Industry Ready Engineer

Structural Analysis Framework

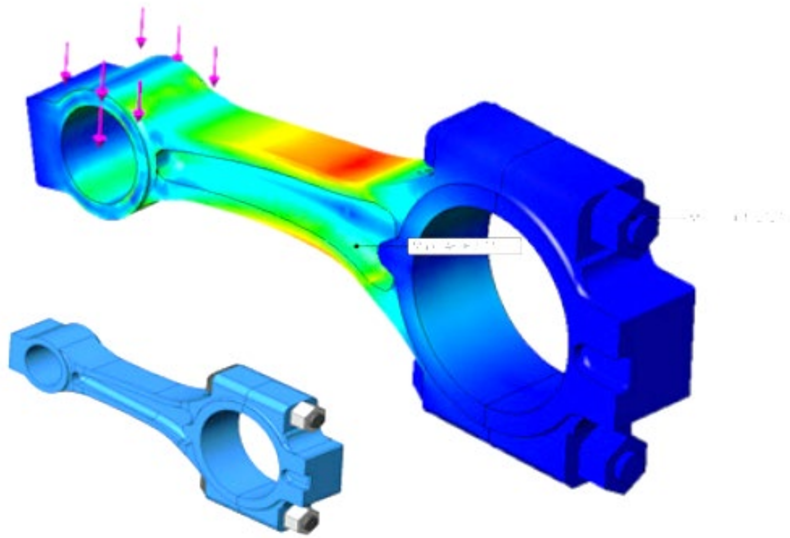
Role of Stress Engineer

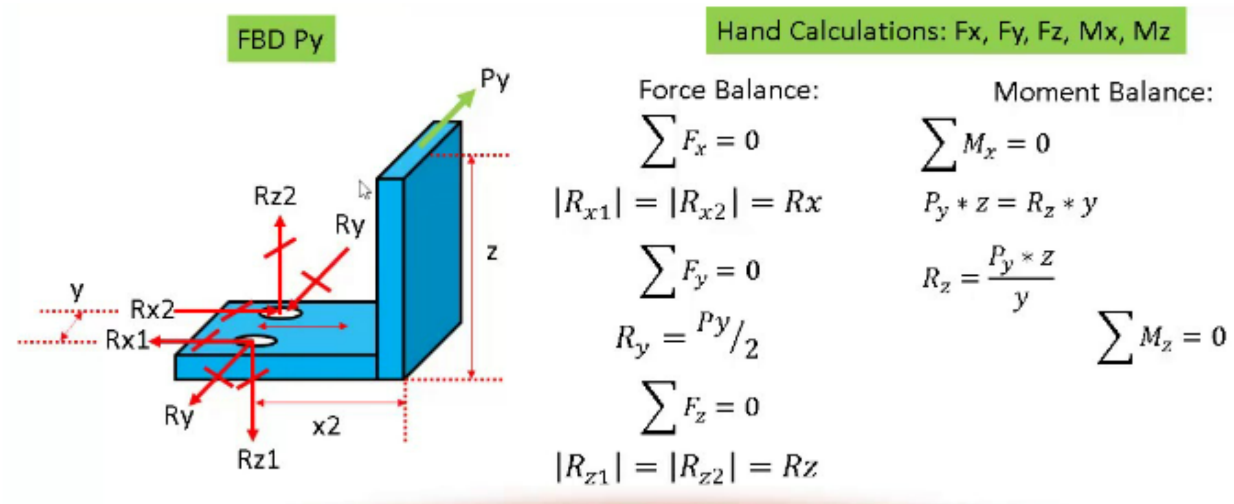
- Stress Engineers ensure that things Do not Break!
- They also predict the instances of loads where things can break!
- For this they do Structural Analysis
- Stress analysis by hand calculations and/or finite element analysis (FEA)
- Give solution to failures of structures
- Understanding of structure using reverse engineering

Tacoma Bridge 1940

Structural Analysis Framework

1. Understanding The Structure and Its Design Requirements
2. Structural Reduction
3. Understanding Material
4. Structural Parameters, Load Calculations and Load Path
5. Analysis Requirements
6. Initial Sizing
7. Performing Detailed Analysis Process
8. Structural Changes Using Analysis Outputs
9. Structural Analysis Reports/ Strength Check Notes
10. Structural Tests / Analysis Validation

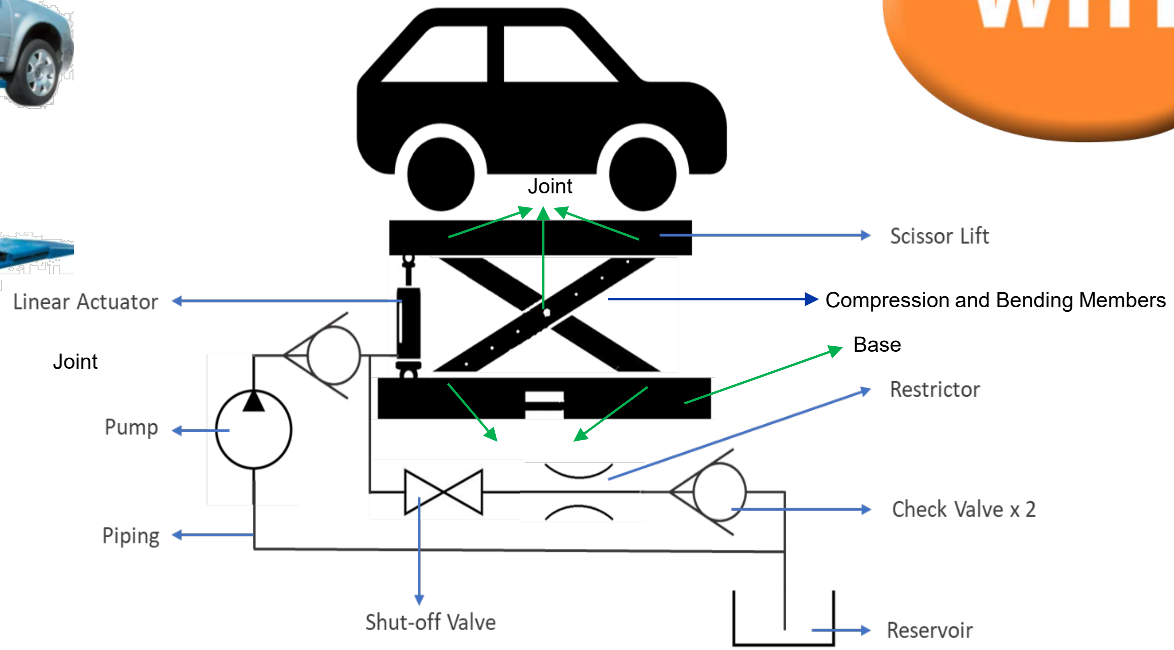




Structural Analysis Framework

1.Understanding the structure:

