Automotive design

Chassis* design

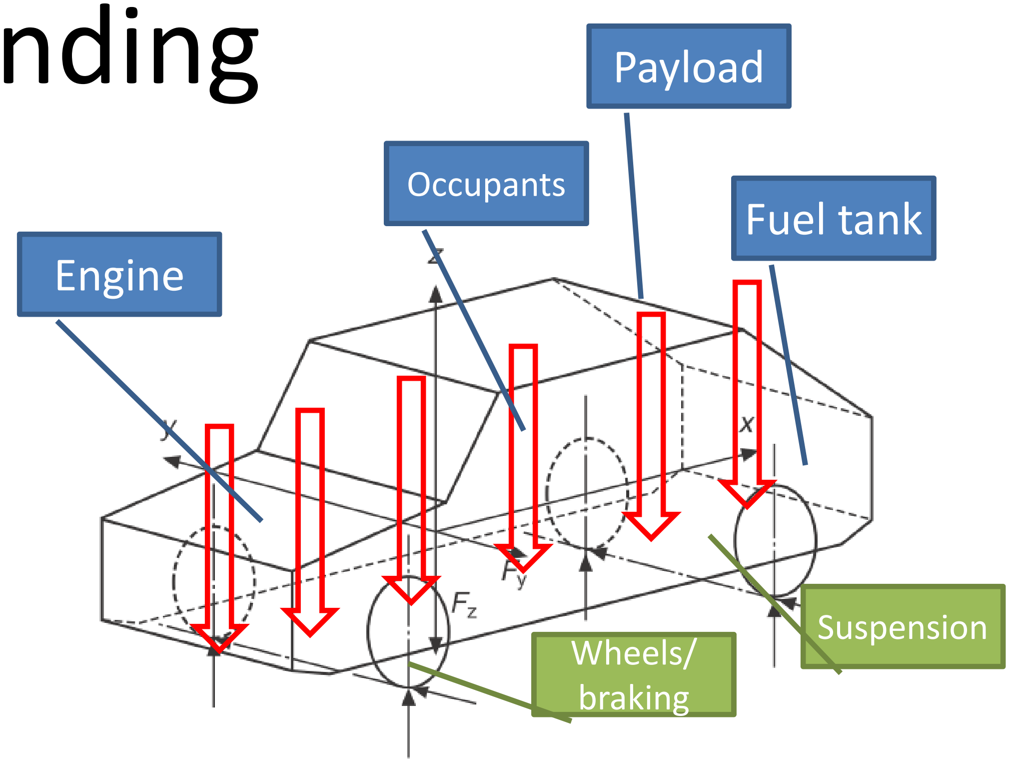
*pronounced: *chas-e – singular*
chas-e-z – plural

Introduction

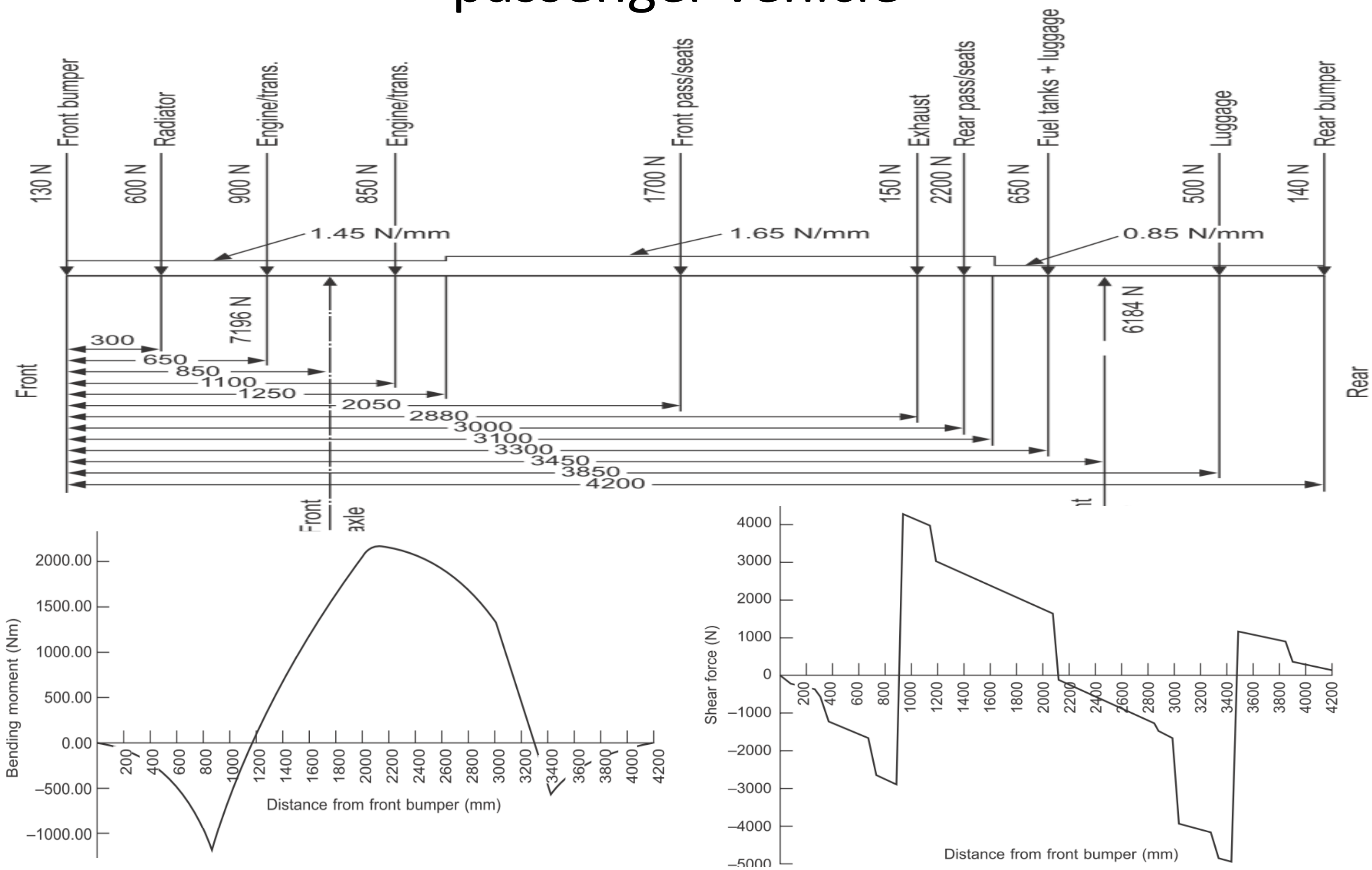
- Loads due to normal running conditions:
  - Vehicle transverse on uneven ground.
  - Manoeuver performed by driver.
- Five basic load cases:
  - Bending case
  - Torsion case
  - Combined bending and torsion
  - Lateral loading
  - Fore and aft loading

Bending

- Due to loading in vertical (X-Z) plane.
- Due to weight of components along the vehicle frame.
- Static condition vehicle structure can be treated as 2-D beam.
  - Vehicle is approximately symmetric in x-y plane.
- **Unsprung mass**
  - Components lie below chassis
  - Do not impose loads in static condition.

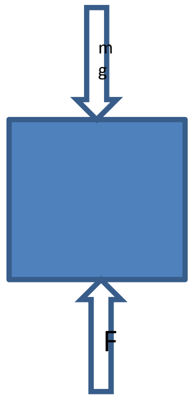


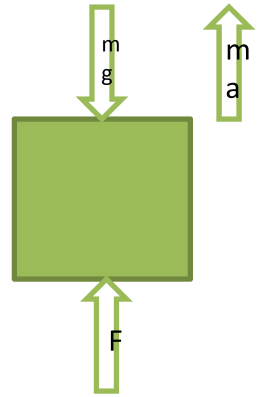
Bending moment/ Shear force diagram of a typical passenger vehicle



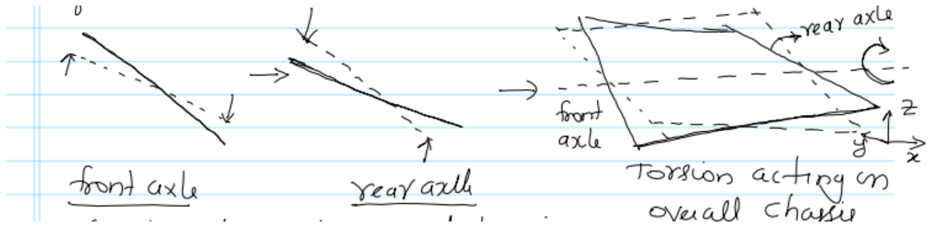
Bending

- Dynamic loading:
  - Inertia of the structure contributes in total loading
  - Always higher than static loading
  - Road vehicles: 2.5 to 3 times static loads
  - Off road vehicles: 4 times static loads
- Example:
  - Static loads
    - Vehicle at rest .
    - Moving at a constant velocity on a even road.
    - Can be solved using static equilibrium balance.
    - Results in set of algebraic equations.
  - Dynamic loads
    - Vehicle moving on a bumpy road even at constant velocity.
    - Can be solved using dynamic equilibrium balance.
    - Generally results in differential equations.

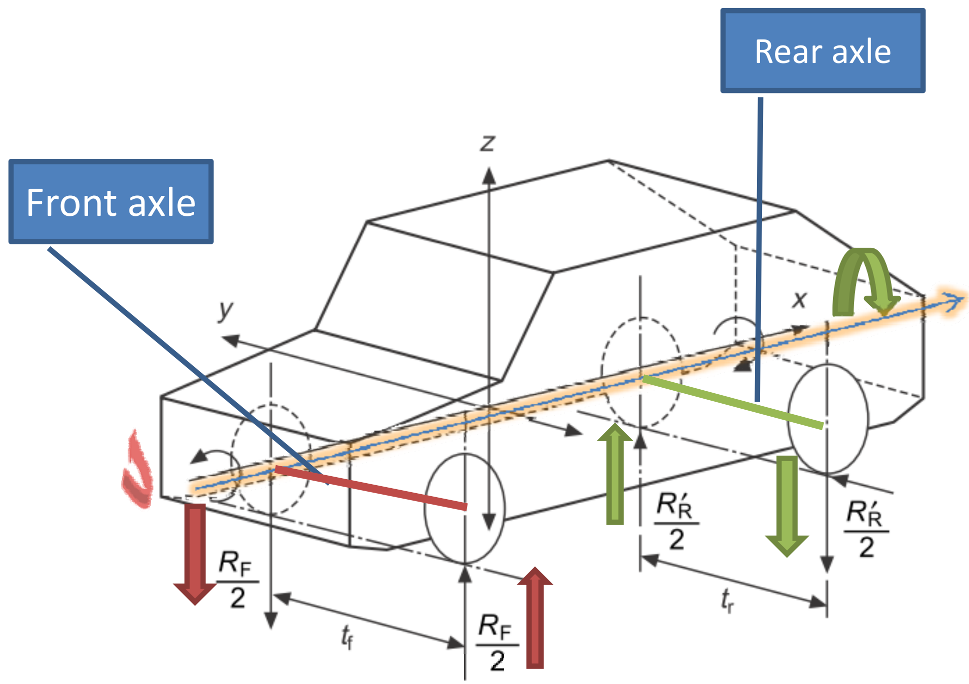




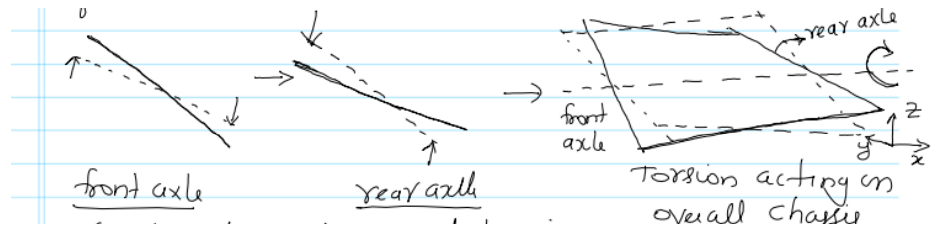
Torsion



- When vehicle traverse on an uneven road.
- Front and rear axles experiences a moment.
- Pure simple torsion:
  - Torque is applied to one axle and reacted by other axle.
  - Front axle: anti clockwise torque (front view)
  - Rear axle: balances with clockwise torque
  - Results in a torsion moment about x- axis.
- In reality torsion is always accompanied by bending due to gravity.



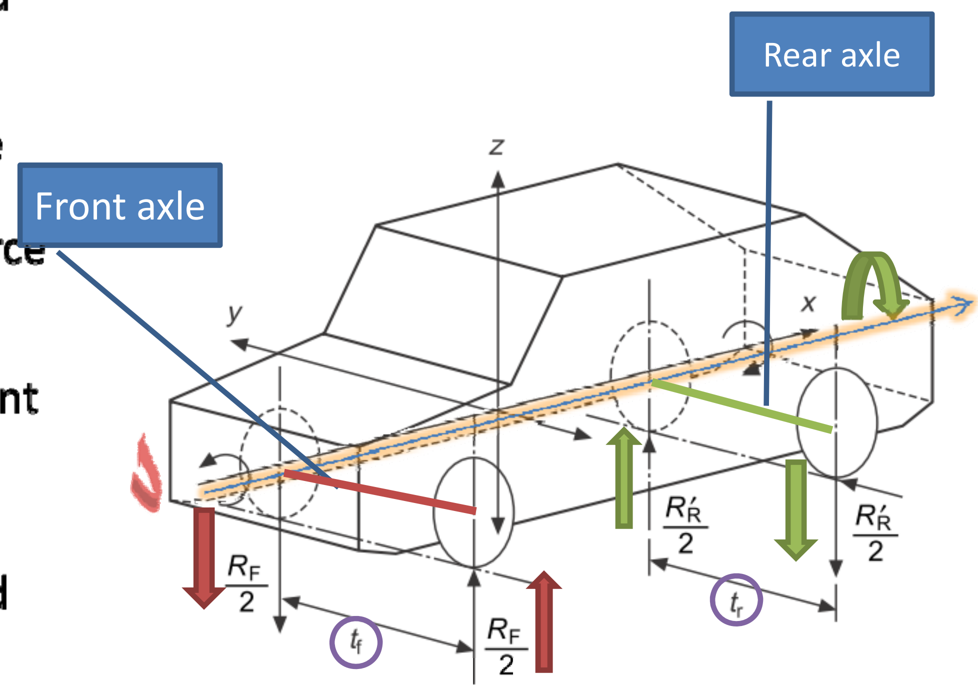
Torsion



- Maximum torsion moment is based on the loads at the lighter loaded axle
- In a generic passenger car rear axle load (R_R) is smaller than R_F.
- R'_R is the modified rear reaction force which will balance the moment at the front axle.
- R'_R can be determined from moment balance

$$\frac{R'_R}{2} * t_r = \frac{R_F}{2} * t_f$$

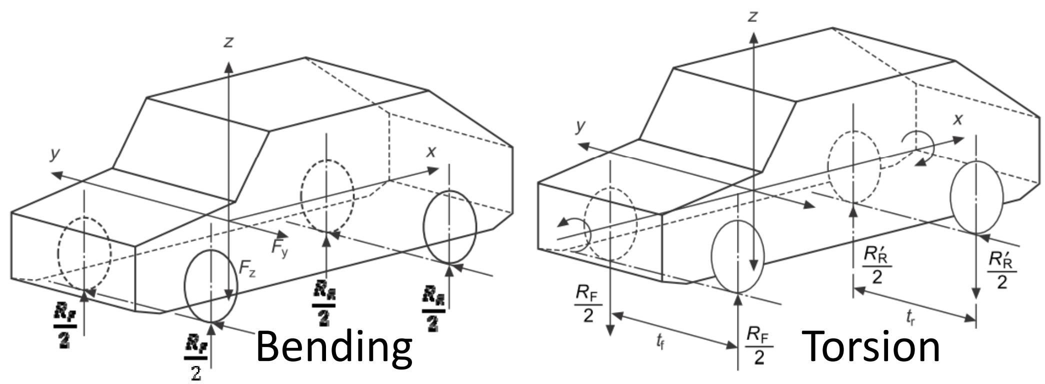
- R'_R is equal to R_F when the rear and front wheel tracks are the same.
- Dynamic factors:
  - On road : 1.3
  - Off road : 1.5 to 1.8.

