Video lectures on SOM by Prof. K. Ramesh complete playlist

| Lecture | Concepts covered |
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| 1. Introduction to Strength of materials - 1 | Common to spectacular failures of structures. Importance of idealisations in Engineering. Idealizations made in Strength of materials - small deformation, material homogeneity, isotropy and elastic continuum. Structures that support transverse loading. Slender member. Knowledge of deformation in solving statically indeterminate problems. Pictorial representation of resistance offered by a member in tension, bending or torsion. Visualization of resistance by photoelasticity for a spanner, a member in tension and in pure bending. Complexity of stress fields due to discontinuities in shape. Historical evolution of stress variation in a beam. Strength of materials in the 17th century. |
| 2. Introduction to Strength of materials - 2 | Strength of materials in the 17th, 18th and 19th centuries. Madhava's contribution to Calculus. Ecole Polytechnique's role in SOM. Timeline of advances in material science. Demonstration of failure of chalk in tension and torsion; ductile material in tension. Orthotropy, anisotropy, composites for light structures. Nature inspired engineering- strain-induced alignment of collagen, biomimetics in self-healing composites. Functionally graded materials: bones, tooth and even plants! All idealizations are violated in modern engineering - Metallic foam, heterogeneity, manufacturing methodology influencing the strength, Rapid Prototyping – Photoelasticity is indispensable for solving modern problems. |
| 3. Stress component is Scalar | Deformation of springs in series, parallel. Importance of force-deformation relation. Extension to characterize the material. Elegance of plotting stress vs strain. Stress appears scalar – can be used to solve simple problems. Geometric compatibility. Force developed while tightening a nut - Bolt-nut problem - need for development of suitable compatibility condition. Deformation of thin cylinders. Taking center line of the pressure vessel for calculations. Photoelastic visualization of stress in thin and thick cylinders. |
| 4. Stress Vector | Stress component is scalar, useful to solve simple problems like thin cylinder subjected to internal pressure. Hoop stress. Stress varies from point to point; evident from photoelastic fringe patterns. Cross-section also can vary from point to point. Desirable to evolve new mathematical entities to go down to a point. Definition of Stress vector, Definition of normal and shear stress, Stress components on x, y, and z planes. Meaning of two indices, Chalk experiment prompts information of stress vector on an arbitrary plane. State of stress at a point, Pictorial representation of stress tensor. Stress vector on an arbitrary plane at a point. Derivation of Cauchy's formula. |
| 5. Stress Tensor | Mathematical representation stress tensor, Stress tensor in two dimensions, Construction of stress tensor for simple problems in tension and pure shear. Variation of stress vector, normal stress and shear stress for a point in a tension member as polar plot. Photoelastic visualization of Saint Venant's principle. |
| 6. Equilibrium Conditions | Necessary and sufficient conditions of equilibrium for a particle, rigid body and deformable solids. Systematic explanation of using Taylor's approximation over a small element in x-direction. Force equilibrium; accommodating body force. |