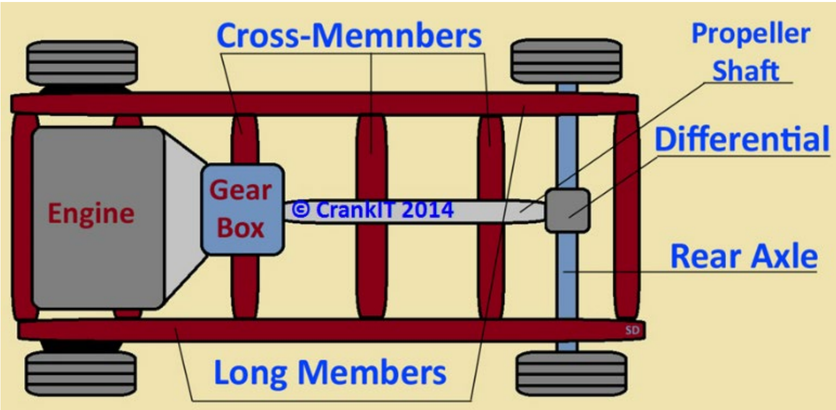
- Understanding the function of structure with WHY, HOW,WHERE and What.
- Why is the structure designed or to be designed (Top level Understanding) ?
- How is the structure connected to other structures or with in the structure itself ?
- Where are the connection points (Joints) and what are the types ?

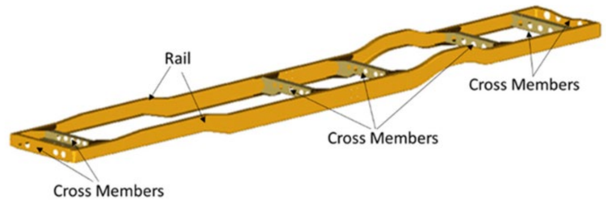


Structural Analysis Framework

1.Understanding the structure:

- Understanding the function of structural components individually on top level, For example: **Identifying rods, beams, columns, plates etc.**
- Understanding the structural requirements (From the owner and from certifying agencies MIL, ASTM, SAE, FAA, EASA etc.)

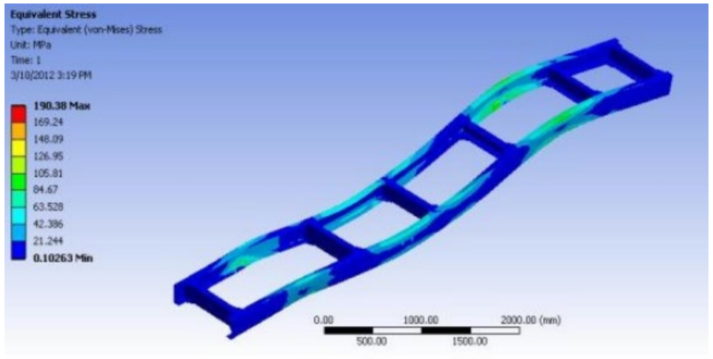




§ 25.303 - FACTOR OF SAFETY.

Unless otherwise specified, a factor of safety of 1.5 must be applied to the prescribed limit loads which are considered external loads on the structure. When a loading condition is prescribed in terms of ultimate loads, a factor of safety need not be applied unless otherwise specified.

[Amdt. 25-23, 35 FR 5672, Apr. 8, 1970]



[CFR Subpart C Section 25 561]

(3) The occupant experiences the following ultimate inertia forces acting separately relative to the surrounding structure:

(i) Upward, 3.0g

(ii) Forward, 9.0g

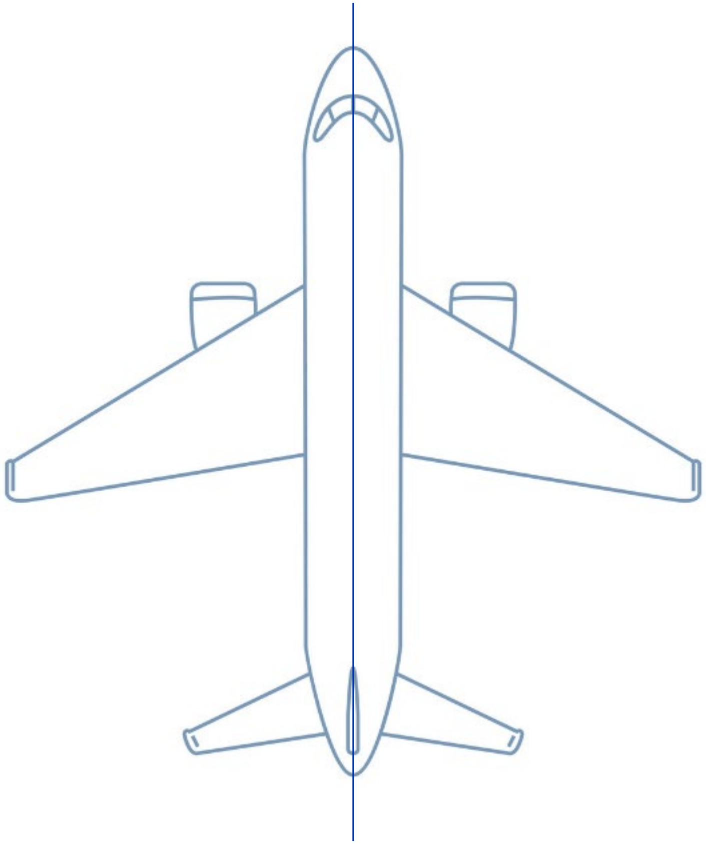
(iii) Sideward, 3.0g on the airframe; and 4.0g on the seats and their attachments.