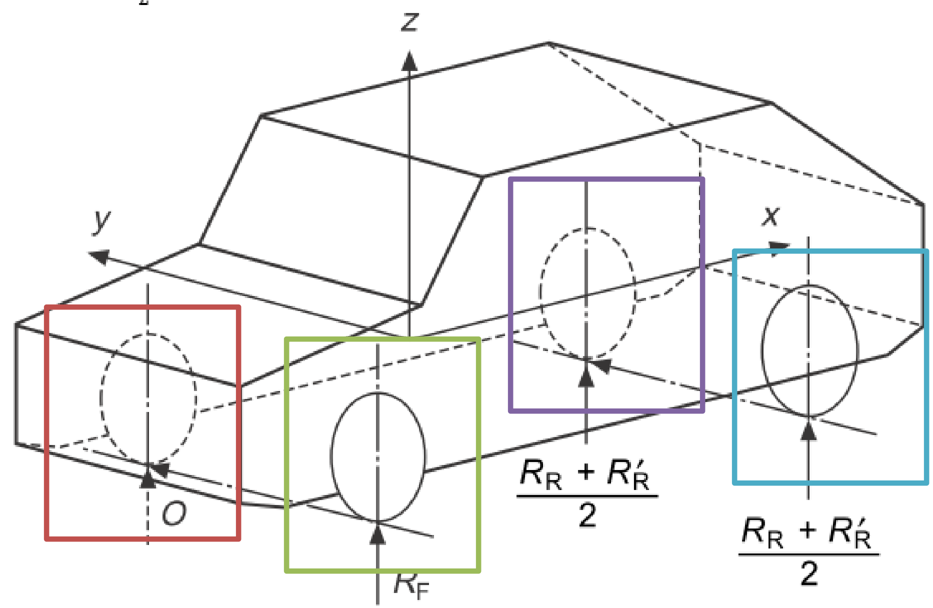


Combined bending and torsion

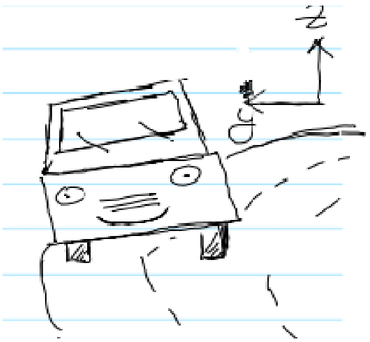
- Bending and torsional loads are super imposed.
  - Loadings are assumed to be linear
- One wheel of the lightly loaded axle is raise on a bump result in the other wheel go off ground.
- All loads of lighter axle is applied to one wheel.
- Due to nature of resulting loads, loading symmetry wrt x-z plane is lost.
- R'_R can be determined from moment balance.
- R'_R stabilizes the structure by increasing the reaction force on the side where the wheel is off ground .
- The marked –
  - Side is off ground
  - Side takes all load of front axle
  - Side's reaction force increases
  - Side's reaction force decreases

  to balance the moment.





Combined bending and torsion

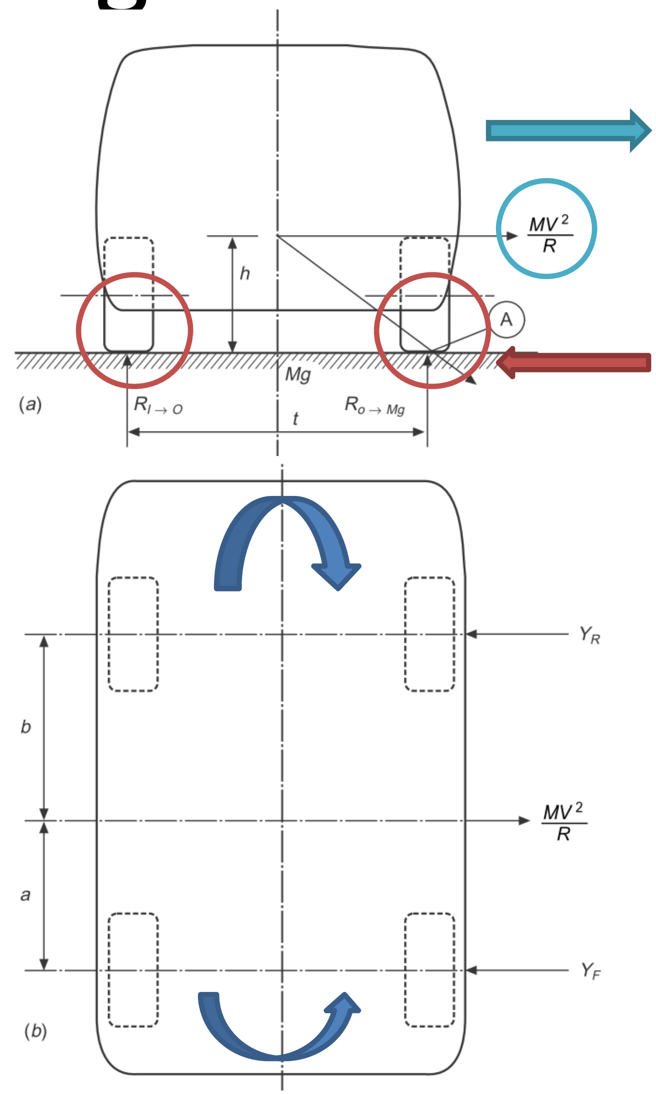


Lateral loading

- Due to cornering
- Generated at the tire to ground contact patch.
- These loads are balanced by centrifugal forces.
- When inside wheel reaction becomes zero the vehicle rollover
- Subjected to bending in x-y plane
- Centrifugal acceleration: $\frac{V^2}{R} = \frac{gt}{2h}$
- Force at CG at the moment of rollover.

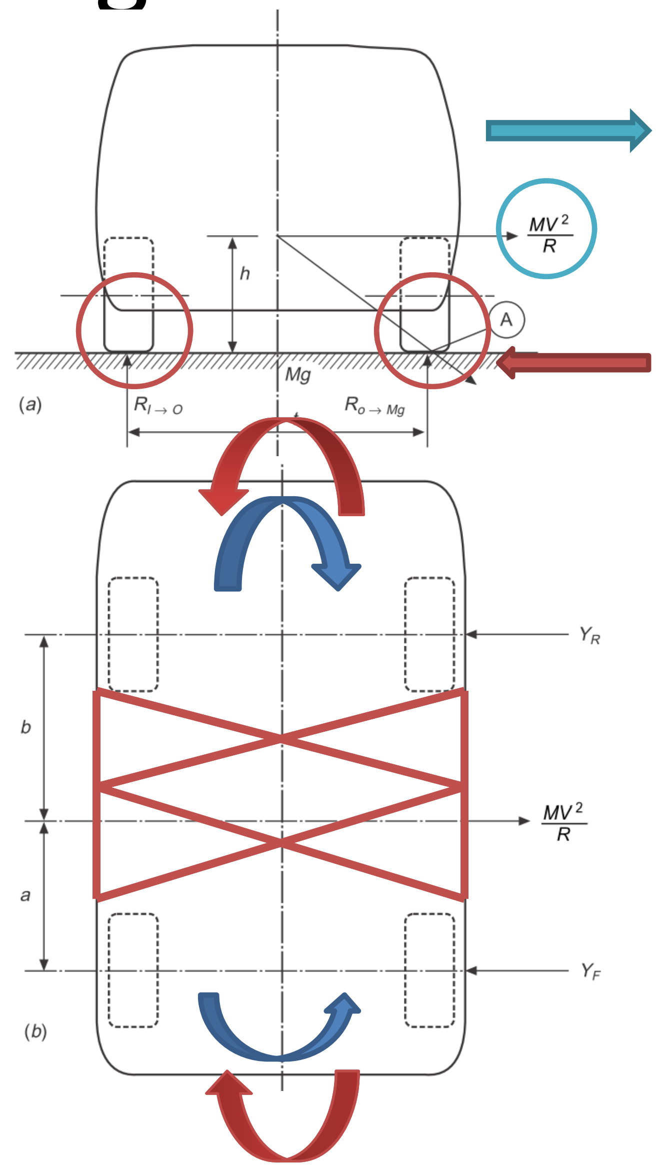
$$\frac{MV^2}{R} = \frac{Mgt}{2h}$$

- Taking moment it can be shown that
  - $Y_F = \frac{MV^2}{R}\frac{b}{a+b}$
  - $Y_R = \frac{MV^2}{R}\frac{a}{a+b}$



Lateral loading

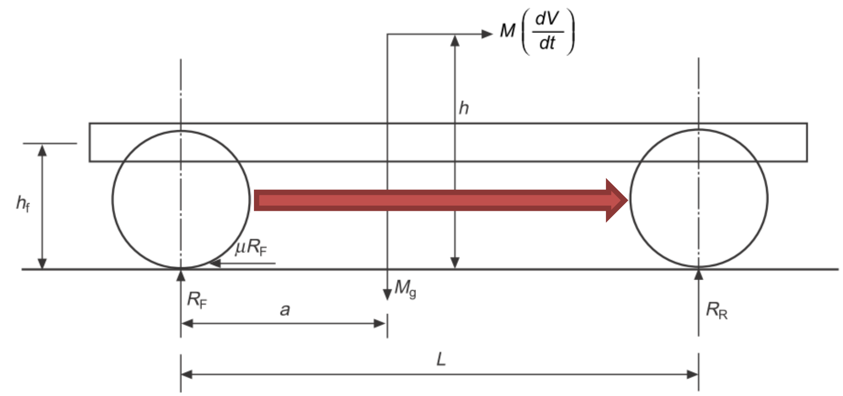
- For a modern car t = 1.45 m and h = 0.51 m.
- Critical lateral acceleration = 1.42 g
- In reality side forces limit lateral acceleration is limited within 0.75 g.
- Kerb bumping causes high loads and results in rollover.
- Width of car and reinforcements provides sufficient bending stiffness to withstand lateral forces.
- Lateral shock loads assumed to be twice the static vertical loads on wheels.



Longitudinal loading

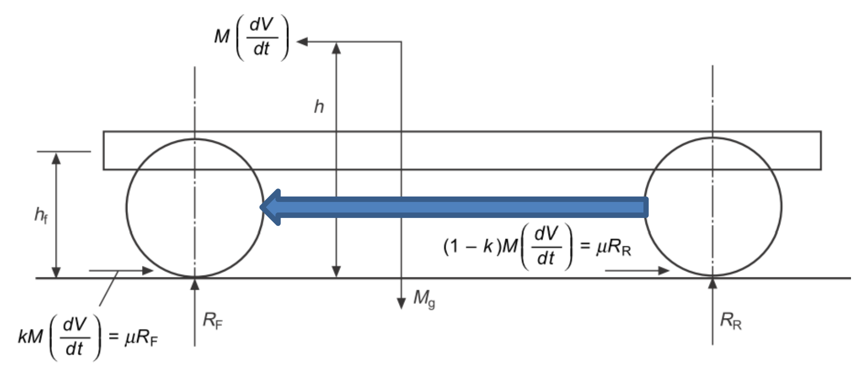
- When vehicle accelerates and decelerates inertia forces were generated.
- Acceleration – Weight transferred from front to back.
  - Reaction force on front wheel is given by (taking moment abt R_R)

$$R_F = \frac{Mg(L-a) - Mh\left(\frac{dV}{dt}\right)}{L}$$



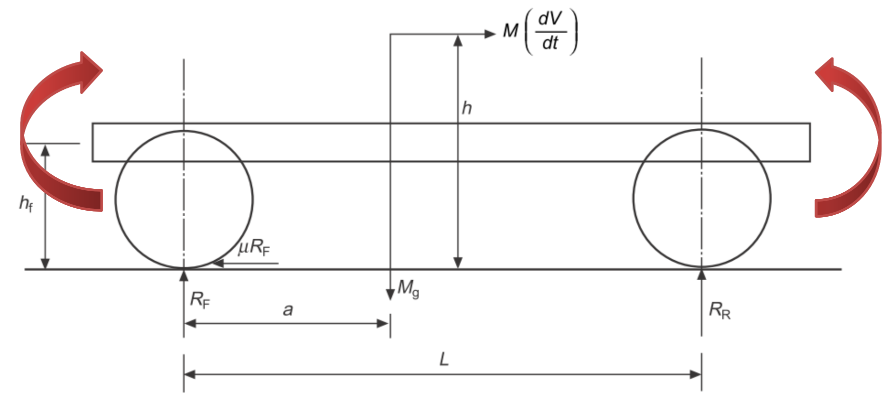
- Deceleration – Weight transferred from back to front.
  - Reaction force on front wheel is given by

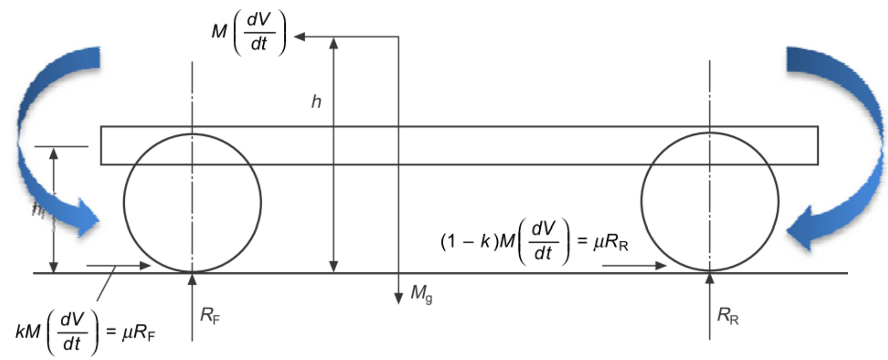
$$R_F = \frac{Mg(L-a) + Mh\left(\frac{dV}{dt}\right)}{L}$$



Longitudinal loading

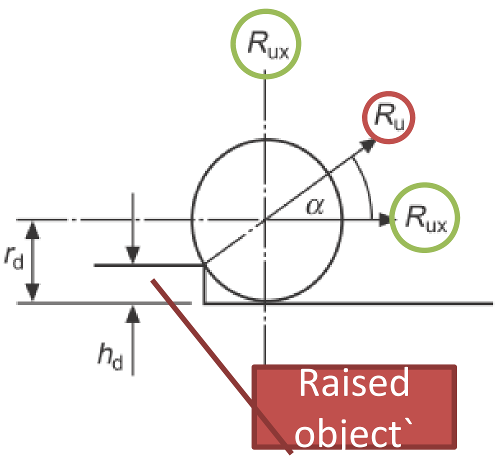
- Limiting tractive and braking forces are decided by coefficient of friction b/w tires and road surfaces
- **Tractive** and **braking** forces adds bending through suspension.
- Inertia forces adds additional bending.