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| | Moment equilibrium, equality of cross-shears. Stress transformation law from first principles. Matrix representation of stress transformation. |
| 7. Mohr's Circle | Review of drawing normal and shear stress as a polar plot. Construction of Mohr's circle. The use of sign convention and its importance. Location of arbitrary planes on a Mohr's circle. Definition of the principal stresses and principal planes using Mohr's circle. Correlation between orientation of principal and maximum shear stress planes. Reason for the chalk failure in a particular manner subjected to tension. |
| 8. Proof of Mohr's Circle | Discussion on planes of maximum shear stress. Each point on a Mohr's circle represents a plane, Proof of Mohr's circle, Mohr's circle for different states of stresses (uniaxial, biaxial and pure shear), Discussion on critical planes for ductile and brittle material failing under uniaxial stress. Importance of zero value of the other principal stress when both the principal stresses are either positive or negative. Special case where all planes are principal planes. Reason for the chalk failure in a particular manner subjected to torsion. Mohr's Circle for 3D stress state. Local and Global maximum of shear stress and their importance in practical applications. |
| 9. Principal Stresses | Different graphical representations of the state of stress other than Mohr's circle - Lame's ellipsoid, Cauchy's stress quadric. Stress transformation using indices. Definition of principal planes. Determination of principal stresses and their directions mathematically from Cauchy's formula. Cubic equation. For non-trivial solution the determinant has to be zero. Definition of stress invariants. Principal stresses and their orientations – expressions for 2-dimensional problems. Different representations of state of stress. Utility of Invariants. |
| 10. Octahedral and Deviatoric Stresses and Principal Directions | Invariants in terms of principal stresses. Octahedral stress plane; expressions for normal and shear stress on the octahedral stress plane. Decomposition of a stress tensor into hydrostatic and deviatoric stress tensor. Relation between stress vectors on any two arbitrary planes. Principal stress direction by eigen vector approach. Mathematical proof that principal planes are mutually perpendicular. Experimental demonstration of principal planes being mutually perpendicular – example of brittle coating results. Numerical verification of the relation between stress vectors on any two arbitrary planes. Solving a numerical problem that involves tensorial representation and pictorial representations of state of stress, stress transformation, principal stress determination, association of its direction based on the sketch of Mohr's circle, and verification of results using stress invariants. Clear appreciation of Mohr's circle. |
| 11. Free Surfaces | Definition and examples of Free surface, Utility of Equality of cross-shears, Explaining shear cannot cross a free boundary with different examples, Proof that at outward corners both stress vector and stress tensor are zero. Importance of free surface in validating boundary conditions in numerical methods, Comparing stress state at free outward and re-entrant corners, State of stress in a Pressure Vessel, Design of composite pressure vessel and tyres inspired by nature. Locomotion of Nemertine worms. |

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| 12. Photoelasticity | Brief introduction to photoelasticity, Nature of light, Concept of birefringence, polarization, basics of crystal optics. Demonstration that ordinary and extraordinary rays are plane polarized, and their planes are mutually perpendicular, Retardation plates, stress-optic law. Conventional Photoelasticity, Home made polariscope setup. Appreciation of whole field information. Features of Simulation software P_Scope® Analytically plotting sigma x contours for a beam under four-point bending. Establishing that photoelasticity gives contours of principal stress difference. Establishing that principal stress directions remains constant even on changing load magnitude. Maximum shear stress occurs beneath the surface for contact stress and role of friction in it. |
| 13. Strain | Perception of large deformation and lateral strain by stretching rubber band, Plane strain, circles deforming into ellipses under load. Investigation under uniform and non uniform strain, example of gudgeon pin by super plasticity. Infinitesimal strain is the focus from Tensile test for Mild steel specimen. Simplistic definition of normal and shear strains. Relation between strain and displacement. All relative displacements do not cause strain with the example of cantilever beam under point load. Strain matrix, Strain tensor and rigid body rotation. Strain Transformation Law, Principal strain and directions. |
| 14. State of Strain | Mohr's circle for Plane Strain, Need for defining strain at a point, Analysing Principal strains and their directions using Mohr's circle, Is Photoelasticity only applicable to transparent materials? Use of Reflection Photoelasticity in practical applications, Strain-displacement relations in Polar coordinates, Finite Strain Components, Deformation Gradient Tensor, Relationship between Displacement gradient, Strain and Rotation |
| 15. Strain Measurement | Range of stress/strain measurement of various experimental techniques, Strain gauge, Gauge length, Thumb rule in selection of gauge length, Strain sensitivity of a wire. Construction of a strain gauge, resistance values, Definitions of transverse sensitivity factor and gauge factor, Pasting of strain gauges and connecting them to the Wheatstone bridge for the optimum measurement. Determination of strain at a point, Rectangular rosette, Delta rosette. Strain gauge designation systems and selection. |
| 16. Tension Test | Normal stress produces normal strain and shear stress produces only shear strain for isotropic materials. For anisotropic materials normal stress can produce both normal and shear strains and vice versa. Salient features of the Tension test – failure of ductile material in tension, DIC integrated testing systems. Overview of DIC. Stress-strain diagram for brittle materials – tension and compression strength. Stress-strain diagram for mild steel, alloy steel, and brass, recognizing that mild steel and alloy steel have the same Young's modulus. Identification of yield strength – use of 0.2% offset. Salient points on the stress-strain curve - Proportional limit, Elastic limit, Upper and lower yield points, strain hardening, necking. Discussion on necking. Experimental results on necking precipitated by internal flaws. Experimental demonstration of fatigue failure. |