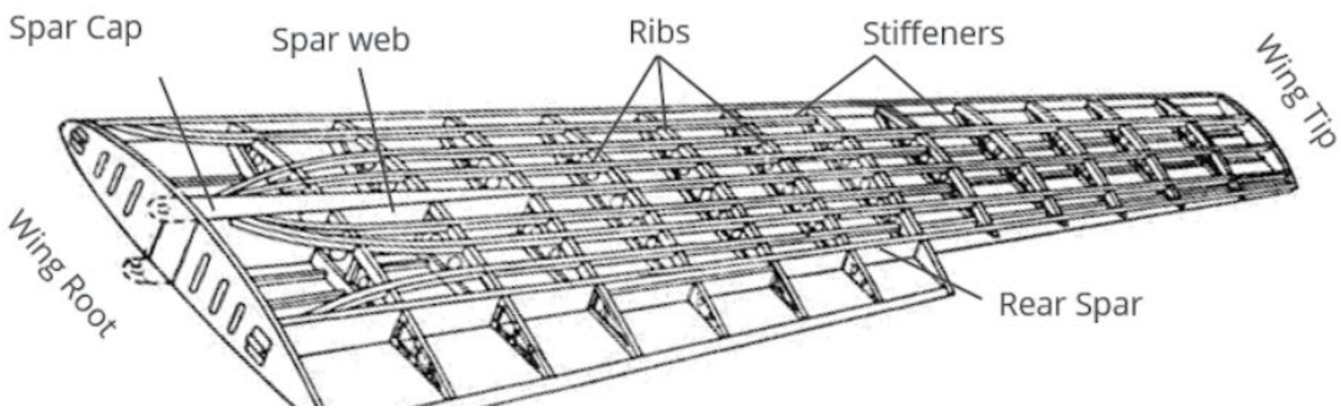
(iv) Downward, 6.0g

(v) Rearward, 1.5g

Structural Analysis Framework
2. Structural Reduction:

- Identifying and listing each structural component.
- Identifying similar components.
- Identifying the structural symmetries
- Summarizing the unique components.





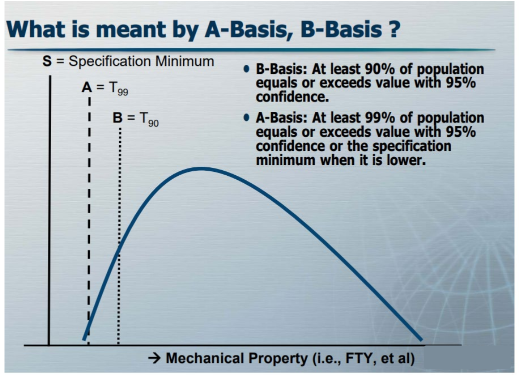
Structural Analysis Framework
3. Understanding Material:

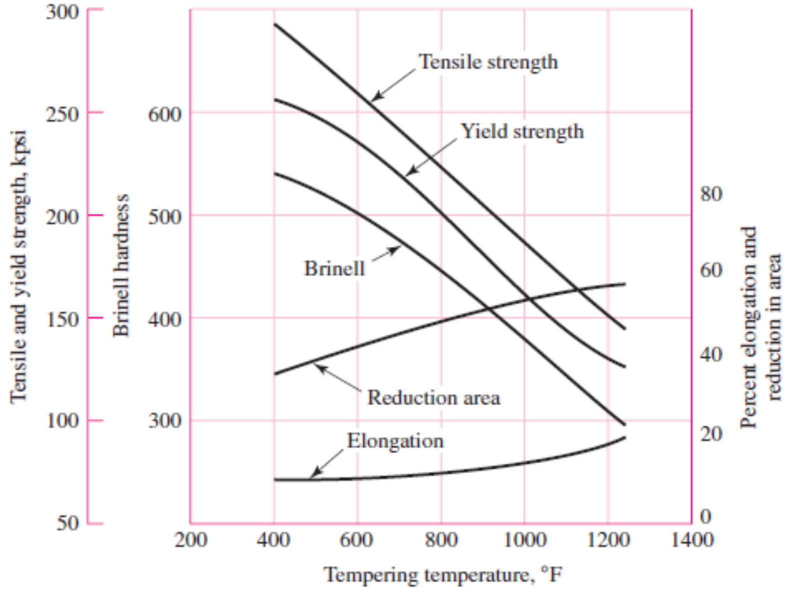
- Understanding the material inputs for structural analysis.
- Material Standards
- Material allowable and knockdowns factors (fitting/environmental) etc.

Table 3.2.4.0(e₁). Design Mechanical and Physical Properties of Clad 2024 Aluminum Alloy Sheet and Plate (Continued)

Specification	AMS-QQ-A-250/5[a]								
Form	Flat sheet and plate								
Temper	T81		T851[b]			T861[b]			
Thickness, in.	0.010-0.062	0.063-0.249	0.250-0.499		0.500-1.000[c]	0.020-0.062	0.063-0.249	0.250-0.499	≥0.500[c]
Basis	S	S	A	B	S	S	S	S	S
Mechanical Properties:									
F_{tu}, ksi:									
L	64	67	65	66	63	65	70	68	67
LT	62	65	65	66	63	64	69	68	67
F_{ty}, ksi:									
L	57	59	56	58	56	59	65	62	61
LT	54	56	56	58	56	58	64	62	61
F_{cy}, ksi:									
L	55	57	56	58	56	59	65	62	61
LT	55	57	57	59	56	61	67	65	64
F_{su}, ksi	38	39	37	37	36	36	39	39	38
F_{bru}[b], ksi:									
(e/D = 1.5)	96	100	99	100	96	99	107	105	104
(e/D = 2.0)	122	127	127	129	123	128	138	136	134
F_{bry}[b], ksi:									
(e/D = 1.5)	78	83	83	86	83	84	93	90	88
(e/D = 2.0)	90	94	98	101	98	99	109	105	104
e, percent (S-Basis):									
LT	5	5	5	...	5	3	4	4	4
E, 10^3 ksi:									
Primary	10.5	10.5	10.7			10.5	10.5	10.5	
Secondary	9.5	10.0	10.2			9.5	10.0	10.2	
E_c, 10^3 ksi:									
Primary	10.7	10.7	10.9			10.7	10.7	10.9	
Secondary	9.7	10.2	10.4			9.7	10.2	10.4	
G, 10^3 ksi	...								
μ	0.33								
Physical Properties:									
ω, lb/in.^{3}	0.100								
C, K, and α	...								

a Mechanical properties were established under MIL-QQ-A-250/5.
b Bearing values are "dry pin" values per Section 1.4.7.1.
c These values have been adjusted to represent the average properties across the whole section, including the 2½ percent nominal cladding thickness.