Asymmetric loading

- Results when one wheel strikes a raised objects or drops into a pit.
- Resolved as vertical and horizontal loads.
- Magnitude of force depends on
  - Speed of vehicle
  - Suspension stiffness
  - Wheel mass
  - Body mass
- Applied load is a shock wave
  - Which has very less time duration
  - Hence there is no change in vehicle speed
  - Acts through the center of the wheel.



Asymmetric loading

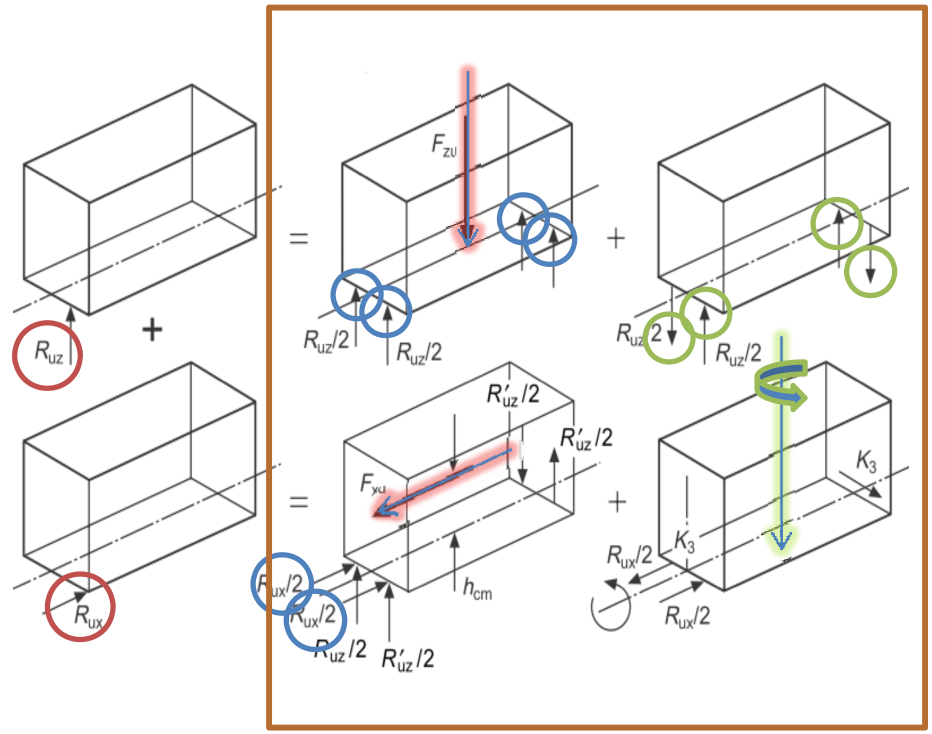
- Resolved vertical force causes:
  - Additional axle load
  - Vertical inertia load through CG
  - Torsion moment

to maintain dynamic equilibrium.

- Resolved horizontal force causes:
  - Bending in x-z plane
  - Horizontal inertia load through CG
  - Moment about z axis

to maintain dynamic equilibrium.

- Total loading is the superposition of all four loads.



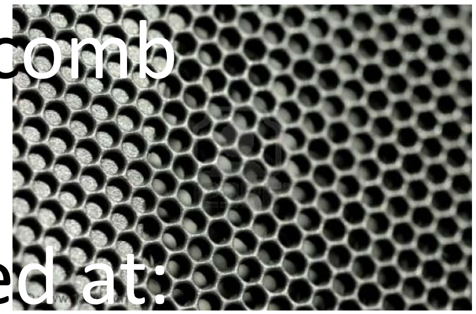
Allowable stress

- Vehicle structure is not fully rigid
- Internal resistance or stress is induced to balance external forces
- Stress should be kept to acceptable limits
- Stress due to static load X dynamic factor ≤ yield stress
  - Should not exceed 67% of yield stress.
- Safety factor against yield is 1.5
- Fatigue analysis is needed
  - At places of stress concentration
  - Eg. Suspension mounting points, seat mounting points.

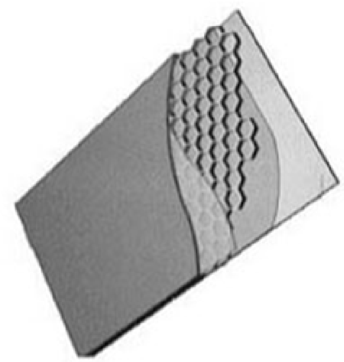
Bending stiffness

- Important in structural stiffness
- Sometimes stiffness is more important than strength
- Determined by acceptable limits of deflection of the side frame door mechanisms.
  - Excessive deflection will not shut door properly
- Local stiffness of floor is important
  - Stiffened by swages pressed into panels
  - Second moment of area should be increased

Bending stiffness



- Thin panels separated by honeycomb structure reduced vibration
- Local stiffness has to be increased at:
  - Door
  - Bonnet
  - Suspension attach points
  - Seating mounting points
  - Achieved by reinforcement plates and brackets.

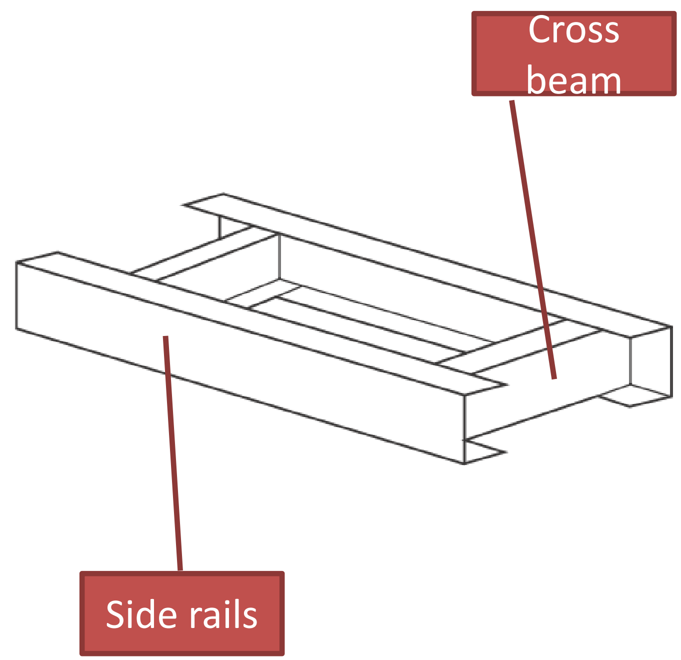


Torsional stiffness

- Allowable torsion for a medium sized car: 8000 to 10000 N-m/deg
- Measured over the wheel base
- When torsion stiffness is low:
  - Structure move up and down and/or whip
  - When parked on uneven ground doors fail to close
  - Doors fail to close while jacking if jack points are at a corner
- Torsion stiffness is influenced by windscreens
- TS reduces by 40% when windscreens removed
- Open top cars have poor torsional stiffness
- Handling becomes very difficult when torsional stiffness is low.

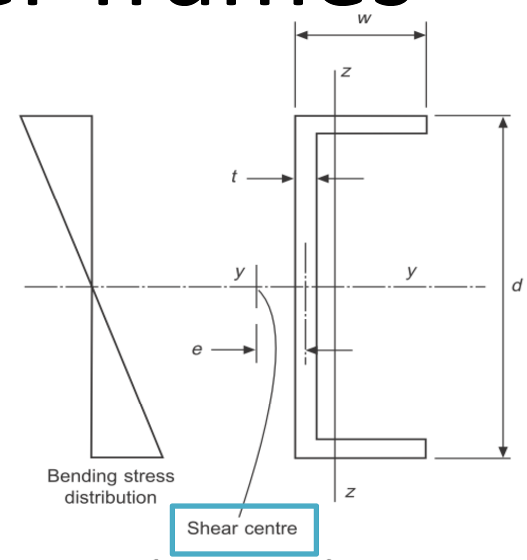
Chassis types- Ladder frames

- Used by early motor cars
- Early car's body frame did not contribute much for vehicle structure.
  - Mostly made of wood which has low stiffness
- Carried all load (bending and torsion)
- Advantages:
  - Can accommodate large variety of body shapes and types
  - Used in flat platforms, box vans, tankers and detachable containers
- Still used in light commercial vehicles like pick up.



Chassis types- Ladder frames

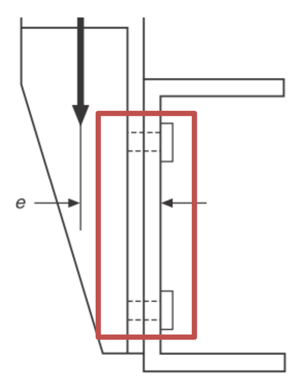
- Side rails frequently have open channel section
- Open or closed section cross beams
- Good bending strength and stiffness
- Flanges contribute large area moment of inertia.
- Flanges carry high stress levels
- Open section : easy access for fixing brackets and components
- Shear center is offset from the web
- Local twisting of side frame is avoided
- Load from vehicle is applied on web
  - Avoids holes in highly stresses flanges
- Very low torsional stiffness.



Second moment of area, $I_{yy} = 2\left\{\frac{wt^2}{12} + wt\left(\frac{d-t}{2}\right)^2\right\} + \frac{t(d-2t)^3}{12}$

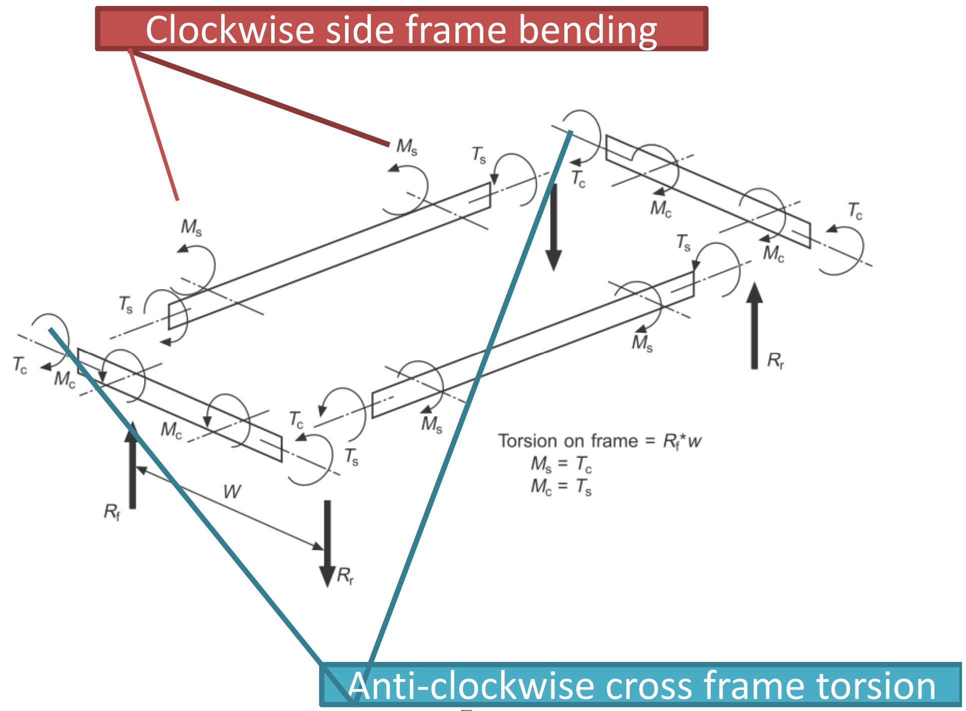
Torsion constant, $J = \left\{\frac{2wt^3}{3} + \left(\frac{(d-t)t^3}{3}\right)\right\}$

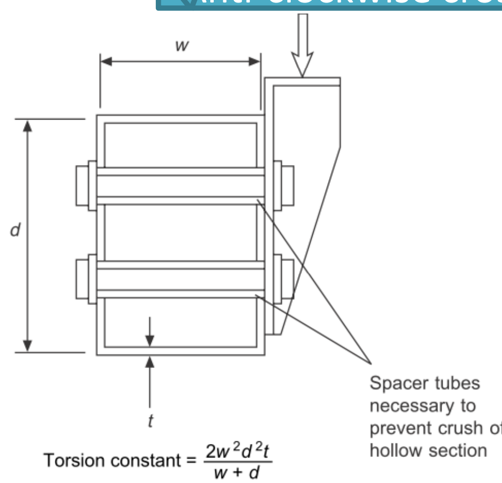
Shear centre offset, $e = \left\{\left(\frac{(w-t)}{2}\right)^2 (d-t)^2\right\}\frac{1}{4I_{yy}}$



Chassis types- Ladder frames

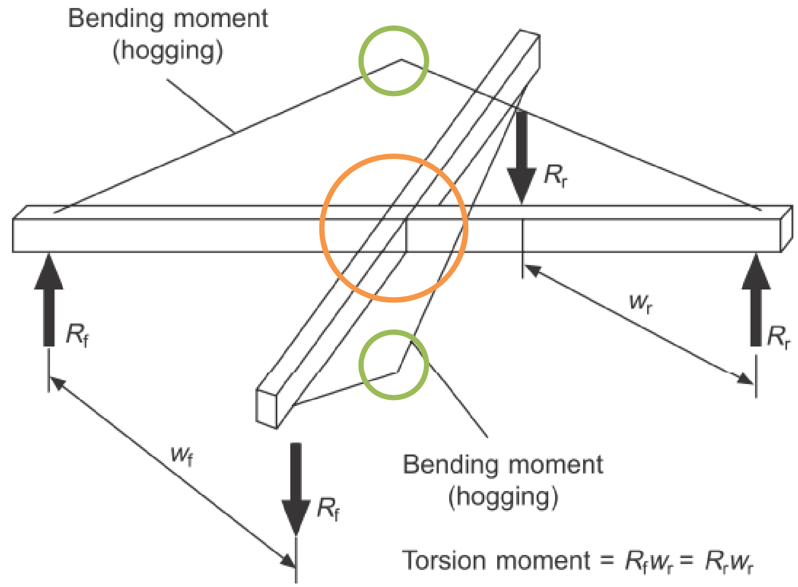
- Torsion in cross member is reacted by bending of side frames
- Bending in cross frames are reacted by torsion of side frames
- All members are loaded in torsion
- Open sections are replaced by closed sections to improve torsional stiffness
  - Strength of joints becomes critical
  - Max bending occurs at joints
  - Attachment of brackets becomes more complex