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| 17. Stress Strain Relations | Necking, Cup and cone fracture. Showing stress-strain curves for various length scales from 40% strain, 30%, 20%, 10%, 4%, 3%, 2%, 1%, 0.4%, 0.3%, 0.2%, 0.1% etc. Justification of simplified modeling such as rigid, rigid plastic, linear elastic, bilinear elastic plastic, elastic perfectly plastic, elastic-plastic. Stress-strain relation in tension test. Determination of Poisson's ratio from the tensile test. True stress – true strain relations. Stress-strain relations under general loading. |
| 18. Inter-relations between Elastic Constants | Elastic stress strain relations, Stress strain curve in tension and torsion. Volumetric strain. Interrelationships between Young's, Shear and Bulk Moduli. Limiting values of Poisson's ratio, Cork and rubber have extreme values. Utility of Negative Poisson's Ratio in stents made of auxetic materials. Stress Strain relationship for General loading case, Stress Strain relationship in terms of Lame's constants. Influence of Loading sequence on Yield strength, Bauschinger's Effect. Relook at Isotropic, Orthotropic and Anisotropic material behaviour. How manufacturing techniques effects the material properties, Generalized Hooke's Law, Number of Elastic constants required for Isotropic, Orthotropic and Anisotropic materials. Isotropic material requires only two elastic constants. |
| 19. Thermal Strain | Thermal Strain, Stress-Strain Temperature relations, Engineering approach to mitigate thermal effects, Continuous welded rails and Rail Neutral Temperature (RNT), Solving a composite hoop subjected to temperature change. What is glass and improvements in Glass strength by using thermal effects. Tempering also makes the glass fail safely, Use of photoelasticity in stress analysis of as well as in checking its manufacturing. Solving the tightened bolt and nut combination subjected to temperature change, Stresses in the system due to mechanical and thermal load, Improved strength and flexibility of Gorilla Glass. |
| 20. Torsion - 1: Thought and Physical Experiments | Introduction to Torsion, Types and application of shafts, Torsional springs, Quantities to be determined in a torsion problem Geometry of deformation of a twisted circular shaft, Cross–section of a uniform circular shaft remains plane before and after twisting, Concept of warping of cross-section in square shafts, Shear effects in circular shaft due to torsion, Twisting Moment diagram. |
| 21. Torsion - 2: Mathematical Development | Discussion on plane sections remain plane before and after loading for a uniform circular shaft, loading of the tension spring, Deformation of a twisted circular shaft, Shear strain components in torsion, Determination of strain components, Stresses from stress-strain relations, Shear stress and its variation and the plane on which it acts, Relation between torque and angle of twist, Spring constant of a shaft, Torsion formula, Stress tensor in torsion. |
| 22. Torsion - 3: Problem solving, Hollow shaft | Torsion formula. Problem of a lift. Design approaches for shaft through an example, Torsion of elastic hollow circular shaft. Shaft design is usually stiffness based. Open sections have poor torsional rigidity. Mohr's circle for stresses in a shaft. How to measure torque using strain gauges? Problem of finding the distribution of twisting moment, angle of twist and shear stress along the shaft. |
| 23. Bending - 1: Euler Bernoulli Hypothesis | What is a beam? – Slender beam. Practical examples of beams – bridges, leaf springs – cross section of a Rail. Resolution of a force into a force and a couple. Simply way to plot SFD and BMD. Beam under four-point loading – SFD and BMD – pure bending – applications in daily life. Variation of internal resistance in axially |

