MLRS-R24

OBE Hand Book

Department of Civil Engineering

MARRI LAXMAN REDDY INSTITUTE OF TECHNOLOGY AND MANAGEMENT

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OVERVIEW

Outcome Based Education (OBE) is the foundation of quality assurance in higher technical education, especially in postgraduate programmes like M.Tech.
Unlike traditional models that focus on syllabus completion, OBE emphasizes what students are able to do at the end of the programme.

Key Focus of OBE

- Clearly defined and measurable learning outcomes
- Alignment of teaching–learning activities with outcomes
- Continuous assessment and feedback
- Student-centric and competency-driven education

Role of Faculty in OBE

Faculty members function as:

- **Instructors** – delivering core concepts
- **Facilitators** – guiding active learning
- **Trainers** – developing professional and technical skills
- **Mentors** – supporting academic and research growth

OBE Framework – Levels of Outcomes

The OBE system is structured across four key levels:

1. Vision and Mission
2. Programme Educational Objectives (PEOs)
3. Programme Outcomes (POs)
4. Course Outcomes (COs)

These outcomes ensure graduates develop:

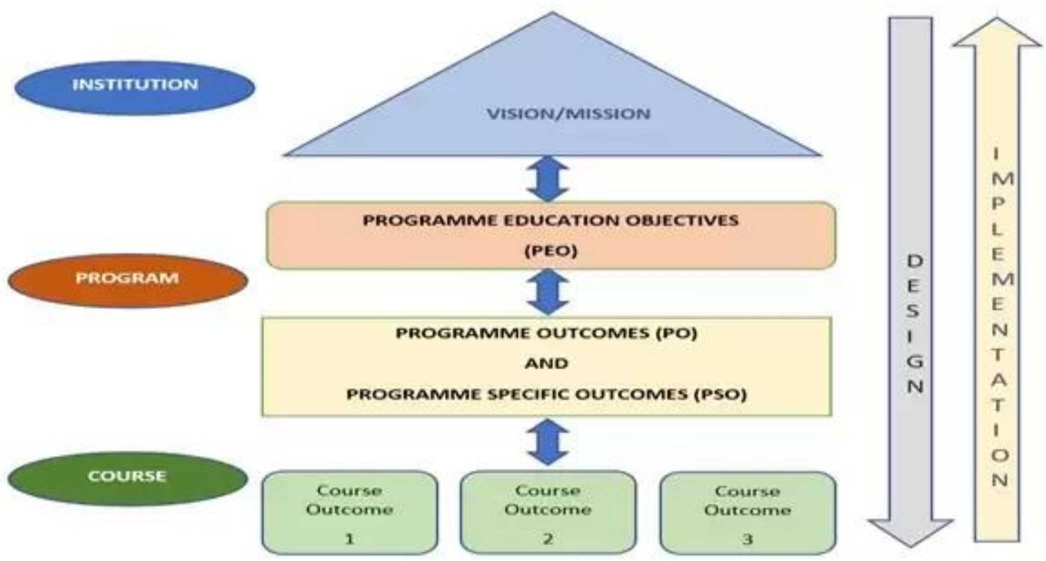
- Advanced technical expertise
- Research and innovation capability
- Professional ethics and social responsibility
- Lifelong learning skills

Why OBE for M.Tech Programmes?

- Facilitates international recognition of qualifications
- Enhances global employability and mobility
- Produces highly skilled and research-oriented graduates
- Strengthens industry relevance and leadership potential
- Improves institutional reputation and accreditation readiness
- Encourages stakeholder participation (students, faculty, alumni, industry)

Key Features of Outcome Based Education

- Transparent and measurable learning achievement
- Improved student engagement and ownership of learning
- Strong linkage between curriculum, assessment, and outcomes
- Continuous improvement through feedback and analysis
- Alignment with global engineering standards



About NBA Accreditation

The concept of OBE gained global recognition through international accreditation frameworks such as the Washington Accord (1989), which emphasized that engineering education should be outcome-oriented rather than input-oriented. The Accord established equivalence of accredited engineering programmes among signatory countries based on the achievement of outcomes and graduate attributes rather than traditional curriculum content or duration.

India became a permanent signatory to the Washington Accord in 2014 through the National Board of Accreditation (NBA). This marked a major shift in India's higher education evaluation system—from a system based on syllabus and content coverage to one that measures the attainment of Course Outcomes (COs), Programme Outcomes (POs), and Programme Educational Objectives (PEOs).

The NBA accreditation framework has undergone several refinements to improve the quality and global recognition of technical education:

- **2013:** Introduction of the first comprehensive OBE-based accreditation format aligned with Washington Accord graduate attributes.
- **2017:** Inclusion of CO–PO mapping, assessment tools, and continuous improvement metrics.
- **2021:** Integration of digital evidence, innovation, entrepreneurship, and sustainability indicators into the Self-Assessment Report (SAR).
- **2024:** Launch of Graduate Attributes and Professional Competencies, emphasizing knowledge attributes (K1–K6 levels), skills, and attitudes in accordance with international educational standards.

Benefits of Outcome-Based Education

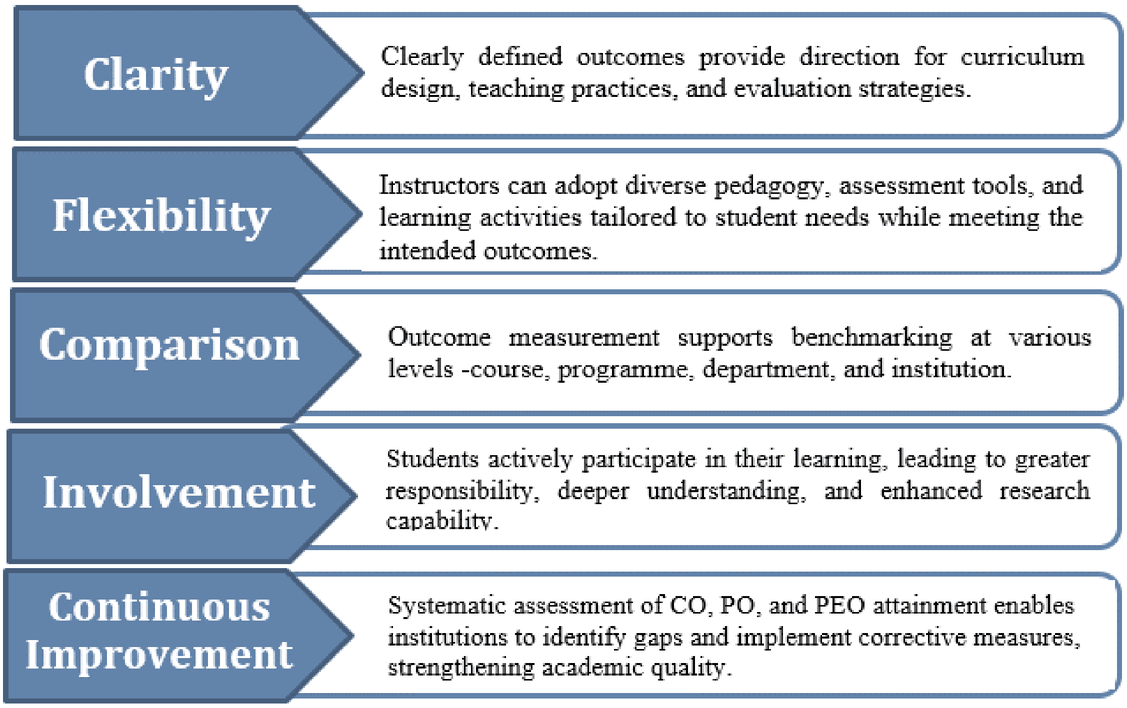


Figure 2: Benefits of Outcome Based Education

VISION OF THE INSTITUTE

To be a globally recognized institution that fosters innovation, excellence, and leadership in education, research, and technology development, empowering students to create sustainable solutions for the advancement of society.

MISSION OF THE INSTITUTE

- To foster a transformative learning environment that empowers students to excel in engineering, innovation, and leadership.
- To produce skilled, ethical, and socially responsible engineers who contribute to sustainable technological advancements and address global challenges.
- To shape future leaders through cutting-edge research, industry collaboration, and community engagement.

QUALITY POLICY

- Ensure excellence in education through innovative teaching and continuous improvement.
- Promote ethical, skilled, and employable graduates who drive sustainable technologies.
- Encourage research, industry collaboration, and community engagement for societal benefit.

PHILOSOPHY

At Marri Laxman Reddy Institute of Technology and Management, we believe that the true essence of meaningful education lies in the pursuit of truth—one that removes ignorance and empowers individuals. Education is viewed not merely as the transfer of knowledge, but as a powerful instrument for liberation, empowerment, and societal transformation.

Holistic Development Approach

- The Institute emphasizes:
- promoting scientific inquiry, technological innovation, and academic excellence aligned with societal and environmental needs.
- Rigorous research and advanced technical learning
- Development of professional competence with strong ethical values
- Harmony between technological growth, nature, and society
- Collaboration with local communities
- Active global engagement for socially relevant education
- Nurturing well-rounded, ethically grounded, and socially conscious professionals
- Preparing graduates for meaningful contributions to industry, academia, and society

CORE VALUES

Excellence:
All activities are conducted according to the highest international standards.

Integrity:
Adheres to the principles of honesty, trust worthiness, reliability, transparency and accountability.

Inclusiveness:
To show respect for ethics, cultural and religious diversity, and freedom of thought.

Social Responsibility:
Promotes community engagement, environmental sustainability, and global citizenship. It also promotes awareness of, and support for, the needs and challenges of the local and global communities.

Innovation:
Supports creative activities that approach challenges and issues from multiple perspectives in order to find solutions and advance knowledge.

OBE IMPLEMENTATION FRAMEWORK

Vision and Mission Statements
The Vision and Mission of the Institute and each Department are defined and reviewed to ensure alignment with institutional goals and societal needs.

Program Educational Objectives (PEOs)
PEOs describe the career and professional achievements that graduates are expected to attain a few years after completing the program.

Program Outcomes (POs)
POs represent the graduate attributes as defined by the NBA, while PSOs represent the discipline specific skills that students acquire during the program.

Identify Knowledge and Attitude Profiles (WKs)
The required knowledge, skills, and attitudes are mapped as per international engineering education standards.

Engineering Competencies (ECs)
Engineering competencies are identified based on the ability to solve complex engineering problems and perform complex engineering activities.

Course Outcomes (COs)
Each course specifies well-defined and measurable Course Outcomes, written using Bloom's Taxonomy action verbs to indicate the level of learning (Remember, Understand, Apply, Analyze, Evaluate, Create).

Map Courses with POs and PSOs
Each course outcome (CO) is mapped to relevant program outcomes (POs) and program-specific outcomes (PSOs) to ensure alignment.

Map Topics with Course Outcomes
Every topic or module within a course is linked to one or more COs for structured delivery and assessment.

Prepare Course Lesson Plan and Schedule of Instruction
Lecture-wise lesson plans are prepared indicating learning objectives, teaching pedagogies, and assessment components.

Pedagogical Tools
Appropriate pedagogical tools are chosen for effective delivery of course outcomes such as case studies, group discussions, flipped classrooms, and problem-based learning

Define Self-Learning and Team Work Activities
Activities like tutorials, practical sessions, seminars, projects, and assignments are designed to enhance self-learning and practical understanding.

Use of Learning Management System (LMS)
The Anvaya and Akshara Learning Management Portal is used for complete course management, including lesson plans, assessments, and feedback.

Assessment and Attainment Analysis
The OBE module in Anvaya is used to measure the attainment of each Course Outcome (CO) through both direct and indirect assessments.

Performance Tracking and Continuous Improvement
Student performance is tracked continuously, and results are analyzed to identify strengths and areas for improvement.