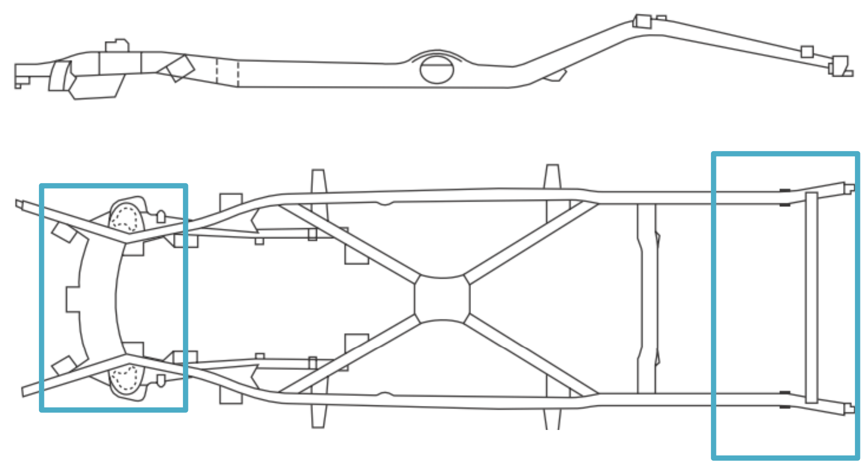




Chassis types- cruciform frames

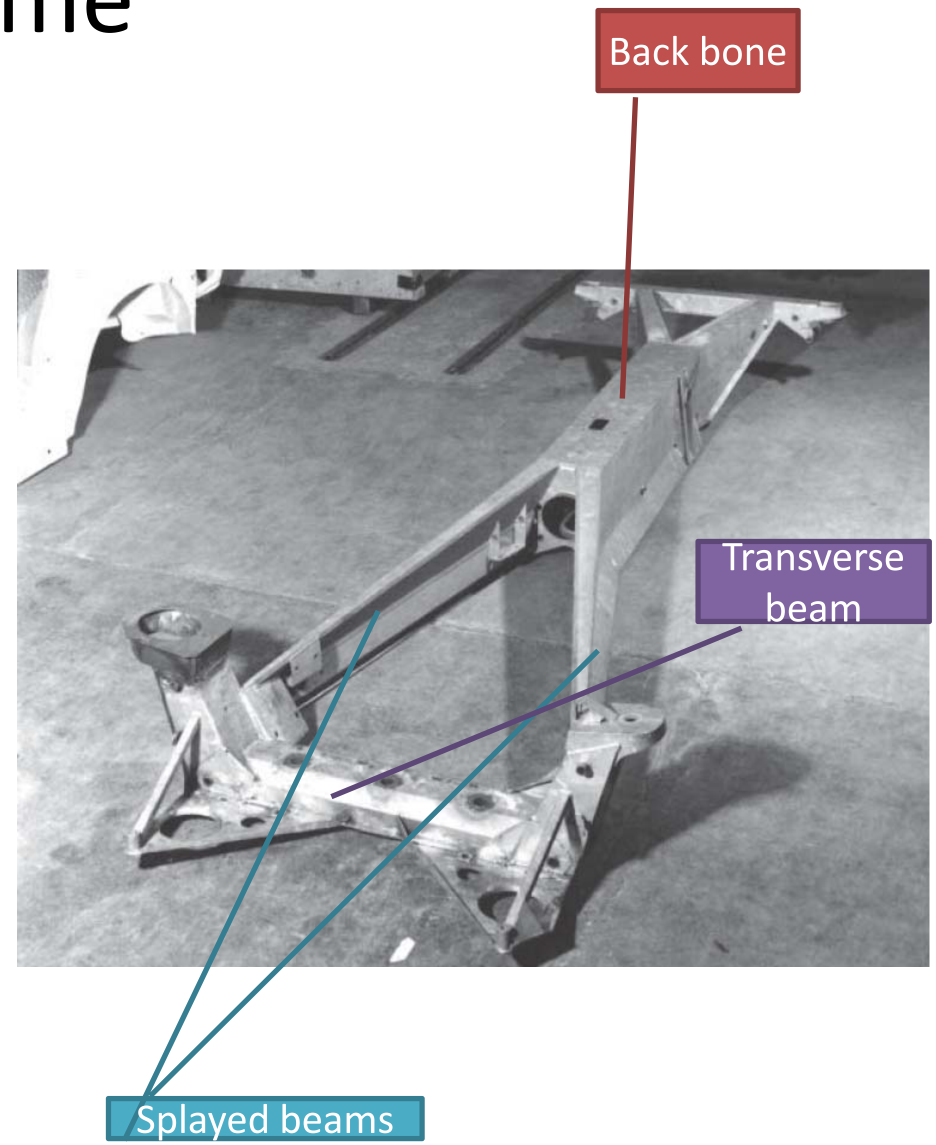
- Can carry torsional loads , no elements of the frame is subjected to torsional moment.
- Made of two straight beams
- Have only bending loads
- Has good torsional stiffness when joint in center is satisfactorily designed
- Max bending moment occurs in joint.
- Combining ladder and cruciform frame provides good bending and good torsional stiffness
- Cross beams at front and back at suspension points are used to carry lateral loads





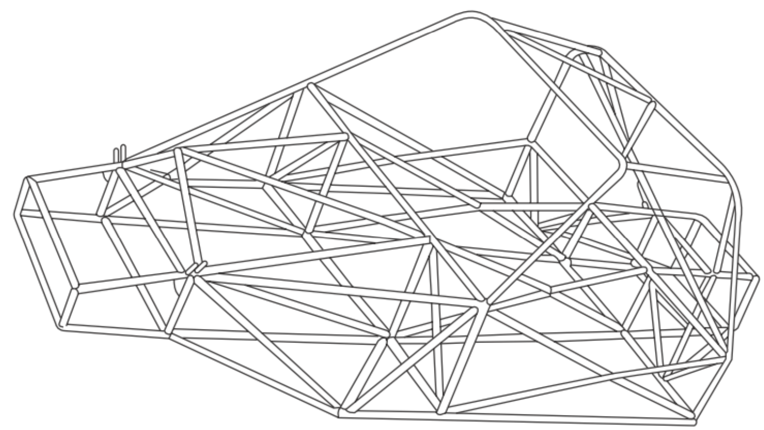
Chassis types- Torque tube back bone frame

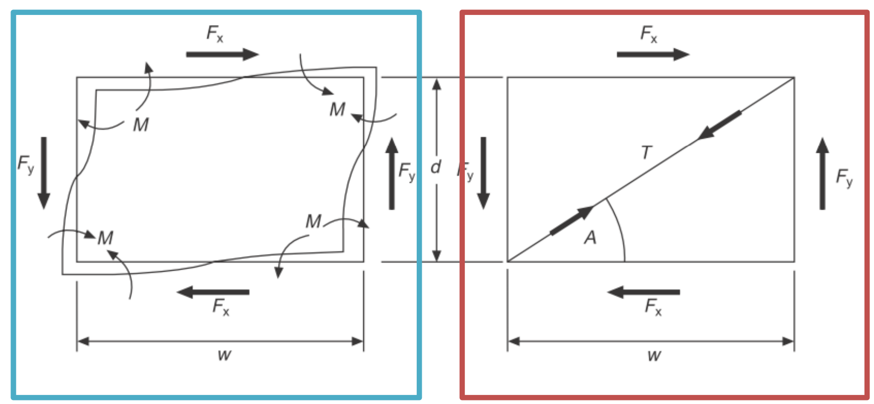
- Main back bone is a closed box section
- Splayed beams at front and rear extent to suspension mounting points
- Transverse beams resist lateral loads
- Back bone frame: bending and torsion
- Splayed beams: bending
- Transverse beams: tension or compression



Chassis types- Space frames

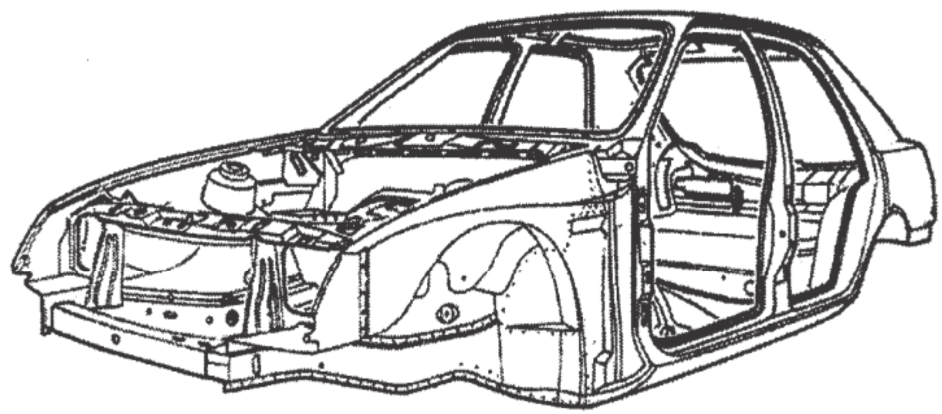
- In all frames till now length in one dimension is very less compared to the other two dimensions
- Increasing depth increases bending strength
- Used in race cars
- All planes are fully triangulated
- Beam elements carry either tension or compressive loads.
- Ring frames depends on bending of elements
  - Windscreen, back light
  - Engine compartment, doors
  - Lower shear stiffness
- In diagonal braced frame s stiffness provided by diagonal element





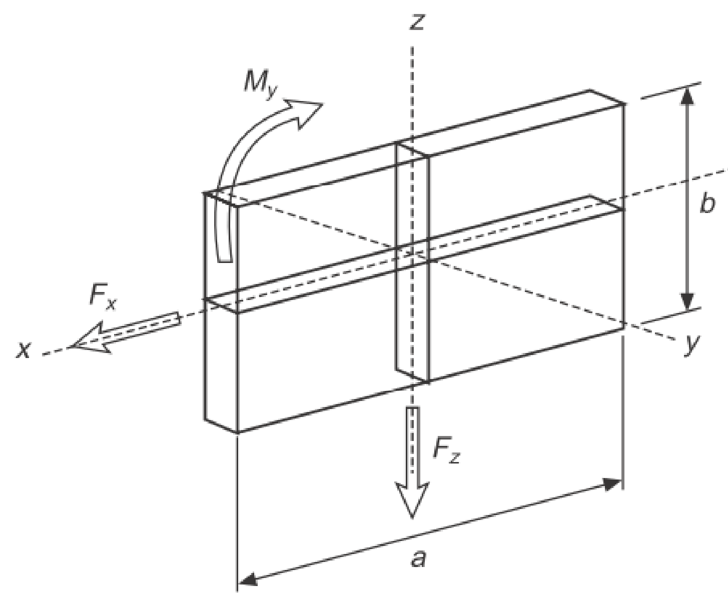
Chassis types- Integral structures

- Modern cars are mass produced
- Sheet steel pressings and spot welds used to form an integral structure
- Components have structural and other functions
- Side frames + depth + roof gives good bending and torsional stiffness
- Geometrically very complicated
- Stress distribution by FEM only
- Stress distribution is function of applied loads and relative stiffness between components
- Advantages:
  - Stiffer in bending and torsion
  - Lower weight
  - Less cost
  - Quiet operation



Structural analysis by Simple Structural Surfaces (SSS) method

- Many methods to determine loads and stresses
- Elementary method is beam method, FEM is advanced method and SSS is intermediate
- Developed by Pawlowski in 1964
- Determines loads in main structural elements
- Elements are assumed to be rigid in its plane
- Can carry loads in its plane
  - Tension, compression, shear and bending
- Loads normal to plane and bending out of plane is invalid and not allowed



$$I_x = \frac{at^3}{12} \quad I_y = \frac{tb^3}{12} \quad I_z = \frac{bt^3}{12}$$

$$I_y >> I_z \quad I_y >> I_x$$

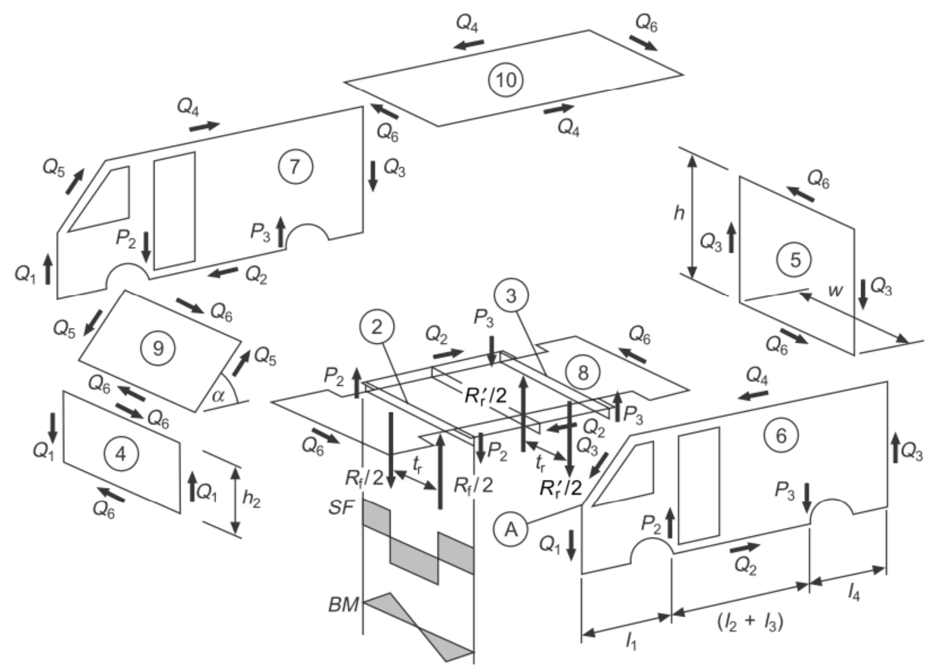
$$F_y = 0 \quad M_x = 0 \quad M_z = 0$$

SSS method – Analysis of simple van (torsion case)

- Ten structural components are considered
- Torsion is generated due to torque moment appleid in the front and rear axle
- If geometry is known and axle loads are known, edge loads (Q s) can be determined
- For a fully laden van front axle load is lighter
- By moment balance R'r can be determined by

  $$\frac{R'_r}{2} * tr = \frac{R_f}{2} * tf$$

- Equilibrium of SSS-2 and SSS-3 can be found by taking moments as R_f and R_r are known P_2 and P_3 are determined
  - $P_2 * w - \frac{R_f}{2} * t_f = 0$
  - $P_3 * w - \frac{R'_r}{2} * t_r = 0$
  - P_2 and P_3 will be equal in magnitude to avoid out of plane bending of SSS-8 and also to balance torque
- Considering loads in SSS-6
  - Loads Q_1 to Q_5 balances the moment generated by P_2 and P_3
  - Taking moment about A gives
  - $P_3(l_1+l_2+l_3)-P_2l_1-Q_2h_2-Q_3(l_1+l_2+l_3+l_4)-Q_4(h_1-h_2) = 0$
- Considering SSS- 4,5,8,9,10
  - Moment balance is taken like in the previous case
- Six equations and six unknowns Q_1 to Q_6, which can be solved



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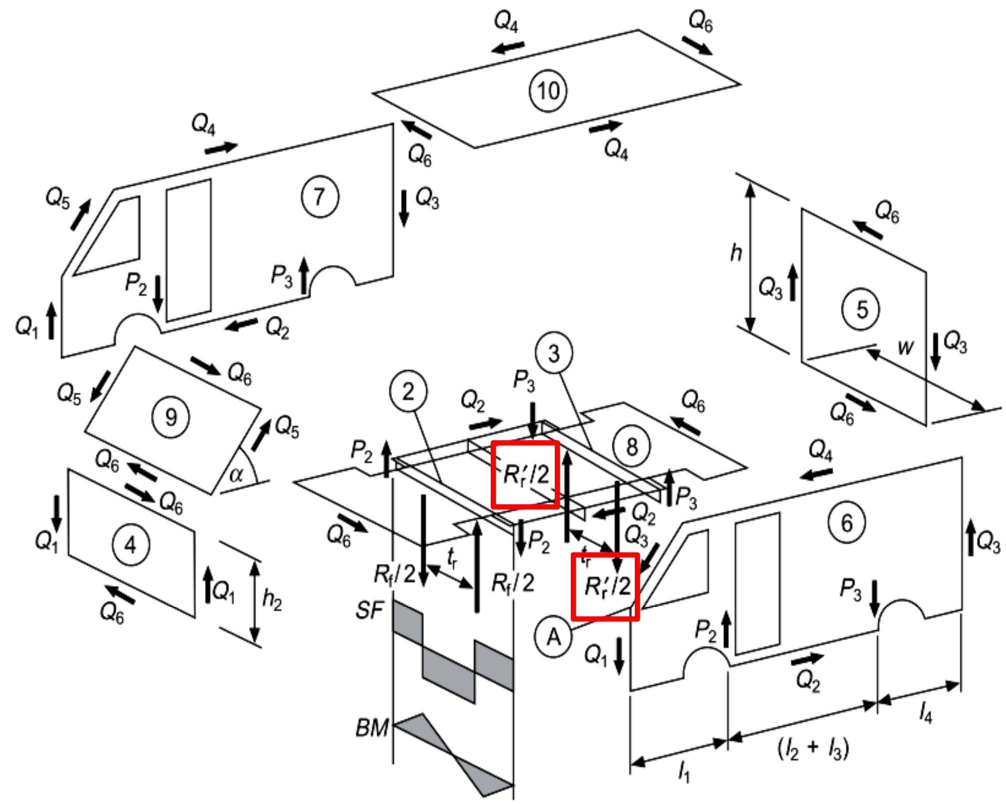
$$\frac{R'_r}{2} * t_r = \frac{R_f}{2} * t_f$$



SSS method – Analysis of simple van (torsion case)

- The equilibrium of SSS-2 and SSS-3 are obtained by taking moments as R_f and R'_r are known.