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| | loaded members, beams and shafts. Assumptions in developing beam theory. Curvature of beams. Engineering and exact analysis of beams. Euler-Bernoulli Hypothesis. Deformation of a cross section of beam under bending. Concept of neutral axis and neutral surface – loading plane – plane of symmetry. Determination of axial strain – linear variation over the depth of beam. |
| 24. Bending-2: Flexure Formula | Axial strain variation over the depth of the beam. Investigation of existence of other strain components. Discussion on assumption of transverse behavior. Stress components in pure bending – Normal stresses $\sigma_y$ and $\sigma_z$ do not exist. Similarly, $\tau_{yz}$ also does not exist. Definition of anticlastic curvature and synclastic curvature – experimental visualisation of anticlastic curvature in beams. Equilibrium requirements. Location of Neutral axis. Role of symmetry of cross-section in satisfying equilibrium requirement. Introduction to flexural formula. Visualization of stresses due to tension or bending – Use of photoelasticity in learning SOM and solving current problems. |
| 25. Bending-3: Engineering Analysis of Beams | Beam theory applied to a stepped beam. Stress tensor in a beam satisfies the equilibrium conditions. Is beam theory applicable to a cantilever beam? – Engineering analysis of beams - just use BM and SF for calculations at that point – Photoelasticity is useful to learn SOM. 3-point bending - need to compare SOM and Theory of elasticity (TOE) solutions - shear effects are strong near load application points as revealed by photoelastic experiment. Inter-relationship between bending moment, loading and shear force. Bookshelf problem – Tips on drawing SFD and BMD quicker – Surprise from TOE on correction to bending stress and existence of σy. Work of Da Vinci and Galileo – His famous beam under bending – Behavior of a ruler under different orientations. Other historical evolution of stress variation in a beam. |
| 26. Bending - 4: Shear Stress in Beams | Warping due to shear. Experimental observation of shear development – a case study using homogenous and layered beams. Slipping of layers of the layered beam. Shear in beams is due to combined effect of shear force and varying bending moment. Determination of shear flow, shear stress and its variation. Shear stress distribution in a rectangular beam. Verifying zero shear stress on top and bottom surfaces through the concepts of a free surface and equality of cross shears. Effect of shear stress in a cantilever – a photoelastic study – absence of neutral axis as black fringe - indication of non-linear variation of shear stress. Relative magnitudes of bending and shear stress in a rectangular beam – pictorial representation. Stress tensor representation at key points in the cross-section. |
| 27. Bending-5: Composite Beams | Shear stresses in beams – A recap, Understanding the contributing moment of area for shear stress in built-up beams, Task to analyse equilibrium of vertical cuts in a rectangular beam section, Strain and stress variations in composite beams, Applicability of simple beam theory to open sections, Bending analysis of composite beams using curvature, Strengthening of beams against bending, Strain compatibility and stress discontinuity at the material interface in composite sections, Shear effects near load application points and inadequacy of SOM solution demonstrated by photoelasticity, Strengthening of beams against high shear. How to reinforce a concrete beam? Concrete beam analysis using |