Curriculum Gap Analysis
Gaps between curriculum outcomes and industry requirements are identified and bridged through additional learning modules, workshops, and expert lectures.

Program Outcome Attainment Review
PO and PSO attainment levels are compared for the past three academic years. Remedial actions are proposed and implemented based on the analysis.

Program Educational Objectives (PEO) Assessment
PEO attainment is assessed periodically using alumni feedback, employer surveys, and higher studies/placement data.

VISION OF THE DEPARTMENT

To empower students to be skilled, competitive and dedicated Civil Engineers by imparting advanced technical knowledge and ethical values, equipping them to play a key role in the planning and execution of the nation's infrastructure and development activities.

MISSION OF THE DEPARTMENT

M1: Provide quality education in civil engineering through a combination of excellent teaching, advanced facilities, and continuous mentorship.
M2: Produce civil engineering graduates who demonstrate strong skills and expertise.
M3: Encourage professional development to address complex technical challenges and engage in innovation with creativity, leadership, ethics, and social awareness.

PROGRAM EDUCATIONAL OBJECTIVES

Program Educational Objectives (PEOs) are defined by the Head of the Department in consultation with various stakeholders such as industry experts, employers, alumni, and students. PEOs represent the department's commitment to prospective students, outlining what graduates are expected to achieve few years after completing the program.

PEO1: Equip for success in the engineering domain through a strong foundation in structural engineering and advanced design skills.

PEO2: Foster industrial awareness and a research-oriented mindset by engaging with emerging trends and technologies in structural engineering.

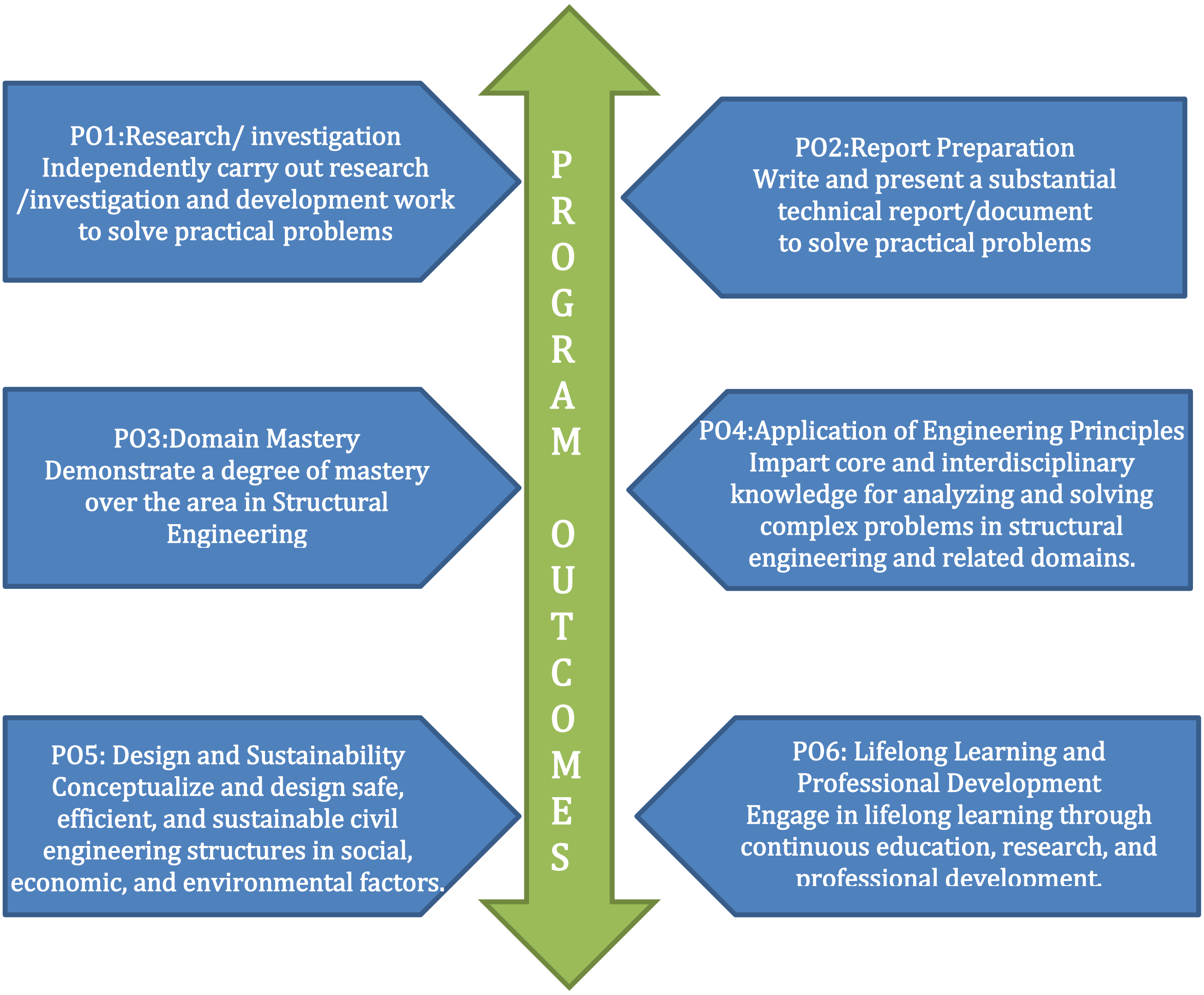
PEO3: Prepare for successful employment by developing professional ethics and critical thinking to address evolving societal needs.

PEO4: Develop leadership qualities to excel in professional and societal environments, contributing responsibly and ethically.

PROGRAM OUTCOMES

Program Outcome (PO) is broad in scope and describes what a student is expected to achieve at the end of the program. Program Outcomes (POs) should be specific, measurable, and achievable.

Out of the six POs, three are defined by the NBA and are common to all institutions in India, remaining three are program-specific, framed by the department to reflect specialization in Structural Engineering. For Postgraduate Programs POs descriptions are generally aligned with national standards



NBA-Defined Common POs

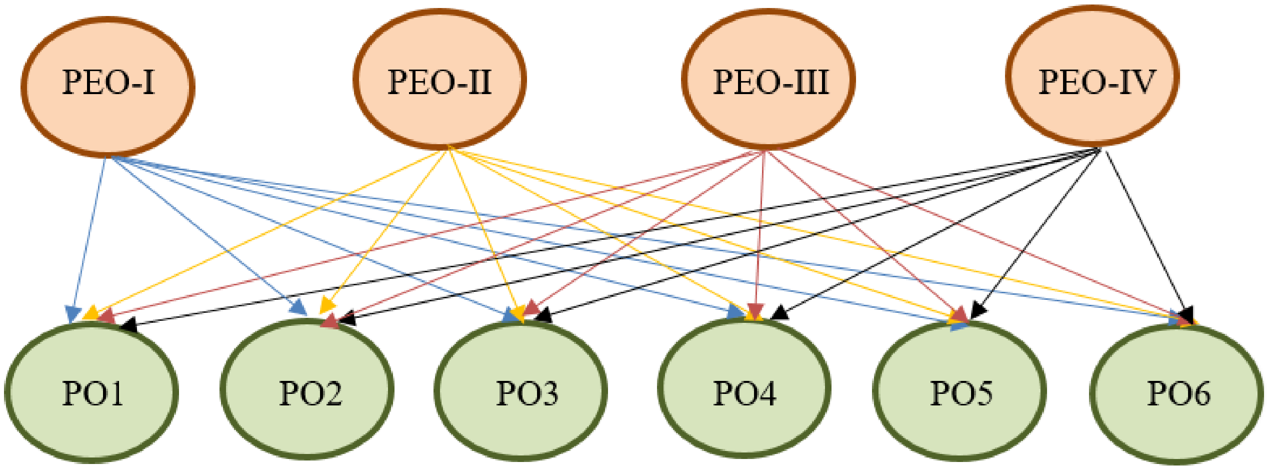
1. Research/ investigation
2. Report Preparation
3. Domain Mastery

Department Defined Program Outcomes

4. Application of Engineering Principles
5. Design and Sustainability
6. Lifelong Learning and Professional Development

RELATION BETWEEN PEOs AND POs

The relationship between Program Educational Objectives (PEOs) and Program Outcomes (POs) is essential, as it ensures that the long-term goals of the program are systematically aligned with measurable outcomes attained by students during the course of study. Establishing this alignment helps the department verify that the curriculum, teaching–learning processes, assessments, and continuous improvement practices are effectively preparing graduates for professional careers, higher education, lifelong learning, and societal contribution. The broad correlation between the PEOs and POs is presented in Figure 4**.**



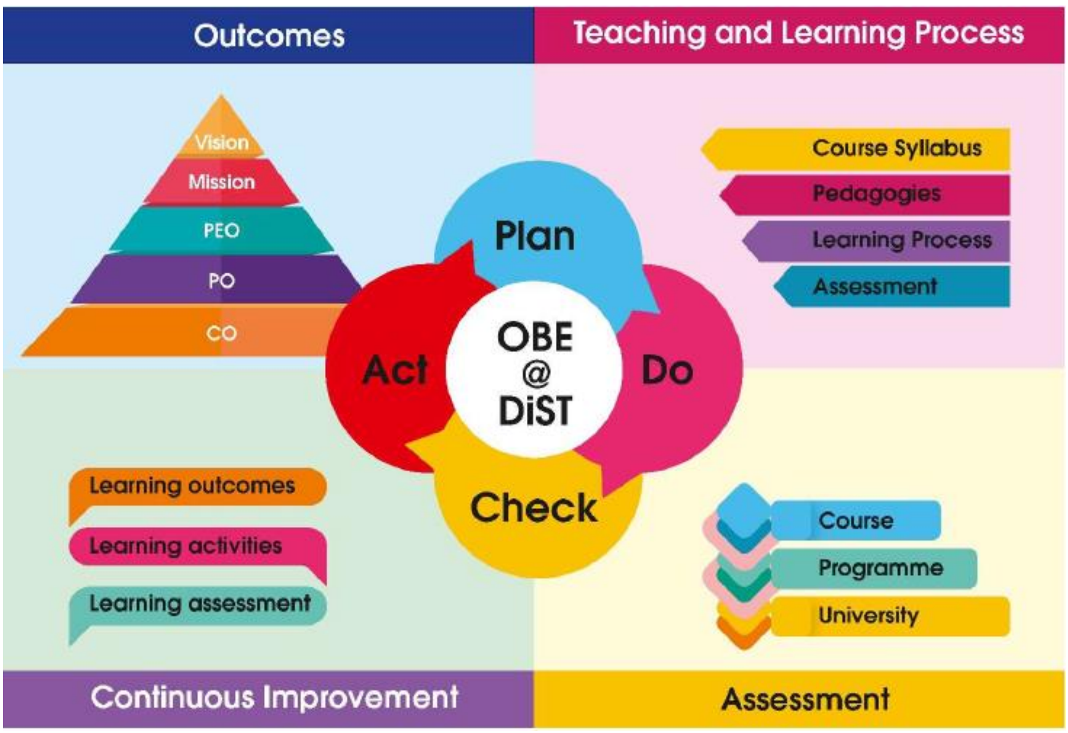
PEO-I
PO:1,2,3,4,5,6

PEO-II
PO:1,2,3,4,5,6

PEO-III
PO:1,2,3,4,5,6

PEO-IV
PO:1,2,3,4,5,6

Figure 4: Correlation between the PEOs and the POs



The detailed mapping illustrating the extent to which each Program Outcome contributes to the attainment of the Program Educational Objectives is shown in Table 1.