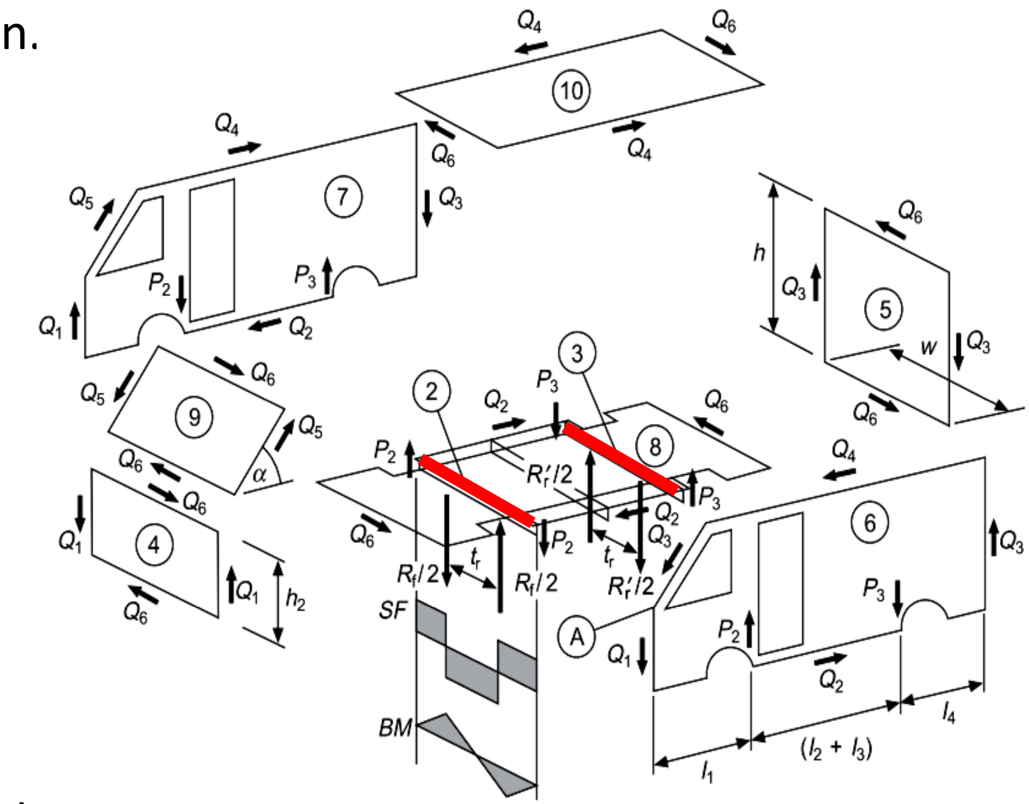
- SSS-2 (front cross beam)

$$P_2 w - \frac{R_f}{2} * t_f = 0$$

- SS-3 (Rear cross beam)

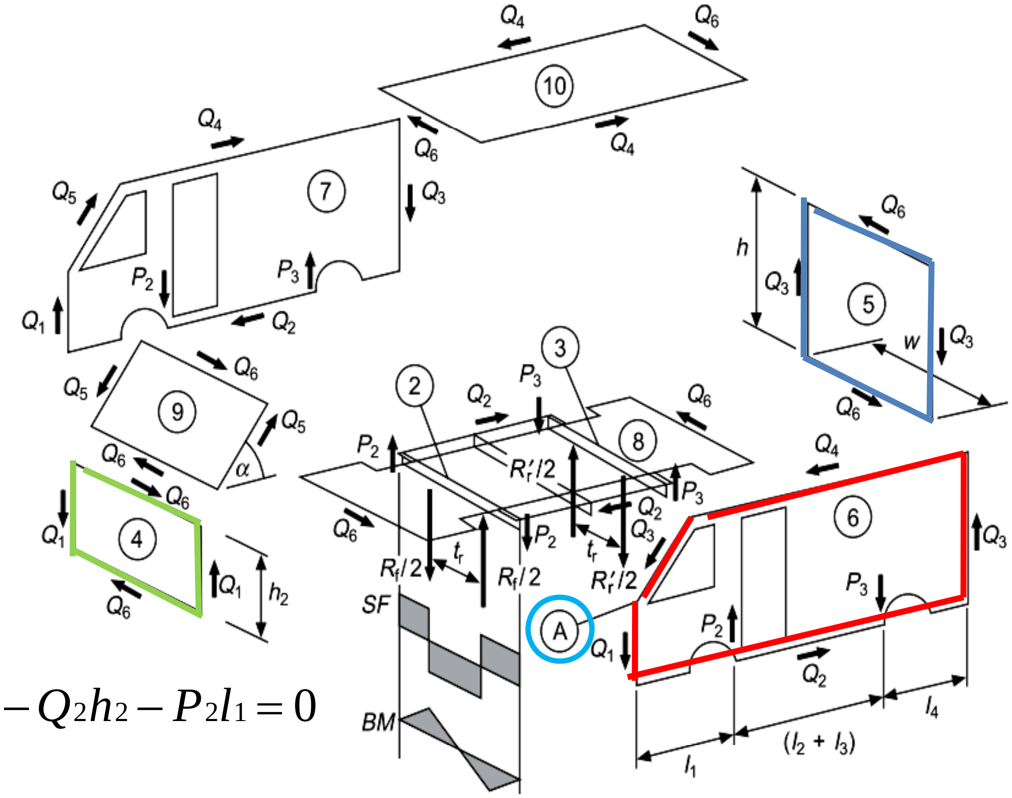
$$P_3 w - \frac{R'_r}{2} * t_r = 0$$

- P2 and P3 will be equal in magnitude as they act at the width of the vehicle and the torque at the front and rear must be equal.



SSS method – Analysis of simple van (torsion case)

- Considering SSS-6
- Q_1 to Q_5 will occur around periphery
- Applies opposite moment to P_2 and P_3
- Taking moment at A



$$P_3(l_1+l_2+l_3)-Q_3(l_1+l_2+l_3+l_4)-Q_4(h_1-h_2)-Q_2h_2-P_2l_1=0$$

- Consider SSS-4 (front panel)

$$Q_6h_2-Q_1w=0$$

- Consider SSS-5 (rear door frame)

$$Q_6h_1-Q_3w=0$$

SSS method – Analysis of simple van (torsion case)

- Consider SSS-8 (floor panel)

$$Q_6(l_1+l_2+l_3+l_4)-Q_2w=0$$

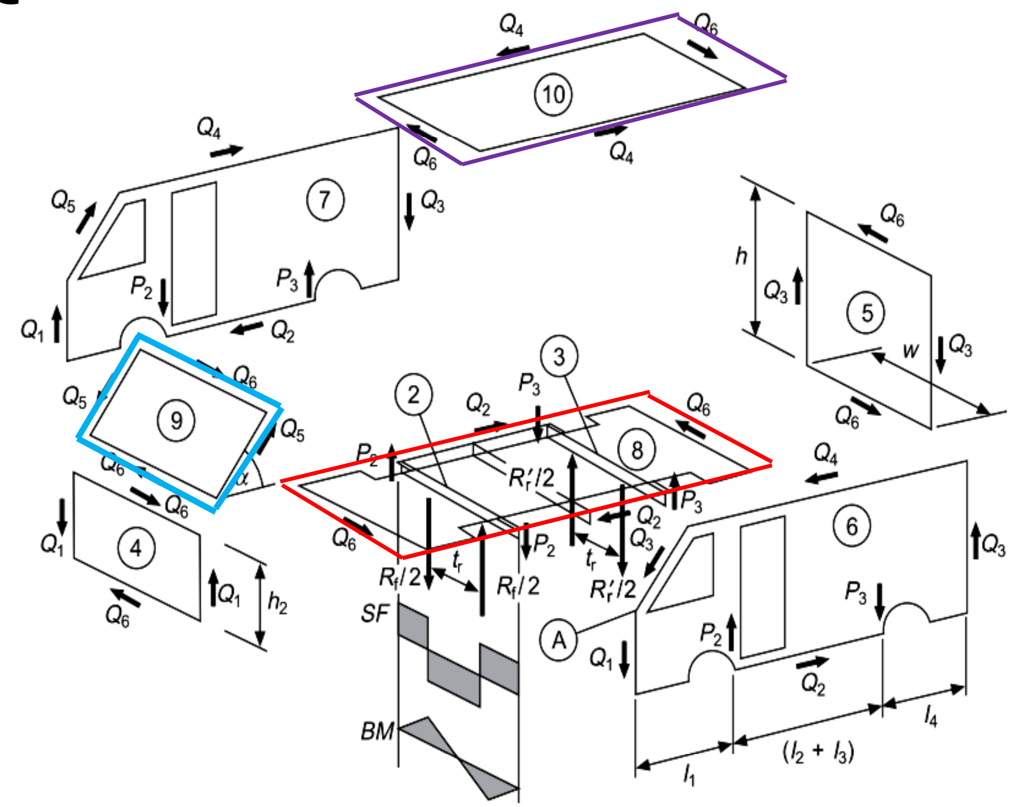
- Consider SSS-9 (windscreen frame)

$$\frac{Q_6(h_1-h_2)}{\sin\alpha}-Q_5w=0$$

- Consider SSS-10 (Roof)

$$Q_6l_5-Q_4w=0$$

- Six unknowns Q_1 to Q_6
- Substitute Q_2, Q_3 and Q_4 in the eqn of SSS-6
- Q_6 can be obtained and hence rest of the unknowns can be derived



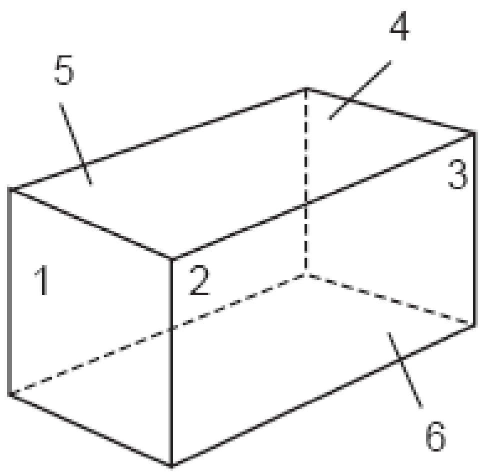
Simple Structural Surfaces representing a saloon car in bending

Material from J.H. Smith, 2002

Passenger car

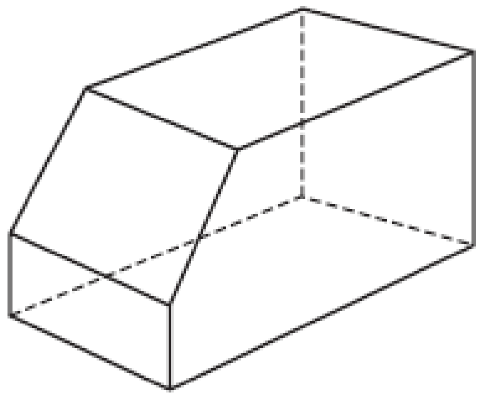
- More complex than box type van
- Detailed model vary according to mechanical components
  - Front suspensions loads applied to front wing as for strut suspension
  - Rear suspension (trailing arm or twist beam) loads to inner longitudinal member under the boot floor
  - SSSs varies with body types