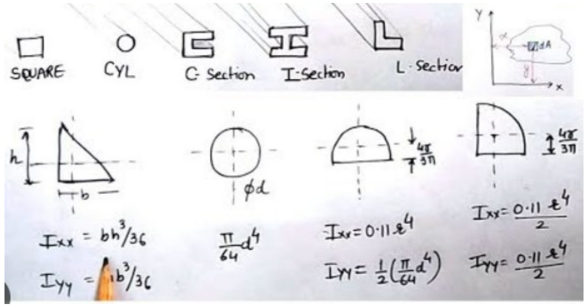


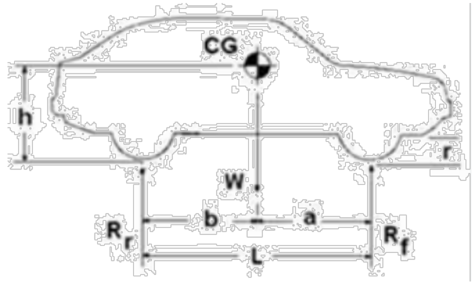


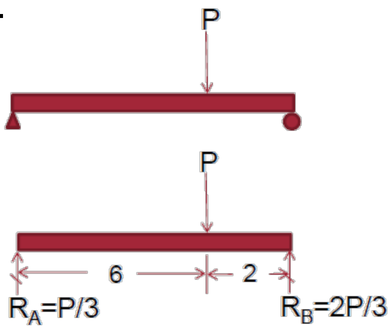
Structural Analysis Framework

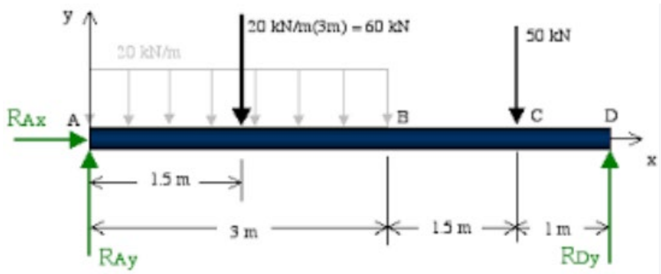
4. Structural Parameters, Load Calculations and load path:

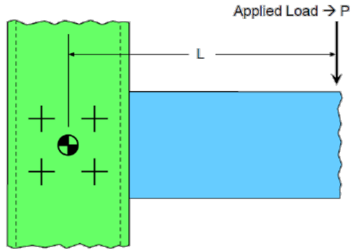
- Estimating the structural dimensions, Mass/C.G. Details, Area centroids, 2nd moment of area etc.
- Summarizing the initial/preliminary loads from structural requirements.
- Developing free body diagrams (FBDs) for structure and individual components using various initial loads.
- Summarize the worst (Limit/Ultimate) loads for structure and its components.



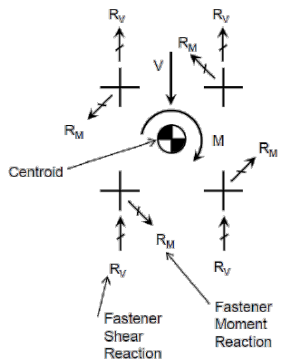




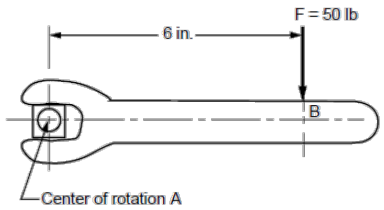




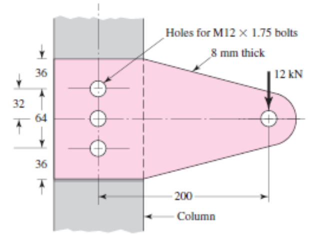
Load P, acting at distance L, is equivalent to a shear load V plus M acting at the fastener centroid
Where:
Shear: V = P
Moment: M = P × L



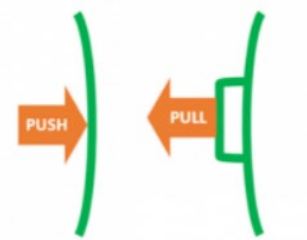
Fastener Load Distribution



M = 50 x 6 = 300 in lbs



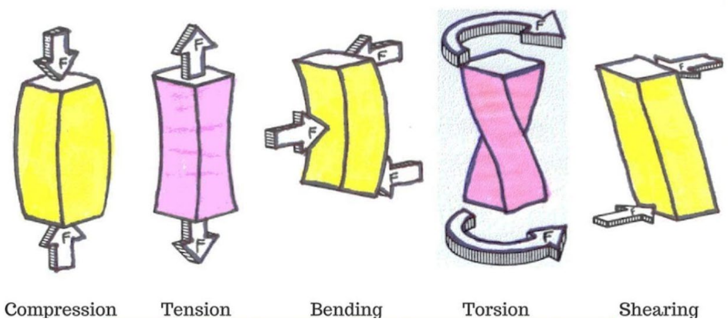
Handling & Abuse Loads



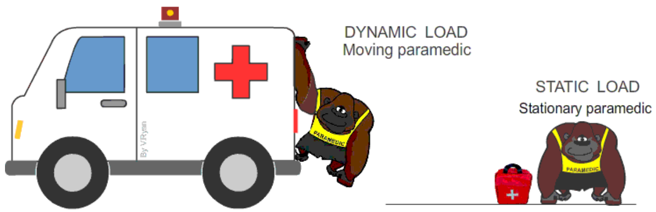
Structural Analysis Framework

4. Structural Parameters, Load Calculations and load path: Types of Loads

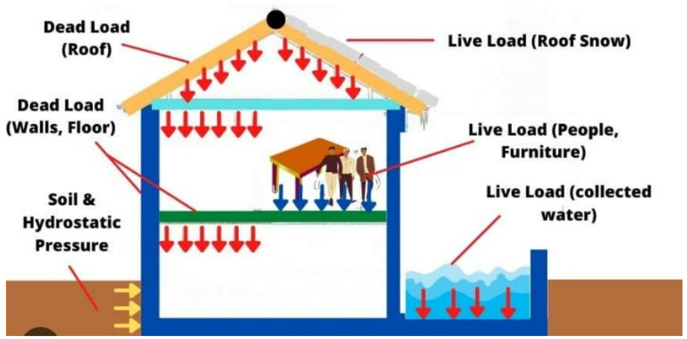
Based on application of Loads:
- Tensile
- Compression
- Shear Loads
- Bending
- Torsional



Based on Nature of loads
- Static
- Dynamic (Shock, Vibration, Fatigue, Creep etc..)