Table 1. Relation between the Program Educational Objectives and the POs

PEO's→ ↓PO's		(1) Professional Excellence	(2) Research and Industry Awareness	(3) Continued Self-Learning	(4) Effective Contribution to Society
PO1	Independently carry out research /investigation and development work to solve practical problems.	3	3	2	1
PO2	Write and present a substantial technical report/document.	3	2	1	2
PO3	Demonstrate a degree of mastery over the area in Structural Engineering.	3	3	2	1
PO4	Impart core and interdisciplinary knowledge for analyzing and solving complex problems in structural engineering and related domains.	3	3	3	2
PO5	Conceptualize and design safe, efficient, and sustainable civil engineering structures in social, economic, and environmental factors.	3	2	2	3
PO6	Engage in lifelong learning through continuous education, research, and professional development.	3	2	3	2

Objectives Key : 3 = High; 2 = Medium; 1 = Low

Note:PO assessment is carried out through both direct and indirect assessment procedures.

Direct Assessment is conducted through:

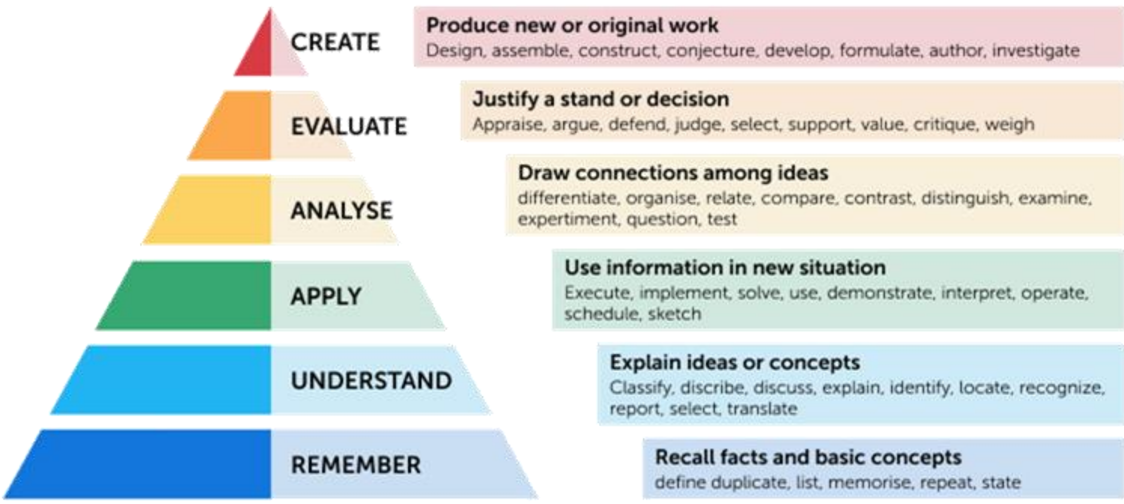
- Continuous Internal Evaluation (CIE),
- Mid-term examinations, and
- Semester-end examinations.

Indirect Assessment is carried out through:

- Program Exit Surveys from graduating students,
- Alumni Surveys, and
- Employer/Employment Surveys.

About Blooms Taxonomy

Bloom's Taxonomy is widely recognized as the global language of education. It is extensively used by educators for framing Course Outcomes, as it offers a well-defined hierarchical structure along with a comprehensive list of measurable action verbs. This structured approach helps ensure clarity, consistency, and alignment between learning objectives, teaching strategies, and assessment methods. A concise overview of the revised Bloom's Taxonomy of critical thinking, proposed by Anderson and Krathwohl, is presented in the figure below.



Different Levels of Thinking Skills in Blooms Taxonomy

Remember

- This is the foundation of learning, where students recall basic information such as facts, definitions, formulas, events, and important concepts.
- Students may be asked to:
  - Recall definitions or key terms from a chapter
  - List steps in a process
  - Identify important dates, people, or events
  - Recognize symbols, diagrams, or formulas
- This level includes recognizing and recalling information from memory.

Understand

- At this level, students demonstrate that they comprehend the meaning of what they have learned. They should be able to explain ideas in their own words or interpret information.
- Examples of tasks include:
  - Explaining the concept behind
  - Summarizing a topic, or lesson
  - Classifying types of phenomena, materials, or data
  - Interpreting graphs, charts, and diagrams
  - Comparing two theories or methods
  - Drawing conclusions from a given situation
  - Key processes include interpreting, summarizing, inferring, comparing, and explaining.

Apply

- Students use their knowledge in practical or new situations. This requires using learned concepts, formulas, rules, or methods in real-life or academic problems.
- Example activities:
  - Solving numerical problems using a learned formula
  - Applying a scientific principle in a lab experiment
  - Using a learned method to analyze a case study
  - Implementing a procedure to complete a task
- This level includes executing (using knowledge in familiar contexts) and implementing (using it in new contexts).

Analyze

- This level focuses on breaking information into parts to understand how they relate, identify patterns, and examine underlying structures.
- Students may be asked to:
  - Analyze data to identify trends
  - Distinguish relevant information from irrelevant details
  - Break down a concept into components
  - Examine causes and effects in a situation
  - Compare different solutions or viewpoints
- Key processes involve differentiating, organizing, and attributing.

Evaluate

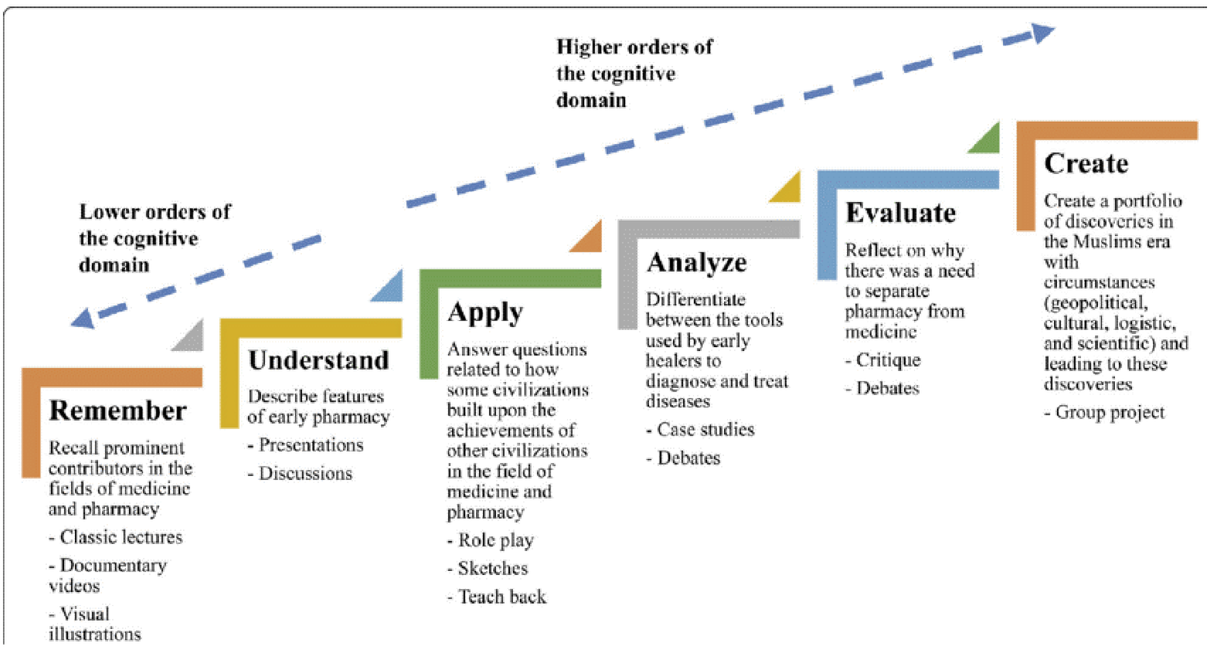
- Students make judgments based on criteria, standards, or evidence. This level requires critical thinking and reasoned decision-making.
- Examples include:
  - Justifying the selection of a method or solution
  - Critiquing an experiment or an argument
  - Assessing the effectiveness of a process or design
  - Checking the validity or accuracy of data and conclusions
- This level involves checking and critiquing using logical reasoning.

Create

- The highest level, where students generate new ideas, products, or processes by combining knowledge and skills creatively.
- Students may:
  - Design a model, project, or experiment
  - Develop a new solution to a problem
  - Construct a plan, report, or prototype
  - Produce original work such as a research project or presentation
- Key processes include generating, planning, and producing.

Lower and Higher Order Blooms Taxonomy

Bloom's Taxonomy is broadly classified into Lower-Order Cognitive Skills and Higher-Order Cognitive Skills. The lower-order levels—Remember, Understand, and Apply—develop foundational knowledge, comprehension, and basic application skills. The higher-order levels—Analyze, Evaluate, and Create—focus on critical thinking, judgment, and creativity, enabling students to examine relationships and generate original solutions. This distinction supports balanced course design and helps educators write clear, measurable Course Outcomes aligned with teaching and assessment.



KNOWLEDGE DIMENSION

The Knowledge Dimension of the revised Bloom's Taxonomy classifies knowledge into Factual, Conceptual, Procedural, and Meta-cognitive categories.

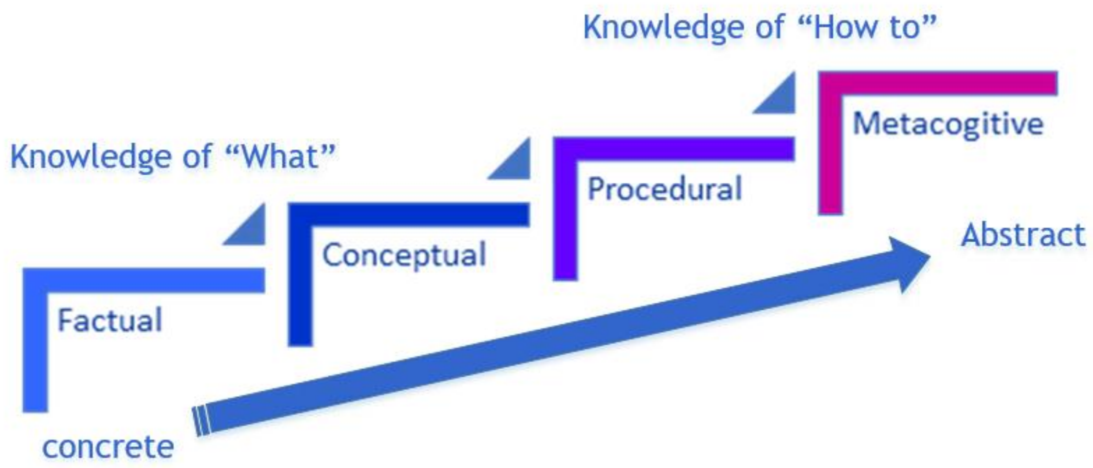


Table 2: The Knowledge Dimension

KNOWLEDGE DIMENSION		Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	Terminology, Elements & Components	Label map, List names	Interpret paragraph, Summarize book	Use math algorithm	Categorize words	Critique article	Create short storey
Conceptual Knowledge	Categories, Principles, Theories	Define levels of cognitive taxonomy	Describe taxonomy in own words	Write objectives using taxonomy	Differentiate levels of cognitive taxonomy	Critique written objectives	Create new classification system
Procedural Knowledge	Specific skills & techniques, Criteria for use	List steps in problem solving	Paraphrase problem-solving process in own words	Use problem-solving process for assigned task	Compare convergent & divergent techniques	Critique appropriateness of techniques used in case analysis	Develop orginal approach to problem solving
Meta-Cognitive Knowledge	General knowledge, Self-knowledge	List elements of personal learning style	Describe implications of learning style	Develop study skills appropriate to learning style	Compare elements of dimensions in learning style	Critique appropriateness of particular learning style theory to own learning	Create orginal learning style theory