Vehicle structures represented by SSS



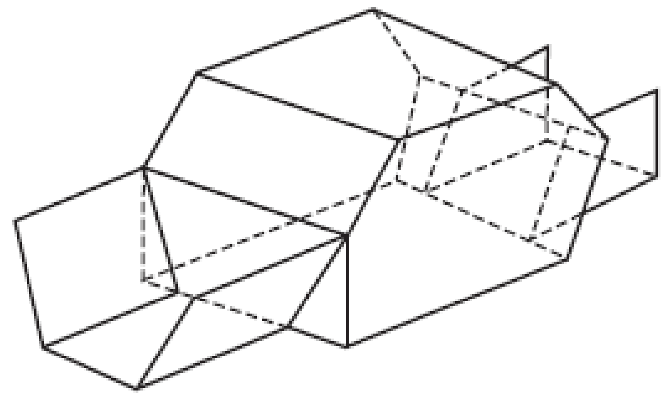
$\eta = 6$

Bus or box type vehicle



$\eta = 7$

Van



$\eta = 14$

Passenger car

SSS and Not SSS

Structures that are structural surfaces

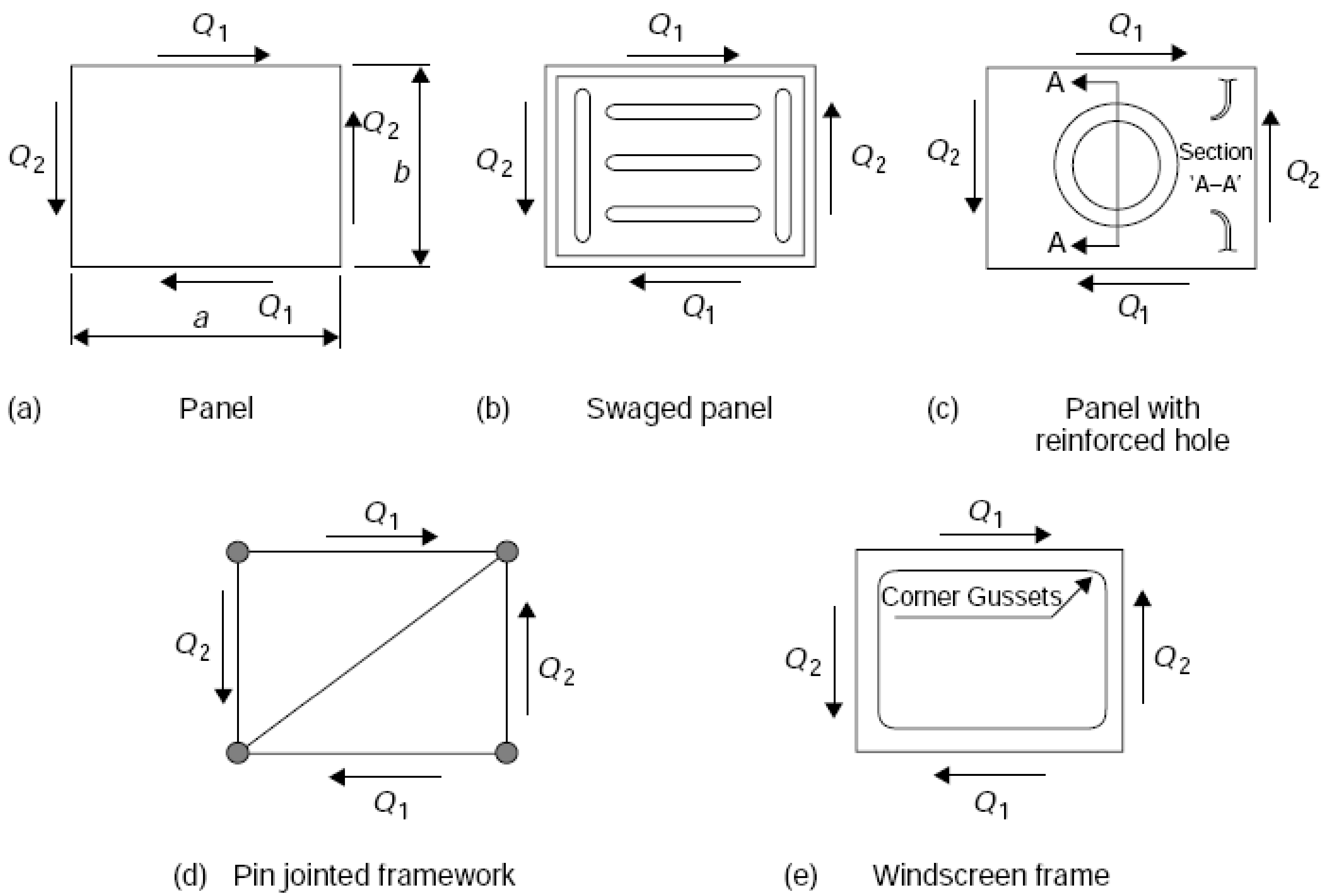
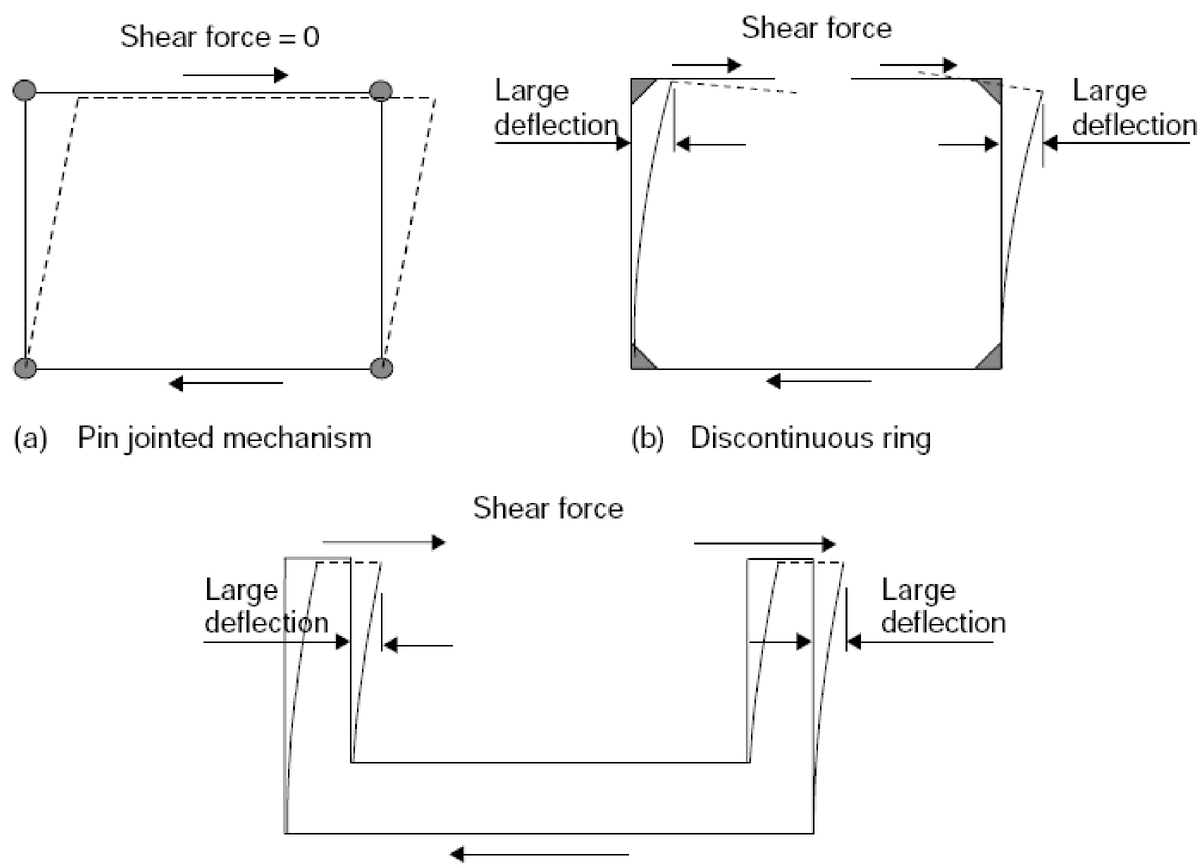


Image from J.C.Brown,2002

Structures that are NOT simple structural surfaces



(a) Pin jointed mechanism (b) Discontinuous ring

(c) Panel with large cut-out

Image from J.C.Brown,2002

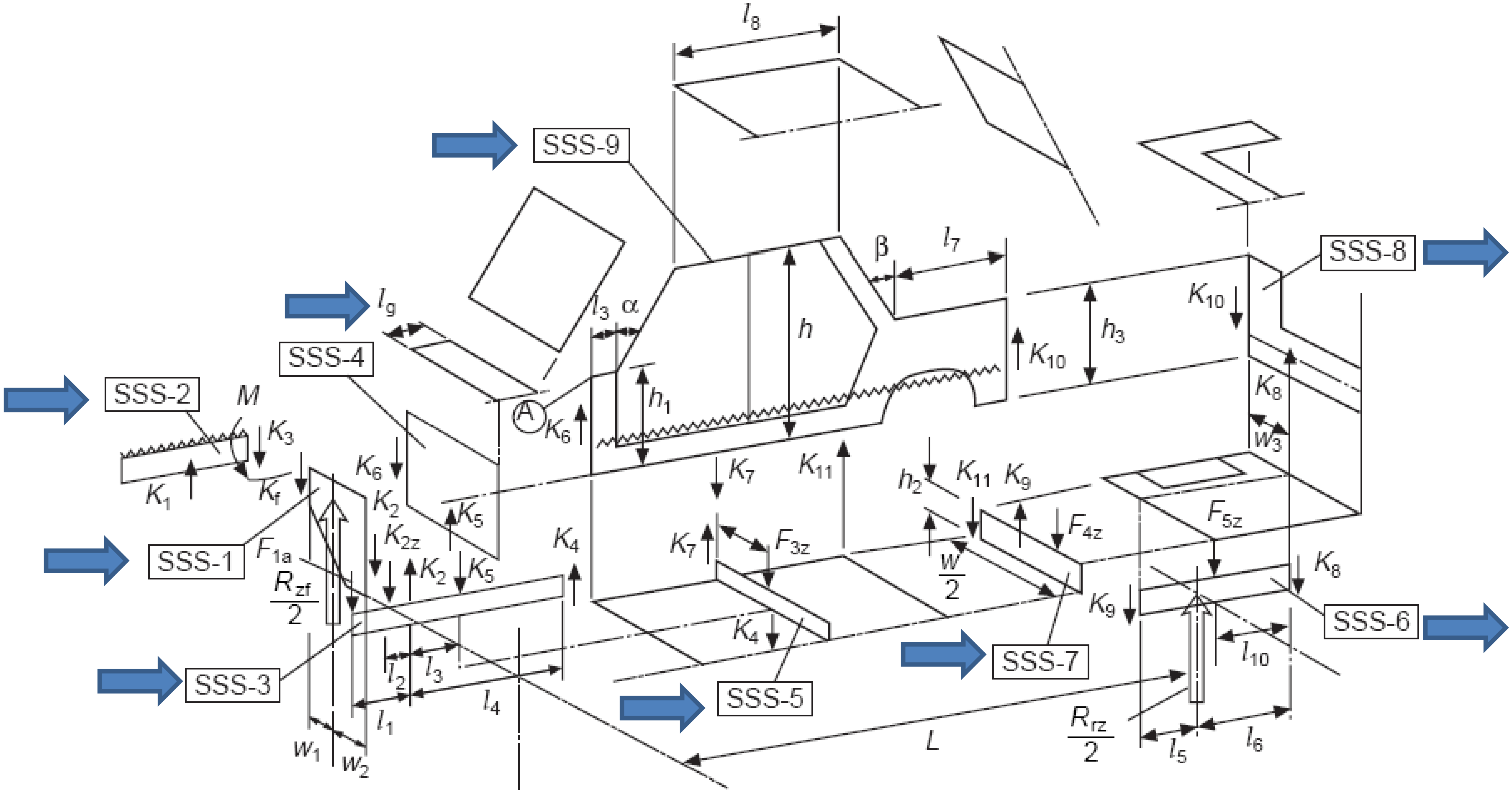
Half saloon model

- Limited to 5 Loads
  - *F_{1z}= (radiator, bumper, battery)/2*
  - *F_{2z}= (engine)/2*
  - *F_{3z}= one front* passenger and seat
  - *F_{4z} = one rear passenger, seat, and half fuel tank*
  - *F_{5z} = (luggage)/2*
- 1 UDL (body weight)

Process

- Calculate reactions at front and rear axles (taking moments and vertical force equilibrium)
  - $R_{zf}/2$
  - $R_{rz}/2$
- Calculate forces in each of the SSS
- 11 equations with 11 unknowns ($K_{1,}$ .. K_{10}, M) can be evaluated from SSS1 to SSS8
- Equilibrium of right frame to be verified with forces and moments

Half Saloon car model - Bending



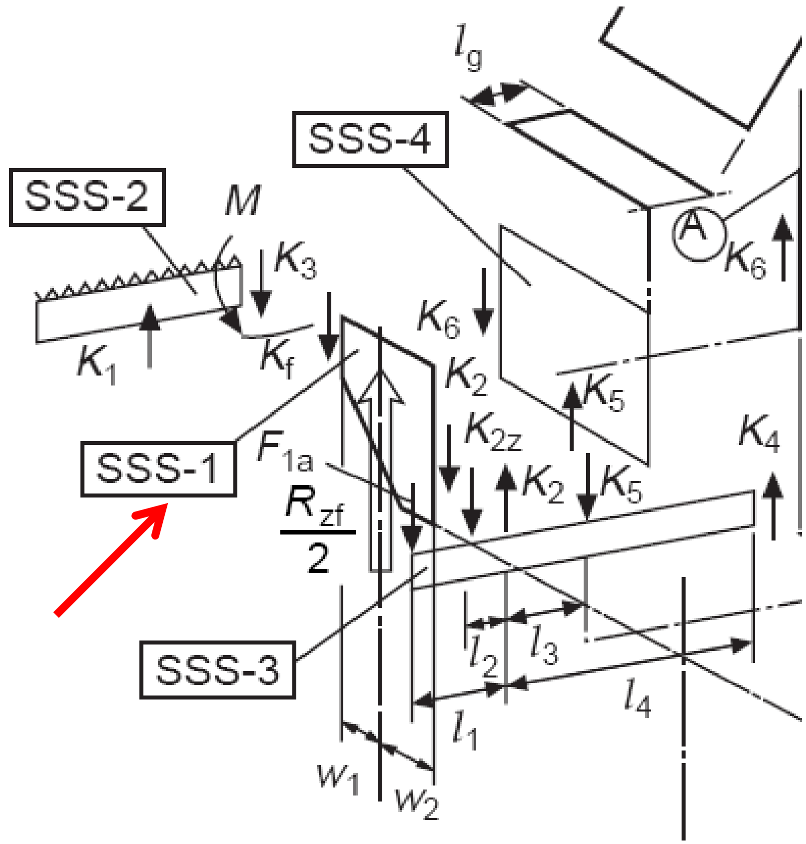
Figure

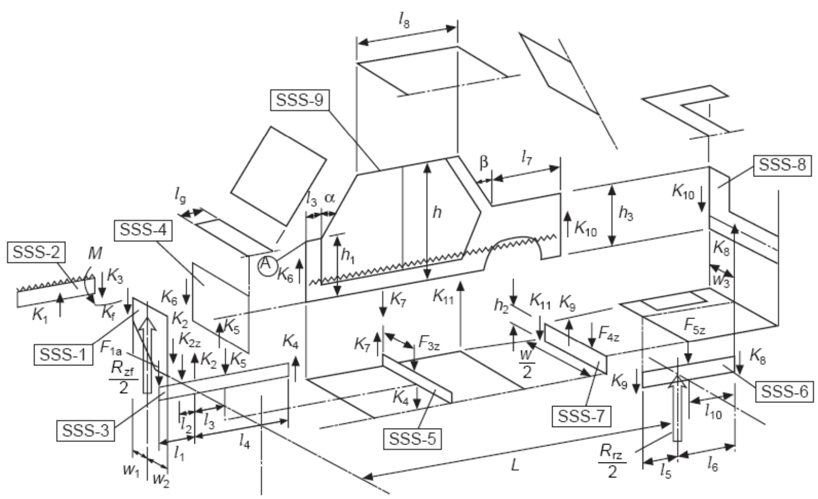
SSS 1

- Transverse SSS representing the strut tower
- Resolving Forces

  $K_1 + K_2 - R_{fz} / 2 = 0$
- Moments

  $K_1 = R_{fz} * w_1 / (2 * (w_1 + w_2))$





Figure

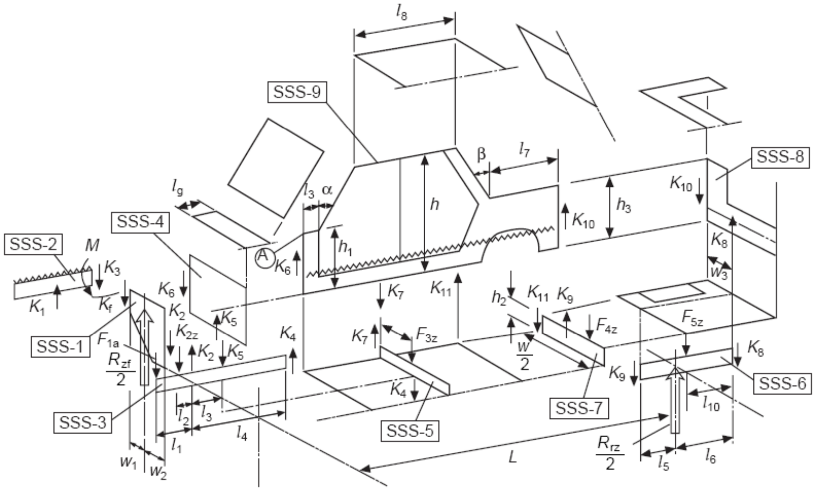
SSS2

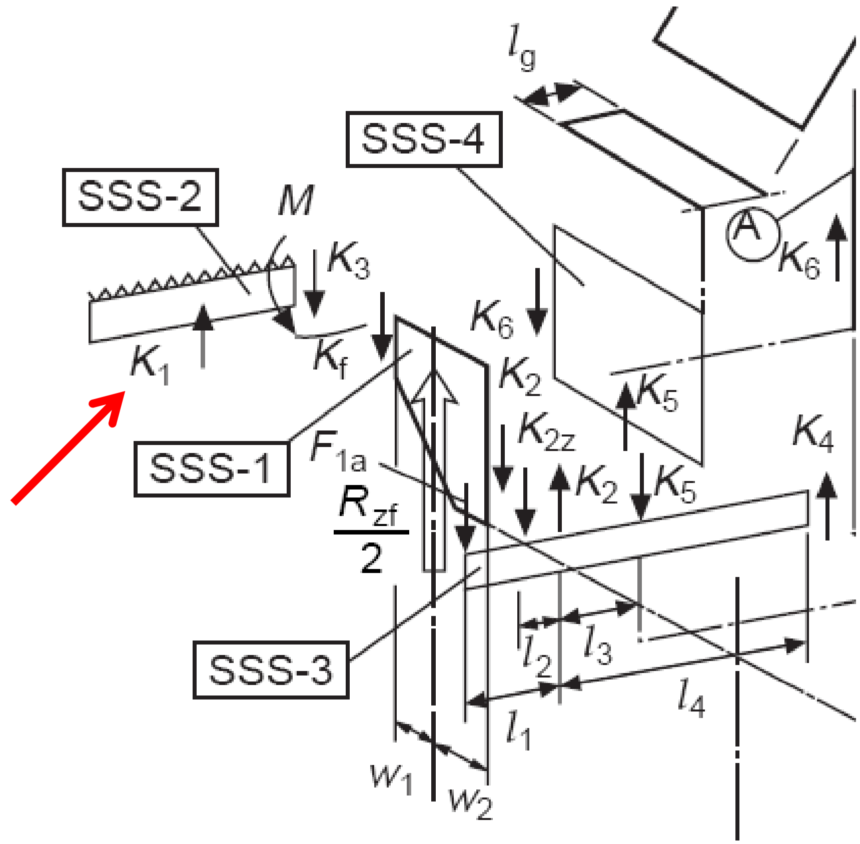
- Upper front longitudinal
- Resolving Forces