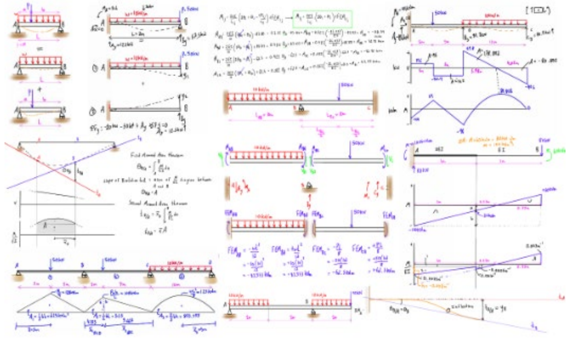


Environmental Loads
- Wind/Snow Loads (Gust, Drag etc..)
- Earth quake
- Loads because of temperature and humidity
- Dead Loads
- Live Loads

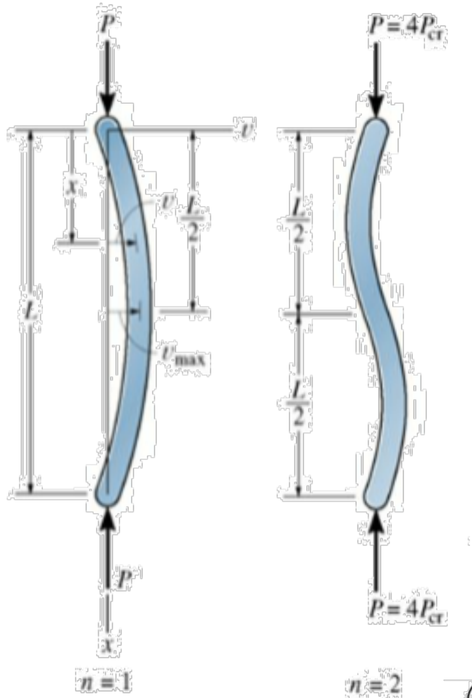


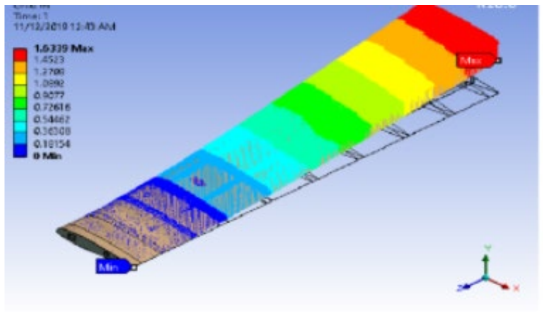
Structural Analysis Framework

5. Analysis requirements:

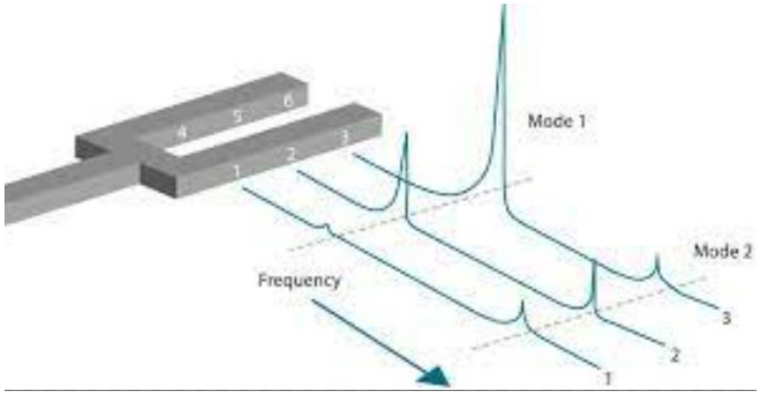


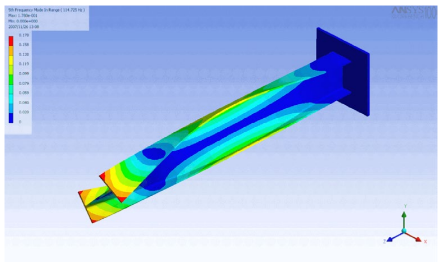
- Based on summarized loads, what are the different kinds of stress/structural analysis required.
- Summarizing various analysis required: For example: Strength, Stiffness and Stability analysis.