BLOOMS TAXONOMY ACTION VERBS

Table 3: Action Verbs for Course Outcomes

Lower Order of Thinking(LOT)				Higher Order of Thinking(HOT)		
Definitions	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Bloom's Definition	Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.	Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpret in, giving descriptions, and Stating main ideas.	Solve problems on new situations by applying acquired knowledge, facts, techniques and rules in a different way.	Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations.	Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria.	Compile information together in a different way by combining elements in a new pattern or proposing alternative solution.
Verbs	• Choose • Define • Find • How • Label • List • Match • Extend	• Classify • Compare • Contrast • Demonstrate • Explain • Illustrate • Infer • Interpret	• Apply • Build • Choose • Construct • Develop • Interview • Make use of • Model	• Analyze • Assume • Categorize • Classify • Compare • Discover • Dissect • Distinguish	• Agree • Appraise • Assess • Award • Choose • Criticize • Decide • Deduct • Importance	• Adapt • Build • Solve • Choose • Combine • Invent • Compile • Compose • Construct
Verbs	• Name • Omit • Recall • Relate • Select • Show • Spell • Tell • What • When • Where • Which • Who • Why	• Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with • Illustrate • Infer • Interpret • Outline • Relate • Rephrase • Show • Summarize • Translate • Experiment with	• Organize • Plan • Select • Solve • Utilize • Identify • Interview • Make use of • Model • Organize • Plan • Select • Solve • Utilize • Identify	• Divide • Examine • Function • Inference • Inspect • List Motive • Simplify • Survey • Take part in • Test for Theme • Conclusion • Contrast	• Defend • Determine • Disprove • Estimate • Evaluate • Influence • Interpret • Judge • Justify Mark • Measure • Opinion • Perceive • Prioritize • Prove • Criteria • Criticize • Compare • Conclude	• Create • Design • Develop • Estimate • Formulate • Happen • Imagine • Improve • Makeup • Maximize • Minimize • Modify • Original • Originate • Plan • Predict • Propose • Solution

Knowledge and Attitude Profile

- Well-Defined Knowledge Profiles (WKs) specify the expected volume of learning and graduate attributes required for effective professional performance.
- WKs help extend and clarify Program Outcomes (POs) by defining measurable knowledge, skills, and attitudes.
- The curriculum is designed to develop mathematical, computational, design, and creative thinking abilities.
- Learning is addressed across the cognitive, affective, and psychomotor domains.
- A total of nine knowledge and attitude profiles are incorporated to ensure holistic graduate development.
- These profiles reflect both the depth of learning and the work attitude expected from graduates.

WK1	A systematic, theory-based understanding of the natural sciences applicable to the discipline and awareness of relevant social science
WK2	Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline.
WK3	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
WK4	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at therefore front of the discipline.
WK5	Knowledge, including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area.
WK6	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.
WK7	Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development.
WK8	Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues.
WK9	Ethics, inclusive behavior and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability etc. with mutual understanding and respect, and of inclusive attitude

KNOWLEDGE AND ATTITUDE PROFILE KEY INDICATORS

Table 3: Key Indicator of Knowledge and Attitude Profile

WK No.	Knowledge & Attitude Profile	Key Indicators	No of Key Indicators
WK1	**Engineering Knowledge & Natural Sciences**	❖ Utilizes principles of physics to solve complex engineering problems. ❖ Employs concepts of chemistry in the analysis of engineering materials and processes. ❖ Uses mathematical principles for the formulation and solution of engineering problems. ❖ Integrates concepts from social sciences to address societal, environmental, and human factors in engineering practice. ❖ Employs discipline-specific engineering fundamentals for analysis, design, and problem-solving in specialized domains.	5
WK2	**Mathematical, Statistical & Data Analysis**	❖ Applies algorithms and numerical methods for engineering analysis. ❖ Uses statistical principles to summarize data and draw valid conclusions. ❖ Performs data cleaning, exploration, visualization, and ethical data handling. ❖ Interprets, evaluates, and compares analytical results using appropriate tools.	4
WK3	**Modelling & System Analysis**	❖ Develops analytical models of engineering systems. ❖ Develops numerical and empirical models to predict system behavior. ❖ Uses physical models to test and validate engineering assumptions. ❖ Evaluates model accuracy and validity of assumptions.	4
WK4	**Computational Tools & Digital Systems**	❖ Uses computer systems to store and manage large datasets ❖ Applies computational tools for simulation and modelling. Uses data visualization techniques for effective analysis and interpretation. ❖ Evaluates limitations of computational tools and results.	3
WK5	**Problem Identification & Engineering Analysis**	❖ Identifies constraints, requirements, and secondary impacts of engineering problems. ❖ Formulates accurate and realistic problem statements ❖ Applies analytical methods for problem investigation. ❖ Validates assumptions and analytical outcomes.	4
WK6	**Engineering Design, Sustainability & Safety**	❖ Develops innovative and sustainable design solutions. ❖ Evaluates feasibility considering technical, economic, environmental, and societal factors. ❖ Conducts life-cycle analysis for sustainability assessment. ❖ Identifies hazards and applies risk mitigation strategies.	5

		❖ Ensures compliance with environmental and safety regulations.	
WK7	**Engineering Management & Professional Practice**	❖ Applies engineering management principles in decision-making. ❖ Performs economic analysis for project implementation. ❖ Manages resources, time, and budget effectively. ❖ Demonstrates professional responsibility in practice.	**4**
WK8	**Research, Investigation & Critical Thinking**	❖ Reviews current research literature to identify research gaps. ❖ Designs and executes experiments and investigations. ❖ Applies qualitative and quantitative research methods. ❖ Analyzes data and considers sources of error. ❖ Draws and justifies valid conclusions. ❖ Evaluates emerging technologies, including Generative AI.	**6**
WK9	**Ethics, Law, Diversity & Inclusivity**	❖ Demonstrates ethical responsibility and professional integrity. ❖ Applies laws, regulations, and professional codes in practice. ❖ Identifies and justifies ethical courses of action. ❖ Respects diversity and promotes inclusivity in professional environments. ❖ Evaluates ethical implications of new and emerging technologies.	**5**

PO-WK MAPPING

Table 4 presents the mapping between the Program Outcomes (POs) and the corresponding elements of the Knowledge and Attitude profile (WK) framework for the M.Tech Structural Engineering programme.

Table 4: PO-WK Mapping

POs		WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9
PO1	Research/ investigation	3	4	4	3	4	5	4	6	4
PO2	Report Preparation	1	1	1	1	1	1	2	1	2
PO3	Domain Mastery	3	3	4	2	4	5	3	6	3
PO4	Application of Engineering Principles	5	3	4	3	4	5	4	6	5
PO5	Design and Sustainability	3	3	4	2	4	5	3	6	3
PO6	Lifelong Learning and Professional Development	3	3	4	2	4	5	4	6	5

Complex Engineering Problems

Complex Engineering Problems are engineering challenges that are broad, open-ended, and ambiguous, requiring the application of advanced engineering knowledge, professional judgment, and integration of multiple disciplines. These problems do not have a single optimal or readily testable solution and are characterized by uncertainty, multiple constraints, and the need for innovative and iterative approaches.

Key features of Complex Engineering Problems

- Broad scope involving multiple interconnected systems and disciplines
- Unstable and unpredictable parameters that evolve over time
- Require advanced and specialized engineering knowledge beyond routine practice
- Multiple experiments or direct testing may not be feasible
- Solutions are iterative, involving analysis, optimization, and innovation
- No bounded set of alternative solutions; trade-offs must be evaluated
- High levels of uncertainty, including unknown variables and risks
- Solutions cannot be based solely on standard codes or practices
- Demand consideration of safety, economy, sustainability, constructability, and societal impact
- Typically require collaboration among multidisciplinary teams and stakeholders

Characteristics Of Complex Engineering Problems

Table 5: Characteristics of complex engineering problems

S No.	Keyword / Aspect	Description
1	**Depth of knowledge required**	Cannot be resolved without in-depth engineering knowledge at the level of one or more of **WK3, WK4, WK5, WK6, or WK8**, enabling a fundamentals-based and first-principles analytical approach.
2	**Range of conflicting requirements**	Involve wide-ranging and often conflicting technical, engineering, economic, environmental, and societal issues.
3	**Depth of analysis required**	Have no obvious solution and require abstract thinking, originality, and advanced analytical skills to formulate appropriate models and solution strategies.
4	**Familiarity of issues**	Involve issues that are infrequently encountered and not routine in professional engineering practice.
5	**Extent of applicable codes**	Lie outside the scope of problems fully addressed by existing standards and codes of professional engineering practice.
6	**Extent of stakeholder involvement & conflicting requirements**	Involve diverse stakeholder groups with widely varying and often conflicting needs, expectations, and constraints.
7	**Interdependence**	Represent high-level problems comprising many interdependent components or sub-problems that must be addressed holistically.

ADOPTING UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS

In the era of rapid industrialization and digital transformation, engineering education plays a decisive role in addressing global challenges such as climate change, energy crises, resource depletion, social inequality, and sustainable urbanization. Recognizing this responsibility, the Engineering Program formally adopts the United Nations' Sustainable Development Goals (SDGs) as a guiding framework to align technical education with sustainable, ethical, and socially responsible development.

The program integrates SDGs within the Outcome-Based Education (OBE) framework to ensure that graduates are equipped not only with advanced technical competence but also with sustainability awareness and global citizenship.

INTEGRATION OF SDGs WITHIN THE M.TECH PROGRAM

S. No.	Keyword / Aspect of Complex Engineering Problems	Relevant Program Outcomes (POs)	Linked UN SDGs	Justification of Linkage (Structural Engineering Context)
1	Depth of knowledge required	PO3 – Domain Mastery, PO4 – Application of Engineering Principles	SDG 4, SDG 9, SDG 7, SDG 6	Advanced education in structural analysis and mechanics enables innovation in infrastructure, renewable energy structures, and water-related systems, supporting sustainable development.
2	Range of conflicting requirements	PO5 – Design and Sustainability, PO6 – Lifelong Learning &	SDG 4, SDG 8,	Sustainable structural design balances safety, economy, inclusivity, and environmental

		Professional Development	SDG 10, SDG 11	impact, promoting equitable urban development and economic growth.
3	Depth of analysis required	PO1 – Research / Investigation, PO4 – Application of Engineering Principles	SDG 4, SDG 9, SDG 12	Research-driven analysis supports material efficiency, life-cycle design, and innovative construction practices for responsible production and infrastructure resilience.
4	Familiarity of issues	PO1 – Research / Investigation, PO6 – Lifelong Learning & Professional Development	SDG 4, SDG 13, SDG 15, SDG 14	Continuous learning enables engineers to respond to climate change, environmental protection, coastal structures, and land-use-sensitive development.
5	Extent of applicable codes	PO4 – Application of Engineering Principles, PO5 – Design and Sustainability	SDG 4, SDG 9, SDG 16	Ethical application of advanced principles beyond codes ensures public safety, institutional accountability, and innovation in complex structural projects.
6	Stakeholder involvement & conflicting needs	PO2 – Report Preparation, PO5 – Design and Sustainability	SDG 4, SDG 5, SDG 11, SDG 16	Inclusive reporting, ethical documentation, and stakeholder engagement promote gender equity, transparent governance, and socially responsible infrastructure.
7	Interdependence of components	PO1 – Research / Investigation, PO3 – Domain Mastery, PO5 – Design and Sustainability	SDG 4, SDG 1, SDG 2, SDG 3, SDG 12	Integrated structural systems support safe housing, healthcare, food storage, and livelihood infrastructure, contributing to social well-being and poverty reduction.
8	Collaboration, outreach & global responsibility	PO2 – Report Preparation, PO6 – Lifelong Learning & Professional Development	SDG 4, SDG 17	Industry–academia collaboration, professional practice, and research partnerships strengthen global cooperation for sustainable development goals.