  $K_1 - K_3 - u\,(l_1 + l_3) = 0$

- Moments

  $K_1 l_3 - u*((l_1+l_3)^2/2) - M = 0$



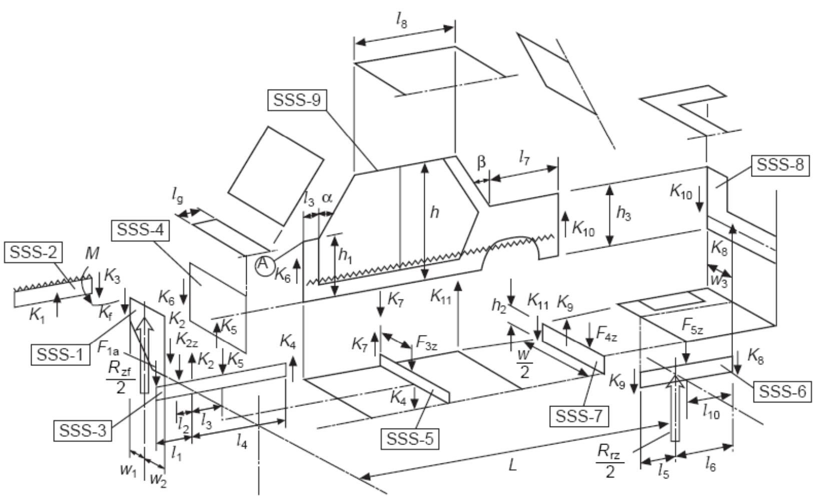


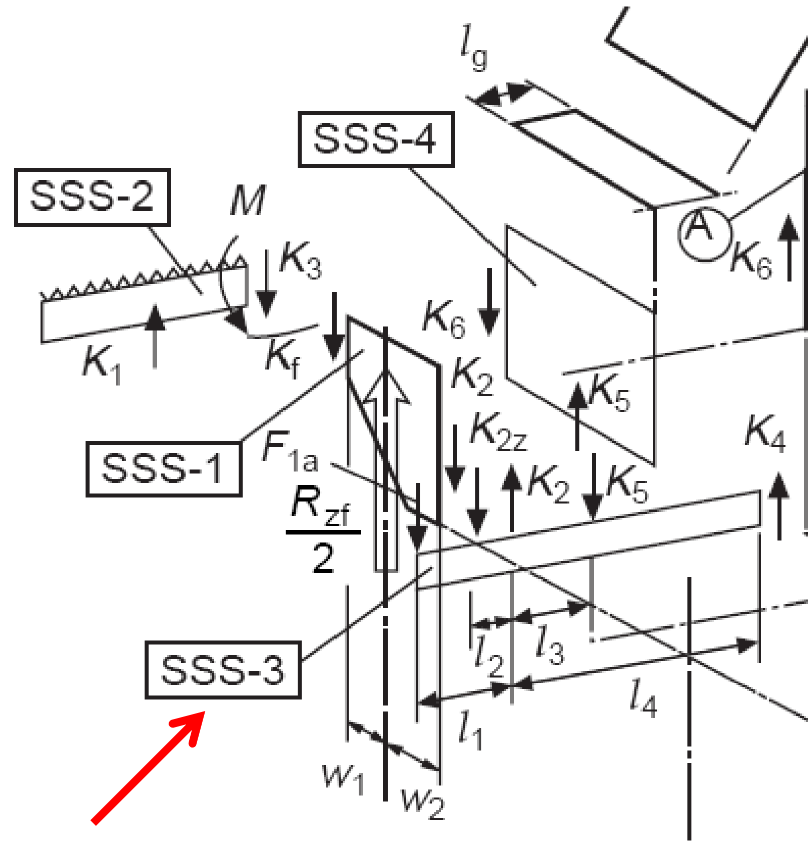
Figure

SSS3

- Lower front longitudinal
- Resolving Forces

$$F_{1z} + F_{2z} + K_5 - K_2 - K_4 = 0$$



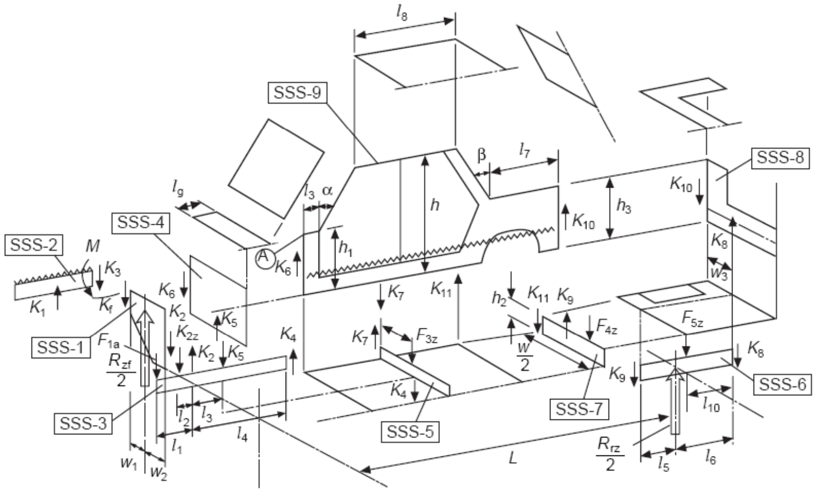


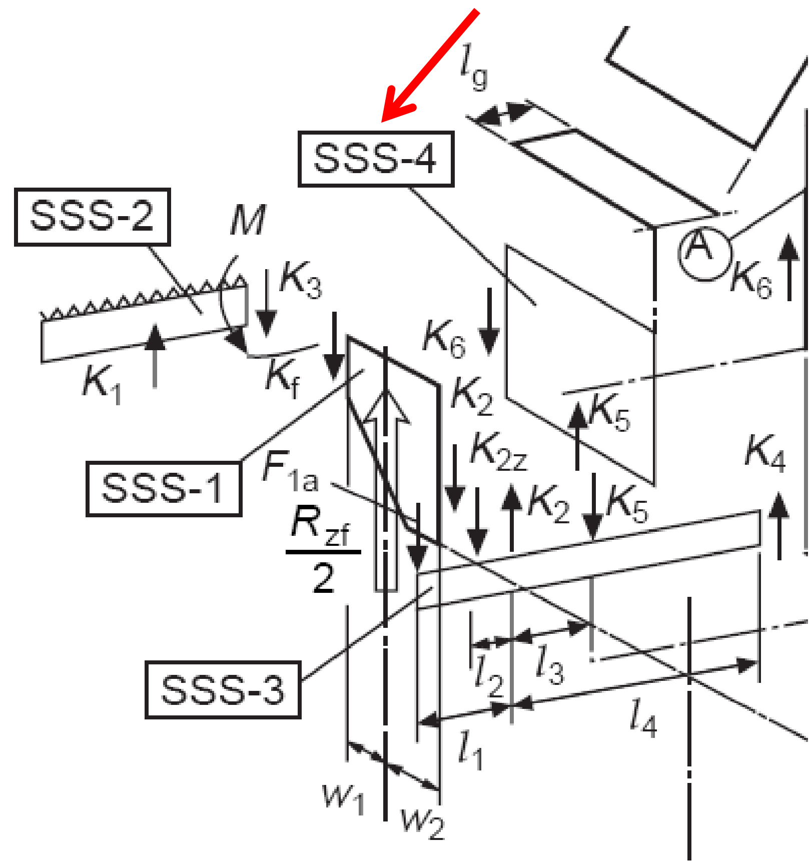
Figure

SSS4

- engine fire wall
- Resolving Forces and by symmetry

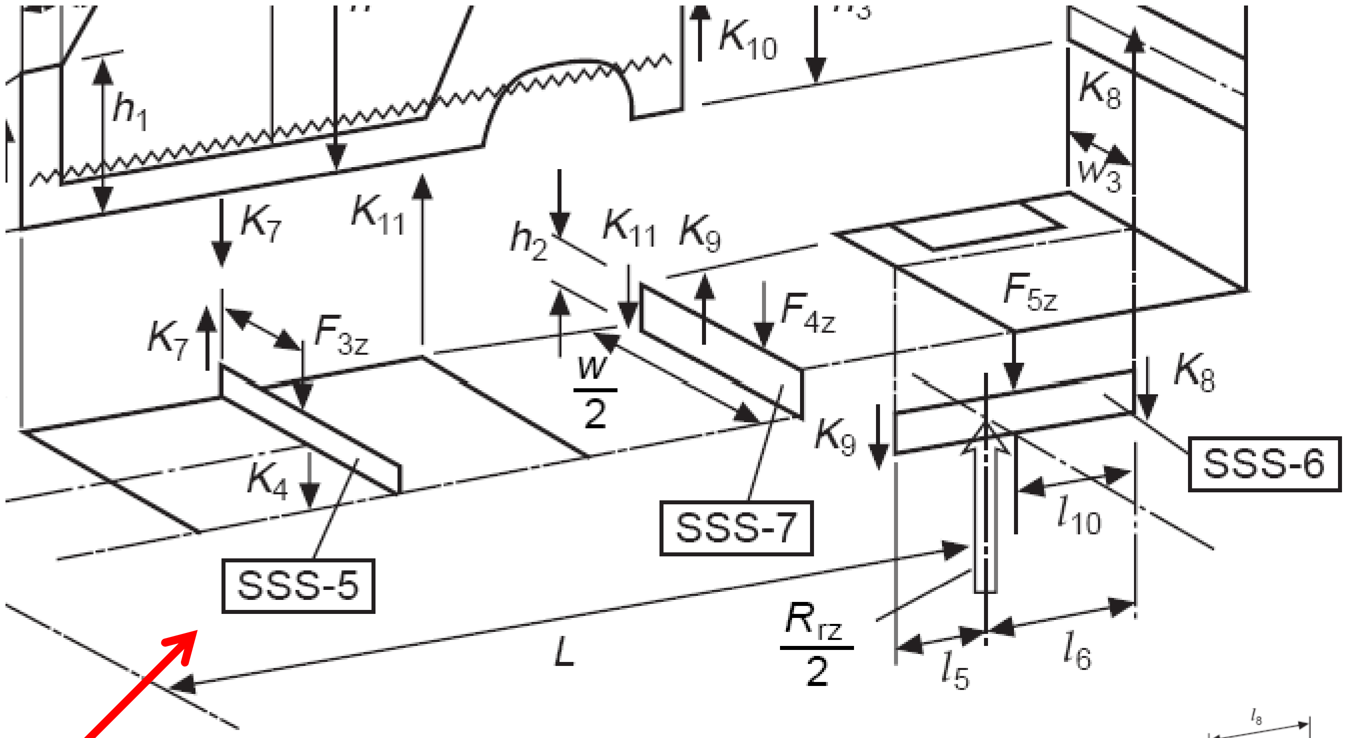
$K_5 - K_6 = 0$





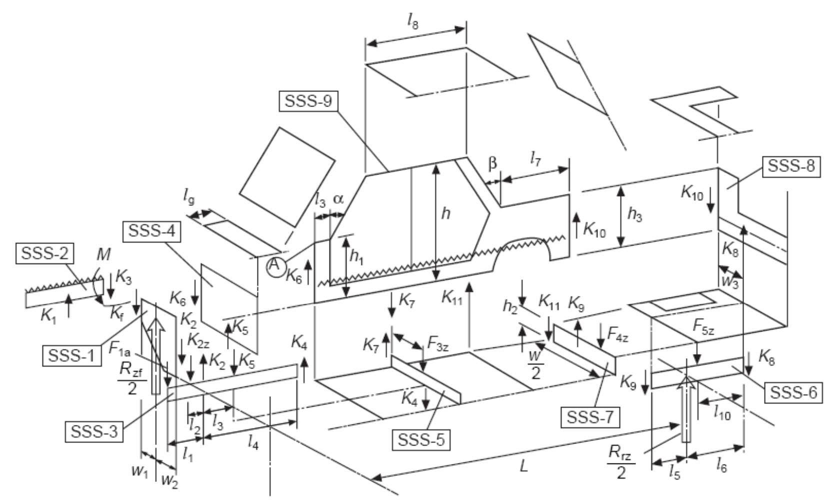
Figure

SSS 5



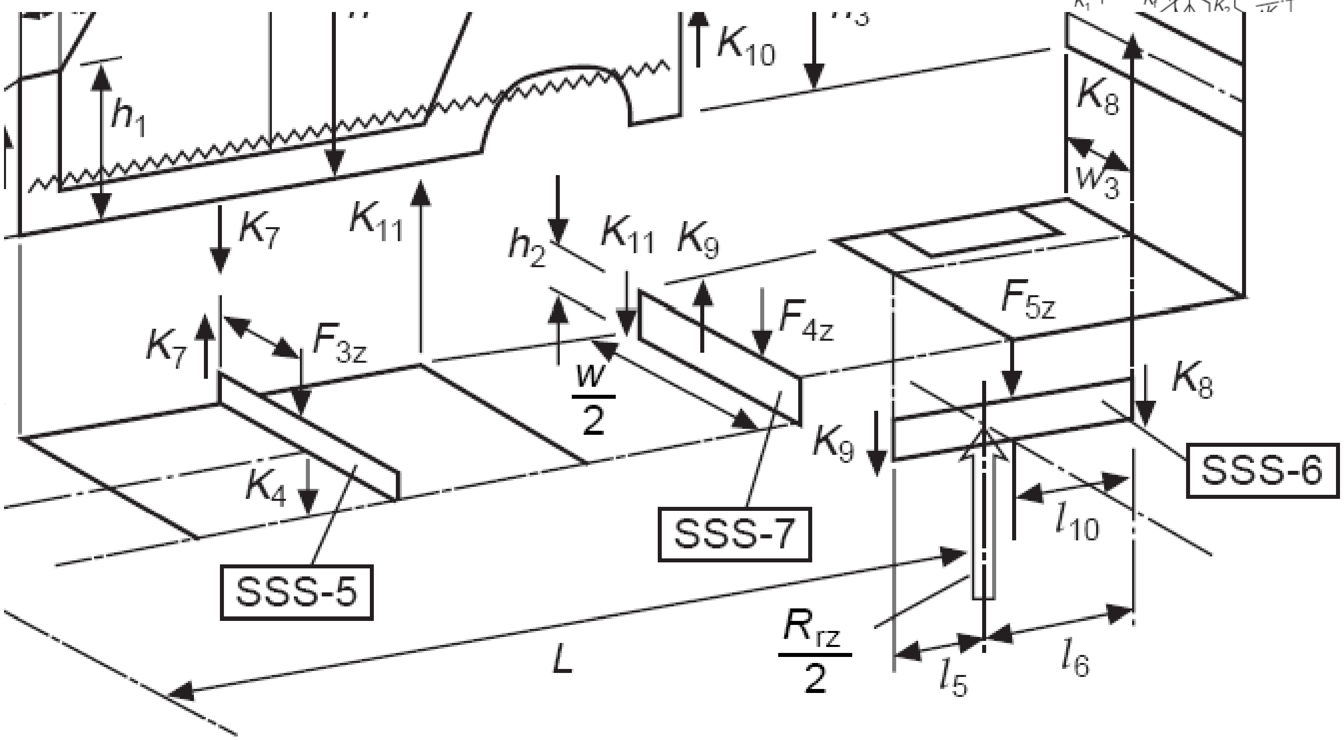
- Floor Cross beam (Front)
- Resolving forces and by symmetr