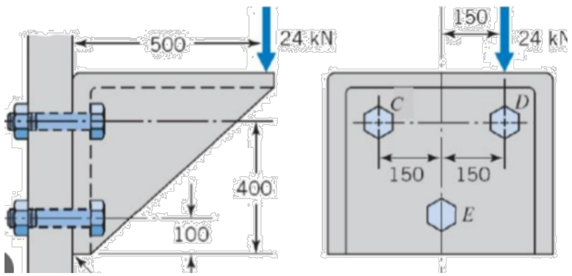


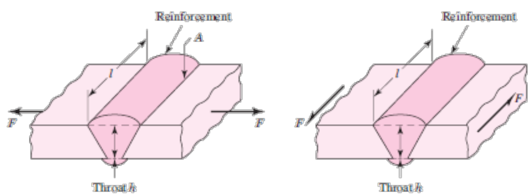


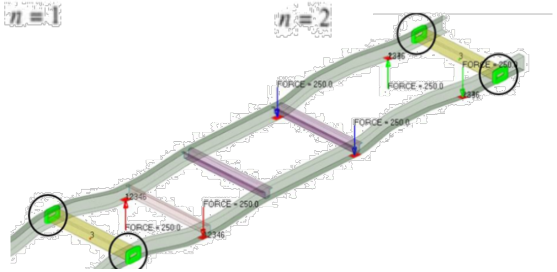
(a) Total deformation





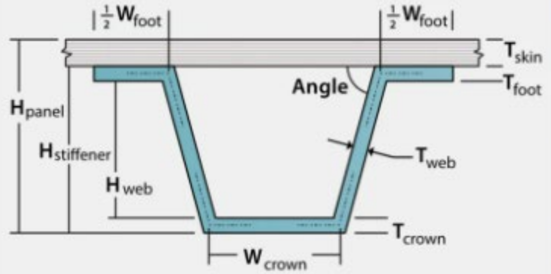




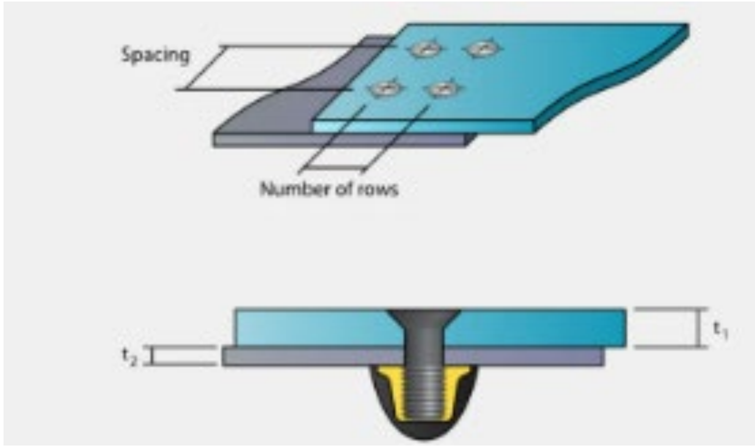


Structural Analysis Framework
6. Initial Sizing::

- Using best approaches for sizing.
- Sizing the structure and its components based on preliminary loads, preliminary materials and analytical calculations
- Sizing the joints (Bolts, rivets, welds etc..)
- Initial material selections.



Dimension	Value	0/45/90 %	0/45/90 #	Plies	Material
T_{skin} (in)	0.033	50/33/17	3/2/1	6	Tape: AS4/3502 Tape Design
T_{web} (in)	0.033	50/33/17	3/2/1	6	Tape: AS4/3502 Tape Design
T_{foot} (in)	0.033	50/33/17	3/2/1	6	Tape: AS4/3502 Tape Design
T_{crown} (in)	0.033	67/17/17	4/1/1	6	Tape: AS4/3502 Tape Design
$H_{stiffener}$ (in)	3.1597				
Spacing (in)	7				
Angle (°)	85				
W_{foot} (in)	1.65				
W_{crown} (in)	1.2087				
H_{panel} (in)	3.1927				
H_{web} (in)	3.0938				
W_{open} (in)	3.5942				

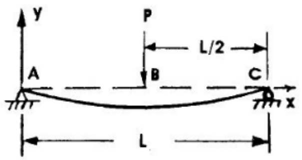


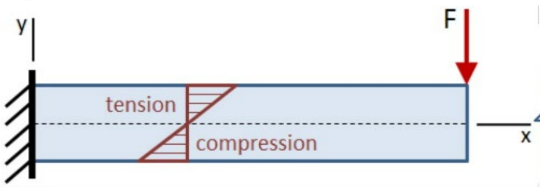
Structural Analysis Framework

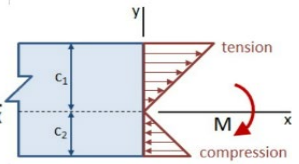
7. Performing Detailed Analysis Process:

- Using Hand/Analytical calculations approach.
- Using Finite element analysis approach with the help of software packages.
- Applying best practices for the Hand/FEA calculations.
- Developing the calculation templates for Hand/FEA calculation
- Performing analysis for worst load cases and get Margin of Safety (MOS) / Factor of safety (FOS) in terms of stresses/displacements etc..

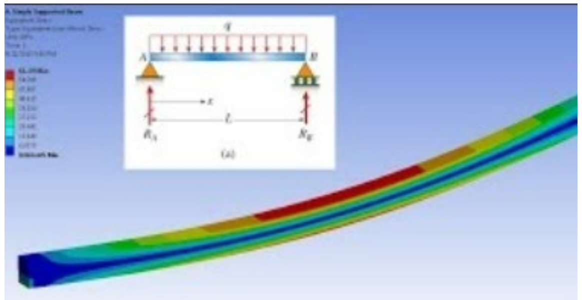
Loading and Support	Reactions and Shears	Bending Moments	Deflections and Slopes
Simple beam, concentrated load at center	$R_A = \frac{P}{2}$	$M_{A-B} = \frac{Px}{2}$	$y_{A-B} = [\frac{-P}{48EI}][3L^2x - 4x^3]$
	$R_C = \frac{P}{2}$	$M_{B-C} = \frac{P(L-x)}{2}$	Max. $y_B = \frac{-PL^3}{48EI}$
	$V_{A-B} = \frac{P}{2}$	Max. $M_B = \frac{PL}{4}$	$\theta_A = \frac{-PL^2}{16EI}$; $\theta_C = \frac{PL^2}{16EI}$
	$V_{B-C} = -\frac{P}{2}$		







Crippling
Column buckling
Flexural-Torsional buckling
Inter-rivet buckling
Boom tension
Von Mises
Max shear



Layer Thickness, H (ft)	3,0	4,0	0,0
Total Unit Weight, γ (pcf)	135	115	110
Friction Angle, ϕ (deg)	38	30	N/A
Young's Modulus, E (psf)	750 000	300 000	N/A
Poisson's Ratio, ν	0,30	0,33	N/A

Pavement plus Traffic Surcharge Pressure, q (psf)	300
Time Available for Consolidation, t (days)	60
Allowable Post-Construction Settlement, S_A (in.)	2,0
Depth to Groundwater, d_w (ft)	3,0
Unit Weight of Groundwater, γ_w (pcf)	62,4

	Exist Sand #1	Exist Sand #2	Clay #1	Clay #2
Layer Thickness, H (ft)	3,0	0,0	20,0	0,0
Total Unit Weight, γ (pcf)	125	125	100	100
Young's Modulus, E (psf)	250 000	250 000	N/A	N/A
Poisson's Ratio, ν	0,33	0,30	0,35	0,35
Lat. Earth Press. Coeff., K'_0	0,50	0,50	0,60	0,60
Interface Frict. Angle btwn Soil and Column, δ (deg)	32	32	24	24
Compression Ratio, $C_{\varepsilon c}$	N/A	N/A	0,220	0,220
Recompression Ratio, $C_{\varepsilon r}$	N/A	N/A	0,022	0,022
Coeff. of Consol., c_v (ft^2/day)	N/A	N/A	0,10	
Initial Eff. Vert. Stress at Top of Layer, $\sigma'_{v,top}$ (psf)	N/A	N/A	375	1127
Preconsol. Press. at Top of Layer, $p_{p,top}$ (psf)	N/A	N/A	375	1127
Initial Eff. Vert. Stress at Bottom of Layer, $\sigma'_{v,bot}$ (psf)	N/A	N/A	1127	1127
Preconsol. Press. At Bottom of Layer, $p_{p,bot}$ (psf)	N/A	N/A	1127	1127