COURSE OUTCOMES

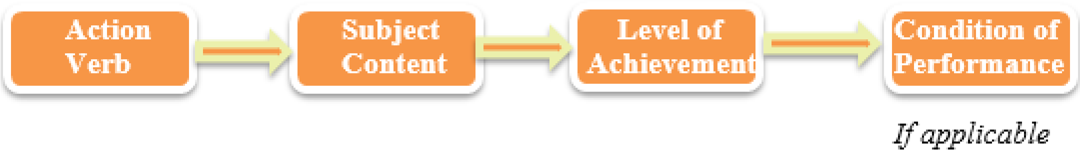
A Course Outcome is a formal statement of what students are expected to learn in a course. When creating Course Outcomes, remember that the outcomes should clearly state what students will do or produce to determine and/or demonstrate their learning. Course learning outcome statements refer to specific knowledge, practical skills, areas of professional development, attitudes, higher-order thinking skills, etc., that faculty members expect students to develop, learn, or master during a course.

A well-formulated set of Course Outcomes will describe what a faculty member hopes to successfully accomplish in offering their particular course(s) to prospective students, or what specific skills, competencies, and knowledge the faculty member believes that students will have attained once the course is completed. The learning outcomes need to be concise descriptions of what learning is expected to take place by course completion.

Guidelines for Writing Course Outcome Statements

Effective Course Outcomes are structured using the following components:

- **Action Verb** – Specifies observable student performance
- **Subject Content** – Indicates the knowledge or skill area
- **Level of Achievement** – Reflects cognitive depth (Bloom's Taxonomy)
- **Conditions of Performance** (if applicable) – Defines context or tools used



Developing Effective Course Outcomes

When formulating Course Outcomes, the following best practices should be followed:

- Limit outcomes to 5–6 statements per course
- Focus on core knowledge and essential skills
- Avoid trivial or overly detailed content
- Use student-centered language
- Emphasize learning results, not teaching activities
- Align outcomes with departmental and institutional mission
- Include multiple ways students can demonstrate learning (analyze, model, design, evaluate, present, etc.)
- Ensure outcomes are observable, measurable, and assessable

Relationship of Course Outcome to Program Outcome

Course Outcomes are systematically mapped to Program Outcomes (POs) to ensure that each course contributes meaningfully to the overall program objectives.

Learning outcomes formula:

STUDENTS SHOULD BE ABLE TO + BEHAVIOR + RESULTING EVIDENCE

Characteristics of Effective Course Outcomes

Well written course outcomes:

- Describe what you want your students to learning your course.
- Are aligned with program goals and objectives.
- Tell how you will know an instructional goal has been achieved.
- Use action words that specify definite, observable behaviors.
- Arrases able through one or more indicators (papers, quizzes, projects, presentations, journals, portfolios, etc.)
- Are realistic and achievable.
- Use simple language.

Examples of Effective Course Outcomes

Examples of Effective Course Outcomes:Course: Structural Stability (2412043)

A structured and measurable approach to stating Course Outcomes involves three essential components:

- **Condition** – the context or tools provided
- **Observable Behavior** – the action performed by the student
- **Standard** – the level of acceptable performance

A more detailed model for stating learning objectives requires at objectives have three parts: a condition, an observable behavior, and a standard.
The table below provides three examples.

Table 4: Examples of Course Outcomes Using the Condition–Behavior–Standard Model

S. No	Condition	Observable Behavior	Standard
1	Given a structural system with specified loading and boundary conditions	The student will be able to explain the criteria of stability, strength, and stiffness and distinguish between linear and nonlinear behavior	Correctly addressing at least 80% of identified criteria
2	Given a column with defined end conditions and loading	The student will be able to determine critical buckling loads and demonstrate axial, flexural, and torsional buckling behavior	Results within ±5% of theoretical values
3	Using a plane frame model with given member properties	The student will be able to investigate global and local stability by evaluating slenderness ratios and buckling interactions	Correct identification of governing buckling mode
4	Given beams and plates subjected to axial, shear, and combined loads	The student will be able to assess susceptibility to various buckling modes	Accurate classification of buckling mode with justification
5	Provided with case studies of structures beyond elastic limits	The student will be able to illustrate inelastic and dynamic buckling behavior	Appropriate interpretation using theory and examples

CO-PO Articulation Matrix

A Course Articulation Matrix (CAM) shows the relationship between the Course Outcomes (COs) and the Program Outcomes (POs). It reflects the level to which each CO contributes to the attainment of specific POs. This matrix helps determine whether students are achieving the intended learning outcomes of a course. It is applicable to any course and is a valuable tool for evaluating and improving a course syllabus.

Observations

- ❖ For theory courses, COs should generally be designed within Bloom's Levels 1 to 4.
- ❖ For programming-oriented courses, COs should usually be limited to Bloom's Levels 1 to 3, while other theory courses may extend up to Level 4.
- ❖ For laboratory courses, COs may be framed within Bloom's Levels 1 to 5.
- ❖ Only in mini-projects and major projects may COs be designed up to Bloom's Level 6.
- ❖ For a given course, the course in-charge should involve all faculty members teaching the course in preparing the CO-PO mapping. The course in-charge may take the average of all submitted mappings or follow the majority. Faculty members should perform the mapping independently, without discussing values among themselves.
- ❖ When correlating COs with POs, ensure that the action verbs in the COs align with the intent and scope defined in the POs.

Method for Articulation

1. Identify the key competencies of POs for each CO and create a corresponding mapping table by assigning marks in the corresponding cell. One important observation is that the first five POs are purely technical in nature, while the other POs are non-technical.
2. Justify each CO-PO mapping with a justification statement and recognize the number of vital features mentioned in the justification statement that match the given Key Attributes for Assessing Program Outcomes. Use a combination of words found in the COs, POs, and your course syllabus for writing the justification.
3. Create a table listing the number of key competencies for CO-PO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
4. Create a table displaying the percentage of key competencies for CO-PO mapping with reference to the maximum given Key Attributes for Assessing Program Outcomes.
5. Finally, prepare a Course Articulation Matrix (CO-PO Mapping) with COs and POs on a scale of 0 to 3, where:
   - 0 = No correlation (marked as "-")
   - 1 = Low/slight correlation
   - 2 = Medium/moderate correlation
   - 3 = Substantial/high correlation

The correlation is based on the following strategy:

Range	Correlation	Level
$0 \leq C \leq 5\%$	No correlation	0
$5\% < C \leq 40\%$	Low/Slight correlation	1
$40\% < C < 60\%$	Moderate correlation	2
$60\% \leq C < 100\%$	Substantial/High correlation	3

Key Competencies for Assessing Program Outcomes:

To ensure that Program Outcomes (POs) are effectively achieved, each PO must be broken down into measurable Key Competencies. These competencies explain the specific abilities, skills, and knowledge that students must demonstrate. The table 6 below outlines the detailed key components for each PO, along with the total number of components associated with it. This structured approach enables transparency, accuracy in CO–PO mapping, and consistency during assessment and evaluation.

Table 6: Key Competencies for Assessing Program Outcomes

PO No.	NBA Statement / Vital Features	Key Components	No. of Key Components
PO1	Independently carry out research /investigation and development work to solve practical problems	1. Research problems in structural engineering are clearly identified and defined. 2. Literature review highlights research gaps and suitable methods. 3. Experiments or simulations are conducted using appropriate tools. 4. Data is collection, analyses, and interpretation systematically. 5. Innovative approaches are applied to engineering problem-solving. 6. Results are validated against established theories and standards	**6**
PO 2.	Write and present a substantial technical report/document	1. Technical reports, dissertations, and papers are well-structured. 2. Referencing and academic integrity practices are properly maintained. 3. Content is presented with clarity, precision, and logical flow. 4. Oral communication and presentation skills are effectively demonstrated. 5. Digital tools are used for documentation and visualization. 6. Research findings are communicated to both technical and non-technical audiences.	**6**
PO 3.	Demonstrate a degree of mastery over the area in Structural Engineering	1. Knowledge in structural mechanics, design, and analysis is demonstrated. 2. Advanced structural methods are effectively applied. 3. Proficiency in designing RCC, steel, and composite structures is shown. 4. Software tools are used for modeling and structural design. 5. IS codes, international standards, and recent research are followed. 6. Theoretical knowledge is applied to real-world structural challenges.	**6**

PO 4.	Impart core and interdisciplinary knowledge for analyzing and solving complex problems in structural engineering and related domains.	1. Core knowledge in structural engineering is effectively applied. 2. Interdisciplinary concepts are integrated into problem-solving. 3. Modern computational tools are utilized for analysis. 4. Complex engineering systems are critically evaluated.	4
PO 5.	Conceptualize and design safe, efficient, and sustainable civil engineering structures in social, economic, and environmental factors.	1. Structural designs are safe, durable, and code-compliant. 2. Sustainability principles are integrated into material selection and construction. 3. Economic feasibility and cost-benefit aspects are considered. 4. Structural designs address disaster resilience and risk reduction. 5. Social, ethical, and environmental implications are incorporated in solutions. 6. Innovative structural systems are developed for future challenges.	6
PO 6.	Engage in lifelong learning through continuous education, research, and professional development.	1. Professional certifications, MOOCs, and higher studies are actively pursued. 2. Emerging technologies and global trends are regularly updated. 3. Seminars, workshops, and professional societies are actively participated in. 4. Contributions to technical literature are made through publications and patents. 5. Knowledge exchange with peers and professionals is continuously maintained. 6. Adaptability to technological and industrial changes is demonstrated. 7. Self-learning, critical thinking, and reflective practices are adopted. 8. Commitment to lifelong personal and professional growth is shown.	8

CO-PO Articulation Matrix

CO-PO articulation matrix for the Courses offered in M.Tech Structural Engineering Curriculum (MLRS-R24) are given below table.7.

Table 7: CO-PO articulation Matrix for M.Tech Structural Engineering (MLRS R 24) regulation

Code	Subject	PO					
		1	2	3	4	5	6
I M. Tech –I Semester							
2412011	Advanced Structural Mechanics	1.4	1	3	3	1.4	2.4
2412012	Theory Of Elasticity And Plasticity	1.2	1	3	3	1.6	1
2412041	Theory Of Plates And Shells	1	1	3	3	2	1
2412042	Advanced Steel and Concrete Composite Structures	1.4	1.4	1	3		1
2412043	Structural Stability	2.2	1	3	3	1	2
2412044	Advanced Reinforced Concrete Design	2.2	1	3	3	2	2.2
2412045	Advanced Design of Metal Structures	2	1	3	3	1.8	2.4
2412046	Structural Optimization	1.8	1	3	3	1.8	2
2412071	Computer Aided Design Laboratory	1.8	1	3	3	1.8	3
2412072	Structural Engineering Laboratory	1.4	1.6	3	3	1.2	3
2412021	Research Methodology & IPR	3	3	3	3		1
2410001	English For Research Paper Writing	1	1	3	3	1	1
2410002	Disaster Management	1.4		1	1		1
2410003	Sanskrit For Technical Knowledge		1.2				1
2410004	Value Education					1	1
I M. Tech –II Semester							
2422013	Finite Element Analysis	1.4	1	1.4	1.6	1.8	1
2422014	Structural Dynamics	1.2	1	3	3	1.8	1
2422047	Advanced Structural Steel Design	1.4	1	3	3	1.8	1
2422048	Structural Reliability	1.2	1	3	3	1.8	1
2422049	Design Of High-Rise Buildings	1.2	1	3	3	1.6	1
2422050	Advanced Prestressed Concrete Design	1.6	1	3	3	1.8	1
2422051	Industrial Structures	1.6	1	3	3	1.8	1
2422052	Design Of Bridges	1.6	1	3	3	1.8	1
2422073	Numerical Analysis Laboratory	2	3	3	3	2	3