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| | Transformed Area Method, Shift of neutral axis from centroidal axis in asymmetric composite sections, Strain and stress variations in a concrete beam. |
| 28. Bending-6: Shear in I-Beams and Shear Centre | Shear stress distribution in closed sections, Consistency of free surface arguments, Equilibrium of vertical cuts for closed sections, Deriving the shear stress distribution from differential equations of equilibrium, Shear flow in open sections, Equilibrium of vertical cuts for open sections, Shear stress in I-beams, Linear variation of shear stress in flanges, Quadratic variation of shear stress in webs, Stress Discontinuity at junctions, Inconsistencies in shear stress formula, Relative magnitudes of bending and shear stresses, Web buckling as a result of high shear in webs, Buckling in flanges due to bending compression, Honeycomb structures to enhance moment of inertia, Response of unsymmetrical sections to transverse loading, Shear centre of unsymmetrical sections with non-zero products of inertia, Experiment on shear centre, Stress tensor in bending |
| 29. Bending-7: Unsymmetrical Bending and Combined Loading | Limitations of shearing stress formula: Violation of boundary condition in circular sections subjected to bending shear but consistency when subjected to twisting shear. Unsymmetrical bending: Bending about two axes; Non-zero products of inertia. Neutral axis in unsymmetrical bending. Load transmitted by a torsional spring, Photoelastic experiments on a crane hook, Shift of neutral axis in homogenous curved sections, Hyperbolic stress variation across depth of curved beams. Human femur and its loading, Simplified modelling of load acting on a femur, Careful use of principle of superposition to obtain the stress tensor in a femur for combined loading. |
| 30. Review 1 | Force transmitted by a slender member, Experimentally visualizing variation of internal resistance. Idealisations and characterisation of materials. Axial, Flexure and Torsion Formulae, Relevance of stress and strain, Stress as a scalar, vector and tensor quantity, Stress tensor components, Cauchy's Formula, Equality of cross-shears, Polar plot of normal and shear stresses, Saint Venant's principle using photoelasticity, Taylor's approximation in deriving differential equations of equilibrium, Stress transformation law, Principal stresses and directions using Mohr's Circle and eigen approach, Utility of stress invariants, Orthogonality of principal planes, Free surface, Stresses in thin pressure vessels, Composite cylinders and Nemertine worms, Strain and strain-displacement relations, Strain and rotation tensors, Mohr's circle of strain, Finite strain components, Stress-strain curves for brittle and ductile materials, Determination of yield strength and stress-strain relations. |
| 31. Deflection-1: Moment-Curvature and Load-Deflection | Curvature in pure bending of beams, Euler-Bernoulli hypothesis, Nonlinear relation between curvature and deflection, Error involved in linearised curvature, Moment - curvature relation, Approximation in neglecting shear effects in slender and deep beams, Flexural rigidity (Bending Modulus) of sections. Various methods to determine deflection of beams: Double and quadruple integration methods and their applicability to statically determinate and indeterminate problems, Moment area method, Method of superposition, Energy methods. Evaluation of deflection for a simple beam using double integration method. Experimental visualisation of boundary conditions for various supports, Experiment showing slope and rigid |

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| | body rotation of elastic curve, Slope and deflection of a cantilever beam using double integration method. |
| 32. Deflection-2: Moment-Area Method | Boundary conditions for various supports – revisited, Slope and rigid body rotation of elastic curves, Integration of load-deflection equation for statically indeterminate systems using propped cantilever example. Standard results for slopes and deflections. Moment-area method: Moment-area theorems for change of slope and tangential deviation, Slope and deflection calculation of a simple beam using moment-area method. Method of Superposition: Validity of the method of superposition for small deformations in linear elastic materials, Examples for decomposing unknown problems as sum of known problems. |
| 33. Deflection-3: Method of Superposition and Energy Method | Method of Superposition for solving slope, deflection, unknown reactions in statically indeterminate problems, support reactions in continuous beams. Potential and complementary energy in deformable solids. Simplification in linear systems, Castigliano's theorem to find in-line deflection, Fictitious load method for evaluating generalised deflections at any point and direction. Strain energy stored in structural members subjected to Axial, Bending, Torsion and Shear loads. Elegance of energy approach to determine deflection under combined loading of bending and torsion. Evaluation of shear contribution to deflection in a cantilever beam. |
| 34. Deflection-4: Fictitious Load Method | Relative magnitudes of bending and shear contribution to deflection of beams, Castigliano's theorem and procedure for fictitious load method, Example problem of a cantilever beam using fictitious load method, Generalised force system and generalised deformation. Importance in learning how to move a force acting at one point to another point. Use of this in finding the force system transmitted by a tension spring. Evaluation of stiffness of a tension spring using energy method. Deflection of a frame by different idealisations. How a simple pin joint idealisation makes the mathematics very simple leading to acceptable engineering solution. Brief introduction to the Finite Element Method. |
| 35. Theories of Failure – 1: Overview | Comparison of stress-strain curves – Brittle, Ductile and Highly elastic materials. Failure of brittle materials subjected to tension and torsion – A review. Tension vs Torsion test, Yield strength of material in tension and shear. Why factor of safety required? Theories of failure – An introduction. Multiaxial loading and comparison with test data. Maximum principal stress theory, Maximum elastic strain theory, Maximum shear stress theory. Decomposition of a stress tensor into hydrostatic and deviatoric (pure shear) states, Deviatoric plane or the π-plane, Concept of failure envelope, Yield surface for Tresca Criteria – Shear diagonal. Elastic energy. Maximum Elastic Energy theory. Energy for volumetric change. Maximum Distortion Energy theory. Octahedral stress plane, Octahedral shearing stress theory. |
| 36. Theories of Failure – 2: Yield surfaces, Mohr's Theory and Failure | Failure theories in a nutshell, Yield surface for Tresca criteria and von Mises in 3D – Identifying shear diagonal – limiting values. Comparison of Tresca and von Mises criteria. Bi-axial test specimens. Validation of Tresca and von Mises based on test data. Mohr's theory of failure (Stress-Difference Theory) – Envelope of failure. Modified Mohr's theory. Griffith's modification to Mohr's theory. Combined loading. |

