco-Plasticity and Implementation in the Finite Element Method

1612714 Fracture Mechanics

3 Cr.

This course discusses the principals of fracture as a vital criteria in design of probably defected solids and structures, for which the presence of cracks or notches may cause severe reduction in the strength of the structure, while the usual strength-based design codes do not completely consider such effects. The most important topics presented during the course include, but are not limited to: Importance of Fracture Mechanics, Linear Elastic Fracture Mechanics (LEFM), Stress Intensity Factor (SIF), Elasto-Plastic Fracture Mechanics (EPFM), Brittle and Cohesive crack propagation, Crack Tip Opening Displacement (CTOD), Numerical Fracture Mechanics in 2D and 3D Problems, eXtended Finite Element Method (XFEM), Rock and Concrete Fracture, smeared crack models, Fatigue Crack Growth.

1612715 Optimization in Civil Engineering

3 Cr.

Introduction to numerical optimization in civil engineering, Fundamentals of numerical optimization, Classical (analytical) methods in numerical optimization, Linear and non-linear programming, Un-constrained and constrained optimization, Structural optimization: Trusses, Steel and concrete frames.

1612717 Mechanics of Composite Materials

3 Cr.

Introduction to Composite Materials; Macromechanical Analysis of a Lamina: Hooke's Law for Different Types of Materials/Hooke's Law for a Two-Dimensional Unidirectional and Angle Lamina/Strength Failure Theories of an Angle Lamina/Hygrothermal Stresses and Strains in a Lamina; Micromechanical Analysis of a Lamina; Macromechanical Analysis of Laminates; Failure, Analysis, and Design of Laminates; Bending, Buckling and Vibration Analysis of Laminated Beams and Plates.