2422074	Advanced Structural Analysis And Design Laboratory	2	3	3	3	2	3
2422075	Mini Project With Seminar	3	3	3	3	3	3
2420005	Constitution Of India					1	1
2420006	Pedagogy Studies	1.2	1	1.2	1.4	1.4	1
2420007	Stress Management By Yoga					1	1
2420008	Personality Development Through Life Enlightenment Skills					1	1
IIM. Tech –I Semester							
2432053	Earthquake Resistance Design Of Structures	1.4	1	3	3	1.8	1
2432054	Fracture Mechanics	1.6	1	3	3	2.4	1
2432055	Rehabilitation And Retrofitting Of Structures	1.6	1	3	3	2.8	1
2432001	Green Building	1.4	1	3	3	1.6	1
2432002	Construction Project Management	1.6	1	1.2	1.4	1.6	1
2432003	Safety And Construction Practice Regulations	1.6	1	1.2	1.6	1.6	1
2432076	Dissertation Work Review – I	3	3	3	3	3	3
II M. Tech –II Semester							
2442077	Dissertation Work Review – III	3	3	3	3	3	3
2442078	Dissertation Viva -Voce	3	3	3	3	3	3

METHODS FOR MEASURING LEARNING OUTCOMES

There are many different ways to assess student learning. In this section, we present the different type of assessment approaches available and the different frameworks to interpret the results.

i) Continuous Internal Assessment (CIA).
ii) Semester end examination(SEE)
iii) Laboratory and project work
iv) Course End survey
v) Program exit survey
vi) Alumni survey
vii) Employer survey
viii) Program Assessment and Quality Improvement Committee (PAQIC)
ix) Department Advisory Board (DAB)
x) Faculty meetings

Table 8: CO-PO Mapping

Assessment Method	Assessment Tool	Weightage in CO attainment
Direct Assessment	Continuous Internal Assessments (CIA-1and CIA-2)	80%
	Semester End Examination	
Indirect Assessment	Course End Survey	20%

Direct Assessment

Direct assessment methods are based on the student's knowledge and performance in various assessments and examinations. These assessment methods provide evidence that a student has command over a specific course, content, or skill. Additionally, they demonstrate that the student's work exhibits specific qualities such as creativity, analysis, or synthesis.

The various direct assessment tools used to assess the impact of the delivery of course content is listed in the table.

- Mid Term examination, semester end examinations, Assignment and Viva-voce/Tutorial/Case study/Application/Poster presentation (are used for CO calculation.
- The attainment values are calculated for individual courses and are formulated and summed for assessing the POs.
- Performance in Assignment is indicative of the student's communication skills.
- Viva-voce/PPT/Poster Presentation/Case study reflects the student's knowledge, skills, application, and understanding of the course.

Table 9: Tools used in direct assessment methods

S No	Courses	Components	Frequency	Max. Marks	Evidence
1	Core / Elective	Continuous Internal Examination (CIE)	Twice in a semester	20	Answer script
		QUIZ	Twice in a semester	10	Multiple Choice Questions in Anvaya LMS
		Comprehensive Assessment Tool (CAT)	Twice in a semester	10	Scripts/PPT/student videos
		Semester End Examination	Once in a semester	60	Answer script
2	Laboratory	Day to day evaluation	Once in a week	10	Observation and record
		Viva-voce/Tutorial/Case study/Application/Poster presentation	Twice in a semester	10	Work sheets
		Design/software/hardware Model presentation/App development/Prototype presentation	Once in a semester	10	Presentation
		Internal practical examination	Twice in a semester	10	Answer script
		Semester End Examination	Once in a semester	60	Answer script
3	Dissertation Work	Presentation	Twice in a semester	40	Presentation
		Semester End Examination	Once in a semester	60	Thesis report
4	Mini Project With Seminar	Semester End Examination	Twice in a semester	100	Seminar report

Indirect Assessment

Course End Survey- In this survey, questionnaires are prepared based on the level of understanding of the course and the questions are mapped to Course Outcomes. The tools and processes used in indirect assessment are shown in Table 10.

Table10: Tools used in indirect assessment

Tools	Process	Frequency
Course end survey	• Taken for every course at the end of the semester • Gives an overall view that helps to assess the extent of coverage/compliance of COs • Helps the faculty to improve upon the various teaching methodologies	Once in a semester

Direct Tools: (Measurable in terms of marks and w.r.t.CO) Assessment done by faculty at department level.

Indirect Tools: (Non measurable (surveys) in terms of marks and w.r.t. CO) Assessment done at institute level.

PO Assessment tools and Processes

The institute has the following methods for assessing the attainment of POs.

1. Direct method
2. Indirect method

The attainment levels of course outcomes help in computing the PO based upon the mapping done.

Table11: Attainment of PO

	Assessment	Tools	Weight
POs Attainment	Direct Assessment	CO attainment of courses	80%
	Indirect Assessment	Program exit survey	20%
		Alumni survey	
		Employer survey	

The CO values of both theory and laboratory courses, with appropriate weightage as per CO-PO mapping, as per the Program Articulation Matrix, are considered for the calculation of direct attainment of PO.

7.1 PO Direct Attainment is calculated using the rubric

PO Direct Attainment = (Strength of CO-PO) * CO attainment / Sum of CO-PO strength.

The below figure represents the evaluation process of POs/PSOs attainment through course outcome attainment.

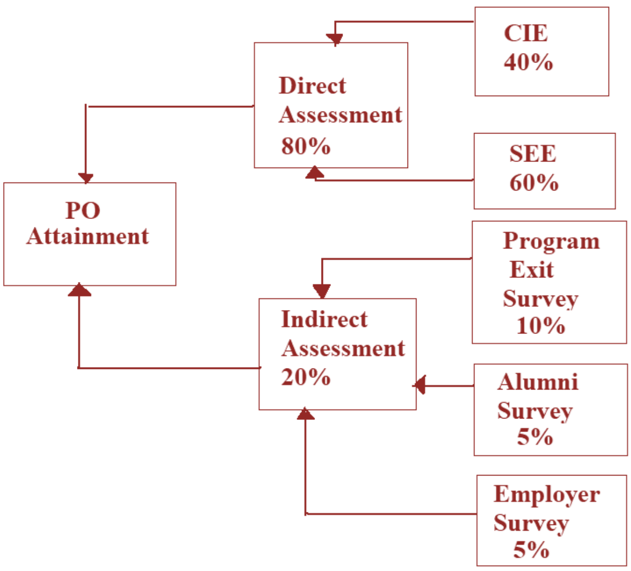


Figure3: Evaluation process of POs attainment

COURSE DESCRIPTION

The "Course Description" provides general information regarding the topics and content addressed in the course. A sample course description is given in Annexure – A for reference.

The "Course Description" contains the following contents:

- Course Overview
- Prerequisite(s)
- Marks Distribution
- Content Delivery / Instructional Methodologies
- Evaluation Methodology
- Course Objectives
- Course Outcomes
- Program Outcomes
- Program Specific Outcomes
- How Program Outcomes are Assessed
- Mapping of each CO with PO(s)
- Justification for CO–PO Mapping - Direct
- Total Count of Key Competencies for CO–PO Mapping
- Percentage of Key Competencies for CO–PO
- Course Articulation Matrix (PO Mapping)
- Assessment Methodology - Direct
- Assessment Methodology - Indirect
- Syllabus
- List of Textbooks / References / Websites

MARRI LAXMAN REDDY
INSTITUTE OF TECHNOLOGY AND MANAGEMENT
(AN AUTONOMOUS INSTITUTION)
(Approved by AICTE, New Delhi & Affiliated to JNTUH, Hyderabad)
Accredited by NAAC with 'A' Grade & Recognized Under Section2(f) & 12(B)of the UGC act,1956

THEORY OF ELASTICITY AND PLASTICITY

COURSE DESCRIPTOR

1	Department	CIVIL ENGINEERING
2	Course Name	THEORY OF ELASTICITY AND PLASTICITY
3	Course Code	2412012
4	Year/Semester	I/I
5	Regulation	MLRS-R24
6	Course Offered	Odd Semester
7	Course Coordinator	Mr.T.Jaya Krishna
8	Date Approved by BOS	14-11-2023
9	Course Webpage	www.mlritm.ac.in/

10.Structure of the Course

Theory		Practical	Project	
Lecture	Tutorials	Practical	Mini project	Major Project
3	-	-	-	-

11. Credits of the Course

Theory		Practical	Project	
Lecture	Tutorials	Practical	Mini project	Major Project
3	-	-	-	-
Total Credits:				

12. Type of the Course

PC	PE	AC	MPS	PS
√	-	-	-	-
Total Credits:				

13. Total Hours Offered

Lectures	Tutorials	Practicals
58	-	-

14. Prerequisites/ Co-requisites

Level	Course Code	Semester	Prerequisites
UG	-	-	

15. Course Overview

The course Theory of Elasticity and Plasticity is designed to provide postgraduate students with a comprehensive understanding of plastic deformation behavior of materials under various loading conditions. It emphasizes the fundamental concepts of stress–strain relations beyond the elastic limit, yielding criteria, plastic stress–strain relations, and hardening rules. The course also covers slip-line field theory, plastic potential, and applications to metal forming processes. Through this course, students will develop the ability to model, analyze, and solve advanced engineering problems related to material plasticity, which are crucial in structural, geotechnical, and manufacturing engineering. By integrating theoretical knowledge with practical problem-solving, the course strengthens analytical skills and prepares students for research, industrial applications, and advanced computational studies in the field of material behavior and plasticity.

16. Course Objectives

The students will try to learn:

1	To impart fundamental knowledge of stress–strain relations in plastic range and various yield criteria governing material deformation.
2	To develop an understanding of plastic stress–strain relations, flow rules, and hardening mechanisms in metals.
3	To introduce slip-line field theory and its applications to plane strain plasticity problems.
4	To enable students to analyze and model metal forming processes using plasticity principles.
5	To strengthen analytical and research skills for solving advanced problems in structural, geotechnical, and manufacturing engineering involving plastic deformation

17. Course Outcomes

After successful completion ofthe course, students should be able to:

CO1	Analyze the state of stress in two- and three-dimensional systems using stress tensors, transformations, and invariants.
CO2	Interpret different components of strain and their transformations to determine principal and octahedral strains.
CO3	Derive stress–strain relationships and material constants for various material symmetries under plane and axi-symmetric conditions.
CO4	Solve two and three dimensional elasticity problems using stress function approaches and membrane analogy concepts.
CO5	Evaluate yielding behaviour of materials using different yield criteria and hardening rules in plasticity.

18. Cognitive Levels

Blooms Taxonomy Level	Cognitive Level in Percentage (%)
Remember	0
Understand	40
Apply	20
Analyse	20
Evaluate	20
Create	0

19. Employability Skills

Skill Category	Description	Relevance to Course
Problem-Solving Skills	Develops ability to identify complex stress and strain problems and propose analytical or numerical solutions.	Solving problems on stress-strain relationships, compatibility conditions, and boundary value problems in elastic and plastic regions.
Analytical Thinking	Encourages logical analysis of material behavior under different loading and boundary conditions.	Deriving stress functions, applying equilibrium equations, and analyzing two- and three-dimensional stress systems.
Software & Hardware Integration	Enhances proficiency in using computational tools for solving elasticity and plasticity problems.	Utilizing software like MATLAB and ANSYS for solving and visualizing stress distribution and deformation patterns.
Collaboration & Teamwork	Fosters teamwork in modeling and analyzing structural components under complex loading.	Working in groups for mini-projects involving stress analysis or validation of theoretical results using simulations.
Adaptability & Continuous Learning	Prepares students to adopt new analytical, experimental, and computational techniques in solid mechanics.	Learning modern theories of plastic flow, yield criteria, and advanced elasticity applications in structural engineering.
System Design Thinking	Develops capability to design and evaluate materials and structures considering elastic and plastic behavior.	Designing components that ensure safety, sustainability, and performance under elastic and plastic deformation conditions.