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| in Combined Loading | Design of shafts subjected to bending and torsion based on bending and twisting moments. Discussion on factor of safety. Rotation of shafts in bending leading to fatigue loading - increasing factor of safety value. More questions need detailed new tests. Test for fatigue strength – Endurance limit. Testing of cracked specimen to generate crack growth curves. Split-Hopkinson's bar for characterizing high strain rate behaviour of materials. Illustrative problems on combined loading and design verification. |
| 37. Stability–1: Governing Equations, Fixed-free and Pinned-pinned | Opening remarks on stability, Classifications of column failure – What is Buckling Failure? Buckling is sudden but configuration is in Neutral Equilibrium! Euler Buckling Loading. Useful effects of buckling! – Snap buckling. Governing equation developed based on deformed configuration. Importance of boundary conditions playing a crucial role on the value of critical load. Analysis of columns with fixed-free ends; Solution based on 4th order and 2nd order differential equations. Pinned-pinned ends using 4th order differential equation; Boundary conditions, Critical load for buckling, Mode shapes, equation of the deflected curve. Reason for the coefficient being indeterminate, Analytical analysis valid till critical load but experiment is truth beyond that. |
| 38. Stability–2: Fixed-pinned, Fixed-fixed | Analysis of columns with Fixed-pinned ends and with Fixed-fixed ends; Boundary conditions, Critical loads for buckling, Mode shapes, Equation of the deflected curve. Summary of critical loads for different end conditions. Equivalent length, Slenderness Ratio. Use of buckling as energy absorber. Buckling experiments are expensive. Deviation from analytical predictions are the highest.<br><br>Collection of photoelastic patterns for different loading and end conditions of beams. Deviations of SOM from TOE for these cases. |
| 39. Review 2 | Continuation of review of Lec. 30. Determination of Poisson's ratio. Inter-relations between E, G and v; E, K and v. Limiting values of Poisson's ratio. Generalized Hooke's Law. Number of Elastic constants required for Isotropic, Orthotropic and Anisotropic materials. Stress-Strain temperature relations – Composite hoops. Stress and strain variations in Composite beams. Basics of photoelasticity. Experimental techniques to measure strain. Strain measurement using strain gauges. Torsion of circular shafts – Torsion formula. Euler-Bernoulli hypothesis – Summary of results – Flexure formula. Applicability of Flexure formula. Shear in beams. Inter-relationship between bending moment, loading and shear force. Slipping of layers causing shear in beams. Relative magnitude of shear stresses in rectangular beams. Shear in open sections, Inconsistencies in shear stress formula; Shear center, Unsymmetrical bending. Actual loading of tension and torsion springs. Inadequacies of solution from SOM: Shear effects near loading points; Stress components in a UDL beam – TOE solution. Deflection of beams, Boundary conditions for various supports, Method of superposition, Fictitious load method. Finite element method – An introduction. Failure theories in a Nutshell. Shaft transmitting bending is loaded in fatigue. Stability of columns: Critical load, Equivalent length. Photoelastic visualization of Saint Venant's Principle |

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**Books and References**


1. Crandall SH, Dahl NC, Lardner TJ. An introduction to mechanics of solids. Tata McGraw-Hill Education


Perquisite: Engineering Mechanics