Reduction in Required Bridging Layer Thickness, $H_{b,red}$ (ft)	1,0
Geogrid Stiffness, J (lb/ft)	48 000
Long-term, In-Service, Allowable Geogrid Strength, S_g (lb/ft)	2 000

	Pile Cap	Column
Vertical Distance from Top to Bottom of Element, H (ft)	0,0	23,0
Column Shape (use R for round and S for square)	R	R
Column Diameter or Width, d_c or a (ft)	3,0	3,0
Young's Modulus, E (psf)	6 500 000	6 500 000
Poisson's Ratio, ν	0,30	0,30
Center-to-center spacing, s (ft)	7,0	

	Value	Criterion
Clear Spacing, $s - a$ (ft)	4,3	≤ 5,7
Area Replacement Ratio at Ground Surface, a_s	0,144	≥ 0.10
Bridging Layer Thickness, H_b (ft)	3,5	≥ 3,3
Maximum differential settlement of geogrid, d (in.)	6,4	N/A

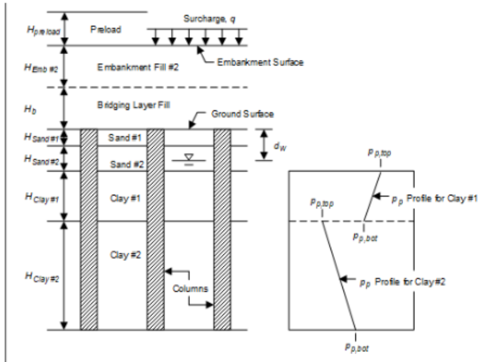
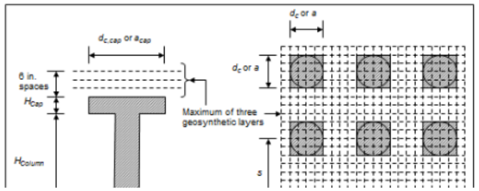


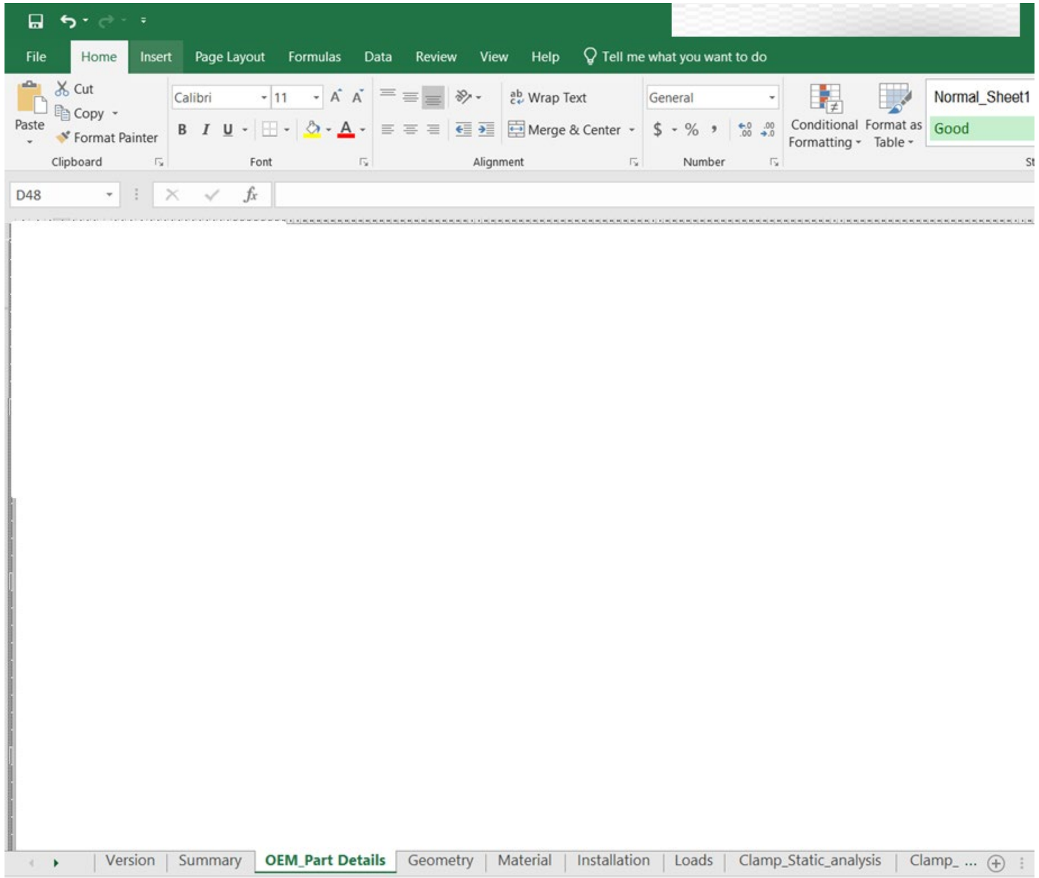
Fig. 1. Elevation View of Embankment, Columns, and Foundation Soil