20. Complex Engineering Problems

The course on theory of Elasticity and Plasticity focuses on developing the ability to solve complex structural engineering problems through rigorous analytical and application-based learning. Students apply fundamental principles of stress, strain, and constitutive relationships to analyze two- and three-dimensional elasticity and plasticity problems under various loading and boundary conditions.

Mandatory problem-solving assignments and in-class exercises emphasize stress and strain tensors, equilibrium and compatibility equations, stress–strain relations, transformations, Mohr's circles, and idealizations such as plane stress, plane strain, and axisymmetric conditions. Advanced applications include beam bending, torsion, stress function methods, membrane analogy, and thin-walled section analysis.

Assessment also covers plasticity concepts, including yield criteria, flow rules, hardening behavior, and introductory numerical solution techniques. All coursework, projects, and examinations are completed individually, ensuring the development of independent analytical thinking, critical reasoning, and professional competence in solving complex engineering problems.

21. Content Delivery / Instructional Methodologies

PowerPoint Presentation	√	**Chalk&Talk**	√	**CAT**	√	**MOOC**	x
Case study	x	**Seminars**	√	**Mini Project**	x	**DSS/Videos**	√

22. Evaluation Methodology

Total marks for each course shall be based on Continuous Internal Assessment (CIA) and Semester End Examinations (SEE). There shall have a uniform pattern of 40:60 for CIA and SEE of both theory and practical courses. The institute shall conduct multiple continuous internal assessments (CIA) for theory courses. All the performances of a student shall be considered for Continuous Internal Assessment (CIA) marks.

Outline for Continuous Internal Assessments (CIA-1and CIA-2) and SEE:

Table 1: **Outline for Continues Internal Evaluation (CIE-I and CIE-II) and SEE**

Activities	CIA-1	CIA-2	SEE	Total Marks

Continuous Internal Examination (CIE)	10	10		20
Quiz	5	5		10
Comprehensive Assessment Tool (CAT)	5	5		10
Semester End Examination (SEE)			60	60
Total	**20**	**20**	**60**	**100**

Continuous Internal Examination (CIE)

For theory courses, two Continuous Internal Examinations (CIE-I and CIE-II) shall be conducted in each semester as per the academic calendar. Each Continuous Internal Examination shall be evaluated for 30 marks. To finalize CIE marks these 30 marks will be scale down to 10 marks.

- The time duration of each CIE shallbe1hour and 30 minutes.
- Question paper pattern for CIE (30Marks) shall be as follows:

PART-A: 5X2M=10M

a. All questions are compulsory.
b. 02 questions from full units and one question from half unit.

PART-B: 4*5=20M

a. There shall be a total of 06 questions.
b. There shall be two questions from each UNIT with internal choice i.e., 'either' 'or' choice.
c. Student shall answer one question from each UNIT.

Quiz – Online Examination:

Two Quiz examinations shall be online examination consisting of 50 multiple choice questions

Comprehensive Assessment Tool (CAT):

The CAT may include Certificate of completion from Open Coding platforms such as Hacker rank, codechef etc., Tech talk,assignments, term paper, open ended experiments, METE (Modeling and Experimental Tools in Engineering), Concept video, MOOCs, Inter-institute participation in hackathons etc, Language Proficiency test .

Semester End Examination (SEE)

Part A consists of five compulsory questions, each carrying 2 marks, totaling 10 marks. There shall be one question from each unit, and all questions are mandatory. This section is intended to assess students' basic conceptual knowledge across the entire syllabus.

Part B carries a total of 50 marks and comprises five questions, each worth 10 marks. Students are required to answer one question from each unit. There will be no choice for questions from the first and second units. From the third unit onwards, an "either–or" choice will be provided, and the student must attempt only one of the two questions. Each question in Part B shall have a maximum of two subdivisions, namely Part (a) and Part (b). Part (a) shall be a descriptive-type question carrying 5 marks, while Part (b) shall be **a critical thinking or problem-solving question,** also carrying 5 marks.

23. Course content - Number of modules: Five:

Module	Module Description	No. of Lectures
MODULE 1	**Stress:** Introduction to Elasticity – Definition of Kinetics and Kinematics - Notation for forces and stress- Components of stresses – Stress tensor - Differential equations of equilibrium in 2D & 3D in Cartesian coordinates and in polar coordinates - boundary conditions – Cauchy's postulate – Stress transformation – Direction Cosines -Principal stresses – Stress invariants – Decomposition of stresses-Hydrostatic and Deviatoric stresses – Octahedral stresses – stress concentration factors	No. of theory classes : 14
MODULE 2	**Strain:** Notation for strain - Components of strain – Strain tensor – Strain Components -Strain -displacement relations - Strain Compatibility Conditions - Strain transformation – Direction Cosines -Principal strains – Strain invariants - Octahedral strains – Strain Rosette	No. of theory classes : 12
MODULE 3	**Stress -Strain Relationship:** Navier's equation for stress-strain relationships – Relationship between Material constants – Stress - strain relations in 2D and 3D – Complementary conditions for shear - Material symmetry -Reduction of Material constants from anisotropic to orthotropic, monoclinic, isotropic and transversely isotropic – Plane stress, Plane strain and axi-symmetric idealizations - Mohr circle in 2D and 3D – Airy's stress function – Potential function	No. of theory classes : 15
MODULE 4	**Solution of 2D and 3D elasticity problems:** Problem solving using stress function approach: Beam bending problems – Symmetric stress distribution problems, Plane problems. Torsion problems in Elasticity – Membrane analogy approach – Application to non- circular thin walled sections	No. of theory classes : 12
MODULE 5	**Plasticity:** Introduction to plasticity – Yield criteria for pressure dependent and independent materials – Tresca's criterion – Von mises criterion – Mohr-Coulomb criterion -Rankine criterion -Flow rule – Associative and Non-Associative-Hardening rules and consistency conditions -Introduction to iterative and return mapping.	No. of theory classes : 5

REFERENCE BOOKS

1. Theory of Elasticity by Timeshenko, McGraw-Hill Publications
2. Theory of Elasticity by Y.C.Fung
3. Advanced Mechanics of solids by LS Srinath,
4. Elasticity and Plasticity for structural Engineers by Wang & Chen

ELECTRONIC RESOURCES

Resource Type	Title/Description	Link
Online Courses	Swayam: Theory of Elasticity By Prof. Amit Shaw, Prof. Biswanath Banerjee, IIT Kharagpur	https://onlinecourses.nptel.ac.in/noc20_ce42/preview
	Mechanical Behaviour Of Materials By Prof. Shashank Shekhar, Prof. Sudhanshu Shekhar Singh, IIT Kanpur	https://onlinecourses.nptel.ac.in/noc23_mm44/preview#:~:text=He%20joined%20IITK%20in%202010%20and%20has,as%20well%20as%

		204th%20year%20 UG%20students.
You Tube DSS Lectures-MLRITM	Theory of Elasticity and Plasticity by Mrs.T.Neha	https://www.youtube.com/watch?v=oI_Srw3FD6g&t=52s

24. COURSE PLAN

S. No.	Topics to be covered	COs	Reference
1	Introduction to Stress: Definitions, Kinetics and Kinematics	CO1	R1: Ch.1, R2: Ch.1
2	Notation for forces and stress	CO1	R1: Ch.1, R2: Ch.1
3	Components of stresses, Stress tensor	CO1	R1: Ch.2, R2: Ch.2
4	Differential equations of equilibrium in 2D Cartesian coordinates	CO1	R1: Ch.3, R3: Ch.1
5	Differential equations of equilibrium in 3D Cartesian coordinates	CO1	R1: Ch.3, R3: Ch.2
6	Differential equations in polar coordinates, Boundary conditions	CO1	R1: Ch.3, R2: Ch.3
7	Cauchy's postulate, Stress transformation	CO1	R1: Ch.4, R2: Ch.4
8	Direction Cosines, Principal stresses	CO1	R1: Ch.4, R2: Ch.4
9	Stress invariants, Decomposition of stresses	CO1	R1: Ch.5, R4: Ch.2
10	Hydrostatic and Deviatoric stresses	CO1	R1: Ch.5, R4: Ch.2
11	Octahedral stresses, Stress concentration factors	CO1	R1: Ch.6, R4: Ch.3
12	Strain: Notation, Components	CO2	R1: Ch.7, R2: Ch.5
13	Strain tensor, Strain components	CO2	R1: Ch.7, R2: Ch.5
14	Strain-displacement relations	CO2	R1: Ch.8, R2: Ch.5
15	Strain compatibility conditions	CO2	R1: Ch.8, R2: Ch.5
16	Strain transformation, Direction Cosines	CO2	R1: Ch.8, R4: Ch.4
17	Principal strains, Strain invariants	CO2	R1: Ch.9, R4: Ch.4
18	Octahedral strains, Strain Rosette	CO2	R1: Ch.9, R4: Ch.4
19	Stress-Strain Relationships: Navier's equation	CO3	R1: Ch.10, R3: Ch.3
20	Relationship between Material constants	CO3	R1: Ch.10, R3: Ch.3
21	Stress-strain relations in 2D and 3D	CO3	R1: Ch.11, R4: Ch.5

22	Complementary conditions for shear	CO3	R1: Ch.11, R4: Ch.5
23	Material symmetry and Reduction of material constants	CO3	R1: Ch.12, R4: Ch.6
24	Plane stress, Plane strain, Axi-symmetric idealizations	CO3	R1: Ch.12, R4: Ch.6
25	Mohr circle in 2D and 3D	CO3	R1: Ch.13, R4: Ch.7
26	Airy's stress function, Potential function	CO3	R1: Ch.14, R4: Ch.7
27	Solution of 2D elasticity problems using stress function	CO4	R1: Ch.15, R4: Ch.8
28	Beam bending problems	CO4	R1: Ch.15, R3: Ch.4
29	Symmetric stress distribution problems	CO4	R1: Ch.15, R3: Ch.4
30	Plane problems, Torsion problems in elasticity	CO4	R1: Ch.16, R4: Ch.8
31	Membrane analogy approach, Application to non-circular thin-walled sections	CO4	R1: Ch.16, R4: Ch.9
32	Introduction to Plasticity	CO5	R1: Ch.17, R4: Ch.10
33	Yield criteria for pressure dependent and independent materials	CO5	R1: Ch.18, R4: Ch.10
34	Tresca criterion, Von Mises criterion	CO5	R1: Ch.18, R4: Ch.11
35	Mohr-Coulomb criterion, Rankine criterion	CO5	R1: Ch.19, R4: Ch.11
36	Flow rules – Associative and Non-Associative	CO5	R1: Ch.20, R4: Ch.12
37	Hardening rules and consistency conditions	CO5	R1: Ch.20, R4: Ch.12
38	Introduction to iterative methods and return mapping	CO5	R1: Ch.21, R4: Ch.13
39	Applications of plasticity in structural engineering	CO5	R1: Ch.21, R4: Ch.13
40	Unit Test / Review of all topics	CO5	R1: Ch.22, R4: Ch.14

25. PROGRAM OUTCOMES

PO NO	**NBA Statement / Vital Features**		
	Graduate Attributes	**Program Outcomes**	**No. of key competencies**
PO1	Research / Investigation	Independently carry out research / investigation and development work to solve practical problems	6
PO2	Report Preparation	Write and present a substantial technical report/document	6

PO3	Domain Mastery (Embedded Systems)	Demonstrate a degree of mastery over the area in Structural Engineering	6
PO4	Application of Engineering Principles	Impart core and interdisciplinary knowledge for analyzing and solving complex problems in structural engineering and related domains	4
PO5	Modern Tools & Societal Impact	Conceptualize and design safe, efficient, and sustainable civil engineering structures in social, economic, and environmental factors	6
PO6	Lifelong Learning & Adaptability	Engage in lifelong learning through continuous education, research, and professional development	8