Structural Analysis Framework

7. Performing Detailed Analysis Process:

- Developing the calculation templates for Hand/FEA calculation

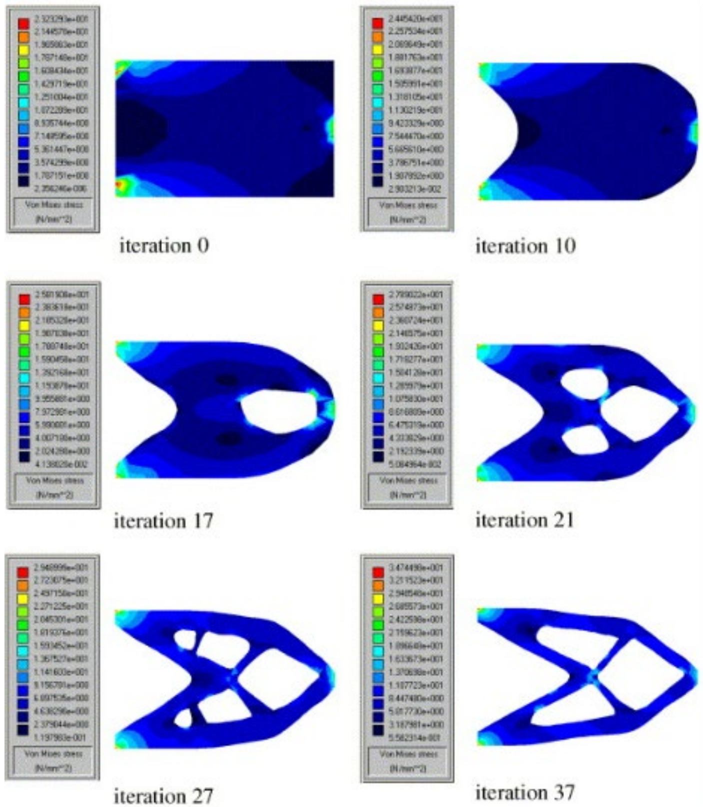


Content of Calculation Template:

1. Version
2. Summary of Analysis Results
3. Component Details
4. Geometry
5. Material
6. Loads and Assumptions
7. Analysis

Structural Analysis Framework
8. Structural Changes using analysis Outputs :

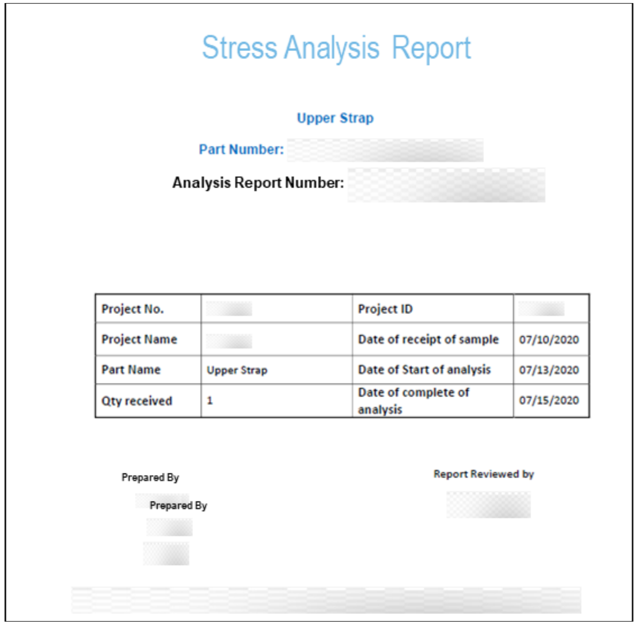
- Using material parameters to improve (Increase/Decrease) MOS.
- Changing the dimensional parameters for optimal MOS.



Structural Analysis Framework

9. Structural analysis reports/ Strength Check Notes:

- Preparing the load assumption reports.
- Preparing the stress analysis reports or strength check notes.
- Best practices for report preparations.



Stress Analysis Report

Upper Strap

Part Number:

Analysis Report Number:

Project No.		Project ID	
Project Name		Date of receipt of sample	07/10/2020
Part Name	Upper Strap	Date of Start of analysis	07/13/2020
Qty received	1	Date of complete of analysis	07/15/2020

Prepared By

Prepared By

Report Reviewed by

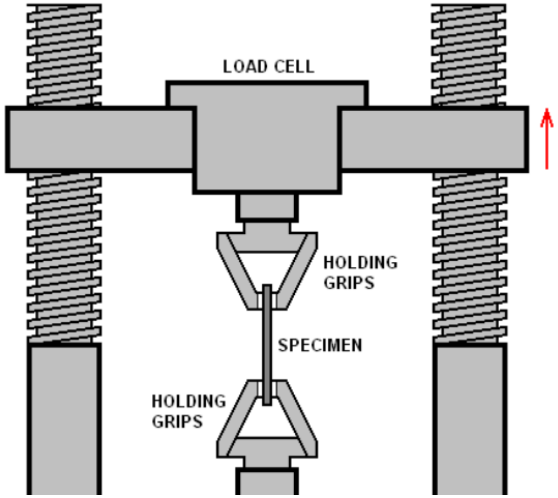
Content of Stress Reports:

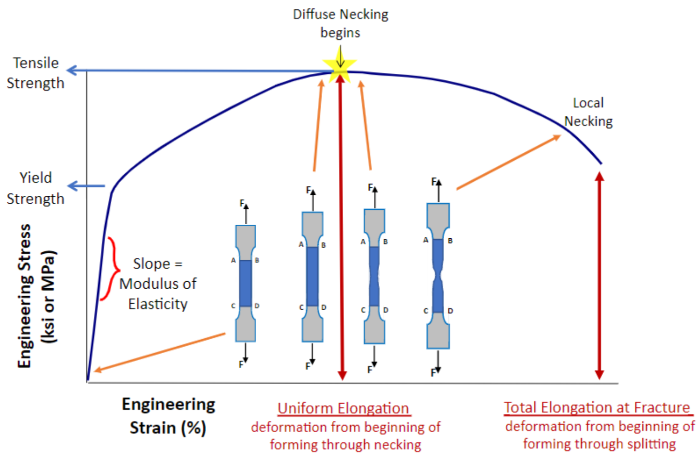
1. Introduction/Background/Objective
2. Structural Details: 3-D Image, Drawings, BOM etc.
3. Materials Used
4. Loads derivation and assumptions
5. Analysis: Hand Calculations and FEA
6. Test details and results
7. Results Summary Tables
8. Observations and Discussions
9. Future work
10. References
11. Appendix

Structural Analysis Framework

10. Structural Test / Analysis Validation:

- Understanding/preparation of the test requirements.
- What kind of structural test required
- Preparing the test plans
- Understanding and processing the test data for generating useful information.
- Test, Hand calculations and FEA validations.





Prerequisites:

- Understanding of geometry (via Drawings/3D models) and engineering math (vectors, algebra and calculus).
- Understanding materials, usage and appropriate applications.
- Understanding of Theories of Failure and applications to problems for various loaded elements.
- Finite Element Methods (Discretization, meshing, solving, post-processing)

Thank You