26. HOW PROGRAM OUTCOMES ARE ASSESSED

PO No.	**NBA Statement / Vital Features**			
	Graduate Attributes	**Program Outcomes**	**Strength**	**Proficiency Assessed by**
PO1	Research / Investigation	Independently carry out research / investigation and development work to solve practical problems	1.2	CIE/ Quiz/ SEE/ CAT
PO2	Report Preparation	Write and present a substantial technical report/document	1	CIE/ Quiz/ SEE/ CAT
PO3	Domain Mastery (Embedded Systems)	Demonstrate a degree of mastery over the area in Structural Engineering	3	CIE/ Quiz/ SEE/ CAT
PO4	Application of Engineering Principles	Impart core and interdisciplinary knowledge for analyzing and solving complex problems in structural engineering and related domains	3	CIE/ Quiz/ SEE/ CAT
PO5	Modern Tools & Societal Impact	Conceptualize and design safe, efficient, and sustainable civil engineering structures in social, economic, and environmental factors	1.6	CIE/ Quiz/ SEE/ CAT
PO6	Lifelong Learning & Adaptability	Engage in lifelong learning through continuous education, research, and professional development	1	CIE/ Quiz/ SEE/ CAT

3 = High; 2 = Medium; 1 = Low

27. MAPPING OF EACH CO WITH PO(s)

COs	Program Outcomes (POs)					
	1	2	3	4	5	6
CO1	√		√	√	√	√
CO2	√		√	√	√	√
CO3	√		√	√	√	√
CO4	√	√	√	√	√	√
CO5	√	√	√	√	√	√

28. JUSTIFICATIONS FOR CO – PO MAPPING - DIRECT

Course Outcomes (COs)	POs	Justification for Mapping (Students will be able to...)	No. of Key Components
CO1: Analyze the state of stress in two- and three-dimensional systems using stress tensors, transformations, and invariants.	**PO1**	1: Identify and define research problems in stress analysis. 2: Apply innovative analytical approaches to evaluate stress states.	2
	PO3	1: Demonstrate theoretical mastery in stress transformation and invariants. 2: Apply analytical and computational tools for principal stress determination. 3: Integrate stress components for advanced problem-solving. 5: Validate analytical results through real-world structural interpretations.	4
	PO4	1: Employ advanced computational tools to solve elasticity and compatibility problems .2: Apply simulation results to assess structural performance. 3: Analyze interdisciplinary data for improved understanding. 4: Develop innovative approaches to validate elasticity theories.	4
	PO5	1: Apply safe and sustainable design considerations in stress evaluation.	1
	PO6	7: Engage in lifelong learning through advanced analysis of stress systems.	1
CO2: Interpret different components of strain and their transformations to determine principal and octahedral strains.	**PO1**	2: Review literature and analytical formulations for strain computation. 4: Conduct experimental or simulation-based analysis to validate strain transformation results.	2
	PO3	1: Demonstrate theoretical mastery of strain transformation concepts. 2: Apply analytical and computational methods for principal and octahedral strain evaluation. 3: Integrate stress–strain relationships for structural performance assessment.	4

		5: Interpret analytical outcomes to improve practical design accuracy.	
	PO4	1: Apply core and interdisciplinary knowledge to analyze strain tensors. 2: Utilize computational mechanics for complex strain field solutions. 3: Combine theoretical and numerical approaches for strain prediction. 4: Critically evaluate model assumptions and limitations.	4
	PO5	1: Ensure safety and material efficiency in strain-based design approaches. 2: Integrate sustainability concepts while optimizing material deformation responses.	2
	PO6	7: Engage in self-learning to advance understanding of modern strain analysis techniques. 8: Demonstrate commitment to professional growth through continuous upskilling in structural mechanics.	2
CO3: Derive stress–strain relationships and material constants for various material symmetries under plane and axi-symmetric conditions.	**PO1**	2: Conduct investigations on elastic constants and strain compatibility. 3: Perform analytical derivations of constitutive equations using theoretical frameworks.	2
	PO3	1: Demonstrate mastery of constitutive modeling and isotropic/anisotropic behavior. 2: Apply advanced elasticity theories to practical structural applications. 3: Validate models using material test data. 5: Relate theory to real-world stress–strain responses in engineering materials.	4
	PO4	1: Integrate material science and structural analysis principles. 2: Utilize computational modeling for material behavior simulation. 3: Employ theoretical-numerical coupling to derive constants. 4: Evaluate results through comparative interpretation.	4
	PO5	1: Incorporate sustainable material use and safety considerations in elastic design. 3: Apply material selection principles in line with environmental goals. 5: Assess economic feasibility of materials through mechanical efficiency.	3
	PO6	7: Exhibit self-directed learning in advanced material mechanics.	1
CO4: Solve two- and three-dimensional elasticity problems using stress function approaches and membrane analogy concepts.	**PO1**	3: Conduct experiments or simulations using appropriate tools. 4: Analyze elasticity solutions using numerical models .6: Validate theoretical solutions with computational outcomes.	3
	PO2	1: Prepare structured technical documentation for problem-solving procedures.	2

		4: Communicate elasticity results with clarity and accuracy.	
	PO3	1: Demonstrate mastery in analytical stress function methods. 2: Apply computational models for two- and three-dimensional elasticity problems. 3: Evaluate principal stresses using simulation-based tools. 5: Validate theoretical findings using applied problem-solving.	4
	PO4	1: Integrate core elasticity principles with interdisciplinary modeling. 2: Apply finite element methods for elasticity solutions. 3: Correlate theoretical and computational stress analysis. 4: Evaluate complex structures under multi-axial stresses.	4
	PO5	1: Design elasticity-based solutions ensuring structural safety. 4: Integrate sustainable and innovative materials in elasticity analysis.	2
	PO6	6: Apply self-learning through computational tools. 7: Engage in reflective learning on stress distribution and deformation. 8: Exhibit commitment to professional development in structural mechanics.	3
CO5: Evaluate yielding behavior of materials using different yield criteria and hardening rules in plasticity.	**PO1**	5: Apply innovative approaches to material yielding behavior. 6: Validate experimental and analytical models of plastic deformation.	2
	PO2	2: Develop structured reports explaining yield theories. 3: Communicate analytical and experimental findings effectively.	2
	PO3	1: Demonstrate mastery of yield criteria (von Mises, Tresca, etc.). 2: Analyze plastic deformation and stress-strain behavior using theoretical models. 3: Validate plasticity models through computational simulation. 5: Apply findings to engineering design processes.	4
	PO4	1: Apply interdisciplinary plasticity concepts with computational mechanics. 2: Evaluate multi-axial yielding problems. 3: Use simulation tools for plastic strain and stress distribution. 4: Assess practical implications in structural components.	4
	PO5	1: Incorporate safety and sustainability in plastic design. 2: Design components for resilience against failure. 5: Address social and environmental aspects in material selection.	4

		6: Apply innovative structural systems for durable plastic design.	
	PO6	6: Enhance self-learning on modern plasticity theories. 7: Pursue continuous learning on material hardening behaviors. 8: Apply advanced simulation tools for plastic deformation analysis.	3

29. TOTAL COUNT OF KEY COMPETENCIES FOR CO – PO MAPPING

Course Outcomes (COs)	**Program Outcomes**					
	1	**2**	**3**	**4**	**5**	**6**
CO1	2		4	4	1	1
CO2	2		4	4	2	2
CO3	2		4	4	3	1
CO4	3	2	4	4	2	3
CO5	2	2	4	4	4	3

30. PERCENTAGE OF KEY COMPETENCIES FOR CO – PO

Course Outcomes (COs)	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
No. of Key Components	**6**	**6**	**6**	**4**	**6**	**8**
CO1	33.33		66.67	100.00	16.67	12.50
CO2	33.33		66.67	100.00	33.33	25.00
CO3	33.33		66.67	100.00	50.00	12.50
CO4	50.00	33.33	66.67	100.00	33.33	37.50
CO5	33.33	33.33	66.67	100.00	66.67	37.50

31. COURSE ARTICULATION MATRIX (PO MAPPING)

CO'S and PO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

0- 0≤ C≤ 5% – No correlation,
1- 5 <C≤ 40% – Low/ Slight
2 - 40 % <C < 60% –Moderate
3 - 60% ≤ C < 100% – Substantial /High

Course Outcomes (COs)	**Program Outcomes**					
	1	**2**	**3**	**4**	**5**	**6**
CO1	1		3	3	1	1
CO2	1		3	3	1	1
CO3	1		3	3	2	1
CO4	2	1	3	3	1	1
CO5	1	1	3	3	3	1
Average	1.2	1.0	3.0	3.0	1.6	1.0

32. ASSESSMENT METHODOLOGY DIRECT

CIE Exams	✓	SEE	✓	Seminars	-
Objective / quiz	-	Viva-Voce/PPT	✓	MOOCS	-
Assignments	✓	Project	-		

33. ASSESSMENT METHODOLOGY INDIRECT

✓	Course End Survey (CES)

34. POs-WKs Mapping

POs		WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9
	No of Indicators	5	4	4	3	4	5	4	6	4
PO1	Research/ investigation	3	4	4	3	4	5	4	6	4
PO2	Report Preparation	1	1	1	1	1	1	2	1	2
PO3	Domain Mastery	3	3	4	2	4	5	3	6	3
PO4	Application of Engineering Principles	5	3	4	3	4	5	4	6	5
PO5	Design and Sustainability	3	3	4	2	4	5	3	6	3
PO6	Lifelong Learning and Professional Development	3	3	4	2	4	5	4	6	5

35. Percentage of POs-WKs Mapping

POs		WK1	WK2	WK3	WK4	WK5	WK6	WK7	WK8	WK9
	No of Indicators	5	4	4	3	4	5	4	6	4
PO1	Research/ investigation	60	100	100	100	100	100	60	100	100
PO2	Report Preparation	20	25	25	33	25	20	20	25	25
PO3	Domain Mastery	60	75	100	67	100	100	60	75	100

PO4	Application of Engineering Principles	100	75	100	100	100	100	100	75	100
PO5	Design and Sustainability	60	75	100	67	100	100	60	75	100
PO6	Lifelong Learning and Professional Development	60	75	100	67	100	100	60	75	100

36. RELEVANCE TO SUSTAINABILITY GOALS

Theory of elasticity and plasticity play a significant role in advancing various SDGs.

S.NO.	SDGS	DESCRIPTION
1	NO POVERTY	
2	ZERO HUNGER	
3	GOOD HEALTH AND WELL-BEING	Ensures safety and reliability of structures such as hospitals and community buildings by accurate stress and strain analysis, preventing structural failures that can endanger lives.
4	QUALITY EDUCATION	Strengthens quality education by developing analytical, design, and problem-solving skills essential for sustainable engineering practices.
5	GENDER EQUALITY	

6	CLEAN WATER AND SANITATION	
7	AFFORDABLE AND CLEAN ENERGY	
8	DECENT WORK AND ECONOMIC GROWTH	
9	INDUSTRY, INNOVATION AND INFRASTRUCTURE	Develops the ability to design, analyze, and optimize safe, sustainable, and innovative infrastructure using elasticity and plasticity principles.
10	REDUCED INEQUALITIES	
11	SUSTAINABLE CITIES AND COMMUNITIES	Enables the design of earthquake-resistant, resilient, and sustainable structural systems for urban and rural development.
12	RESPONSIBLE CONSUMPTION AND PRODUCTION	
13	CLIMATE ACTION	
14	LIFE BELOW WATER	

15	LIFE ON LAND	Promotes sustainable land infrastructure by reducing the environmental footprint through optimized structural design and material selection.
16	PEACE, JUSTICE AND STRONG INSTITUTIONS	
17	PARTNERSHIPS FOR THE GOALS	Encourages interdisciplinary research collaborations and industry partnerships for solving real-world structural and material challenges.

Signature of Course Coordinator **HOD**