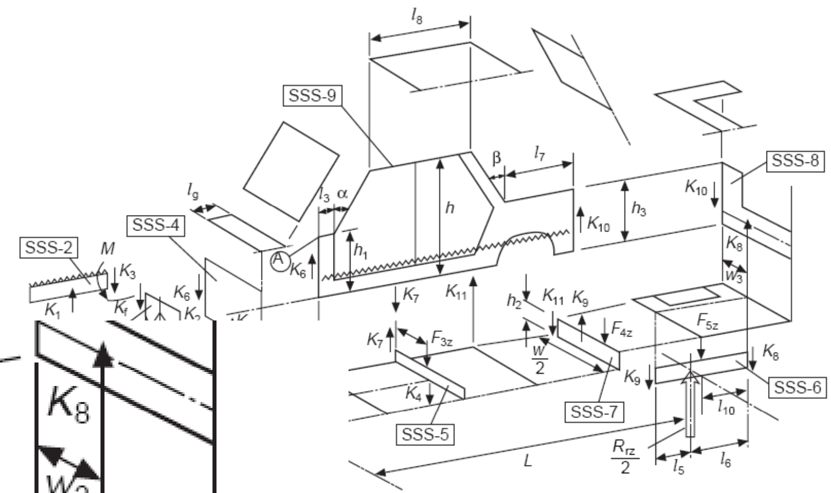
$$K_7 - K_4 - F_{3z} = 0$$



Figure

SSS 6

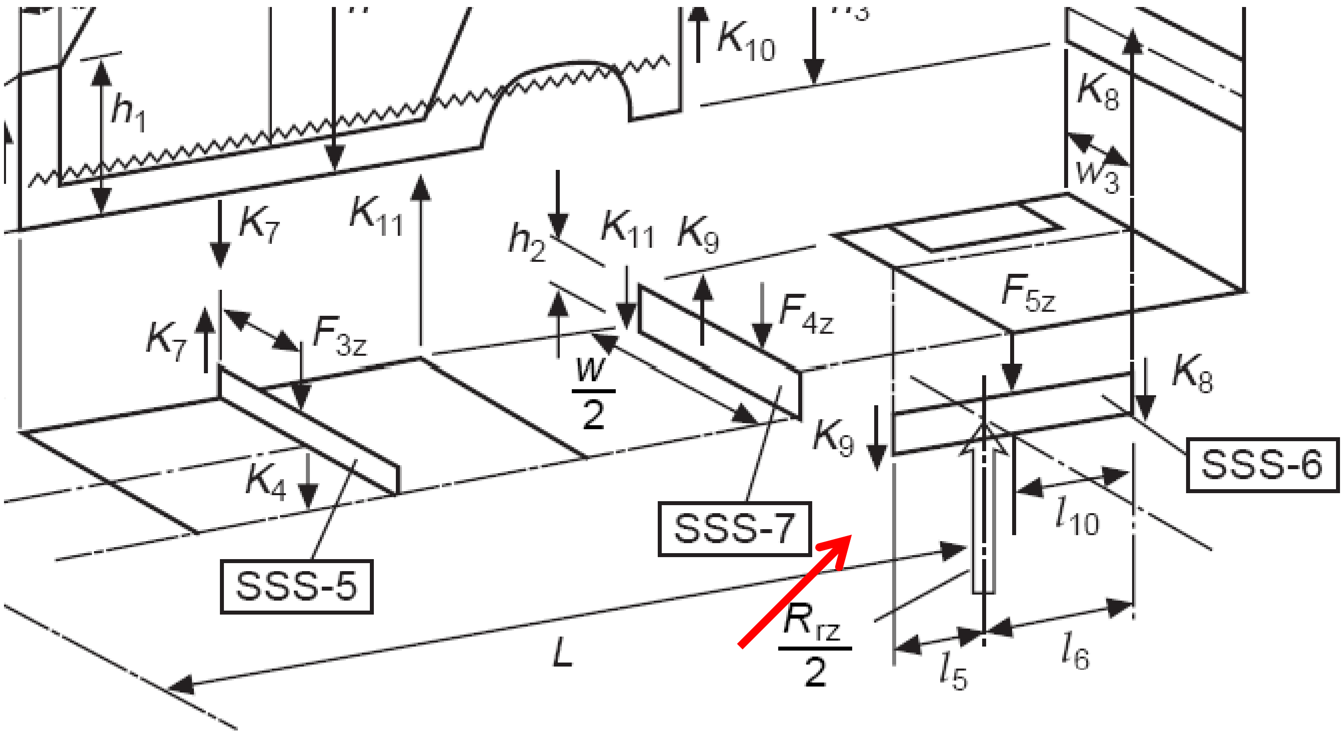




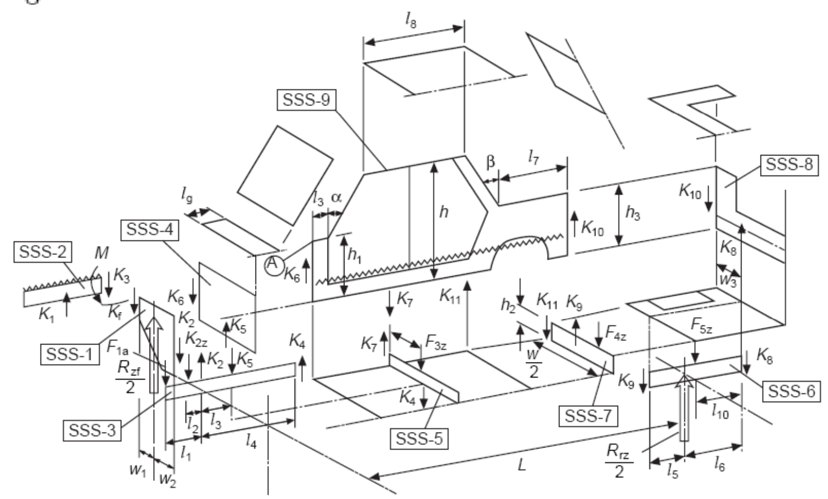
- Longitudinal under boot
- Resolving forces $K_9 + K_8 - R_{rz}/2 + F_{5z} = 0$
- Moments : $K_9 = (R_{rz} * l_6/2 - F_5 l_{10}) / (l_5 + l_6)$

Figure

SSS 7



- Floor cross beam (rear)
- Resolving forces and by symmetr



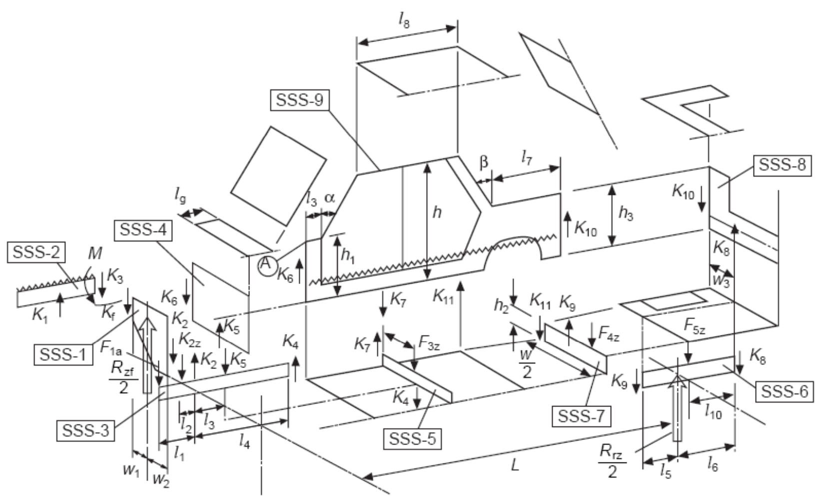
$$K_9 - K_{11} - F_{4z} = 0$$

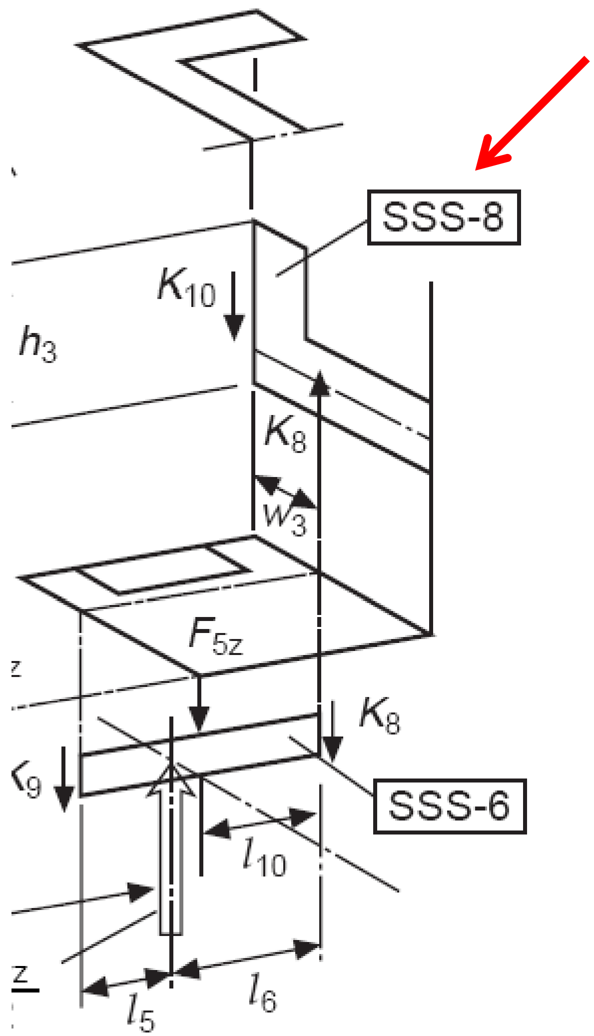
Figure

SSS 8

- Rear Panel
- Resolving forces and by symmetry

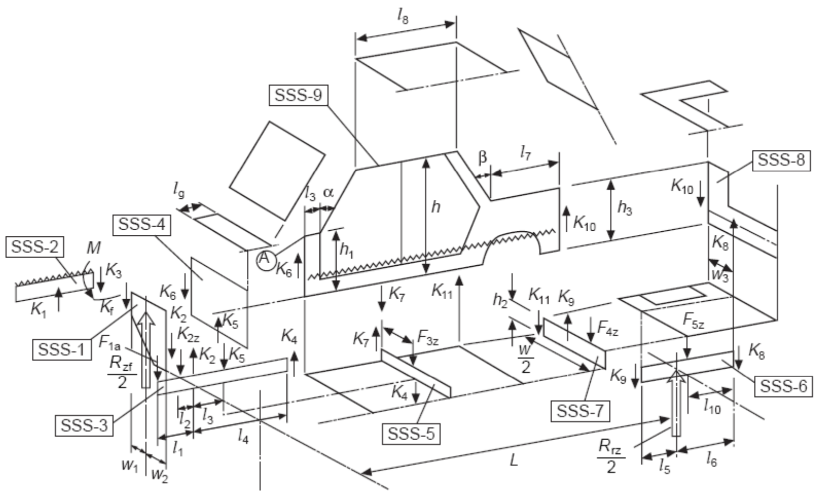
$K_{10} - K_8 = 0$

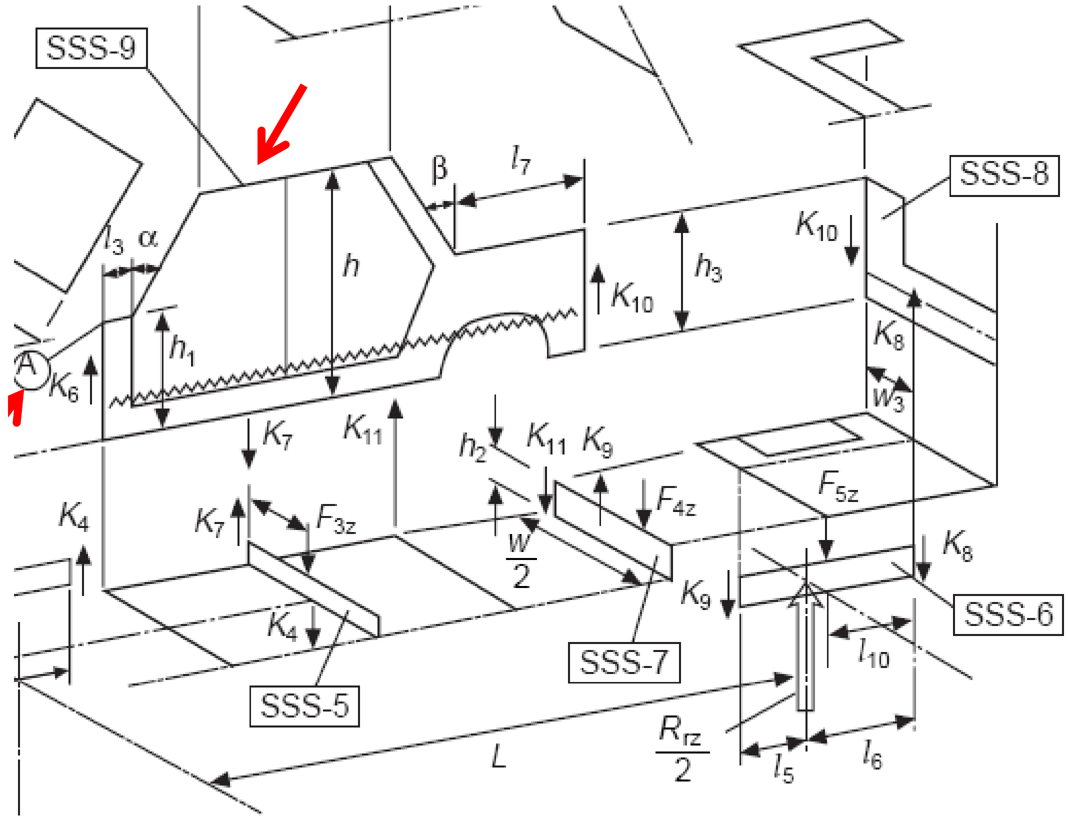




Figure

SSS 9





- Right-hand side-frame
- Resolving forces

$K_6 - K_7 + K_{11} + K_{10} - u*(L + l_6 - l_3) = 0$

- Moments about A

$K_{10}*(L + l_6 - l_3)+K_{11}*(L - l_3 - l_5)-K_7*(l4 - l3)-u*(L + l_6 - l_3)^2/2 = 0$

Conclusion

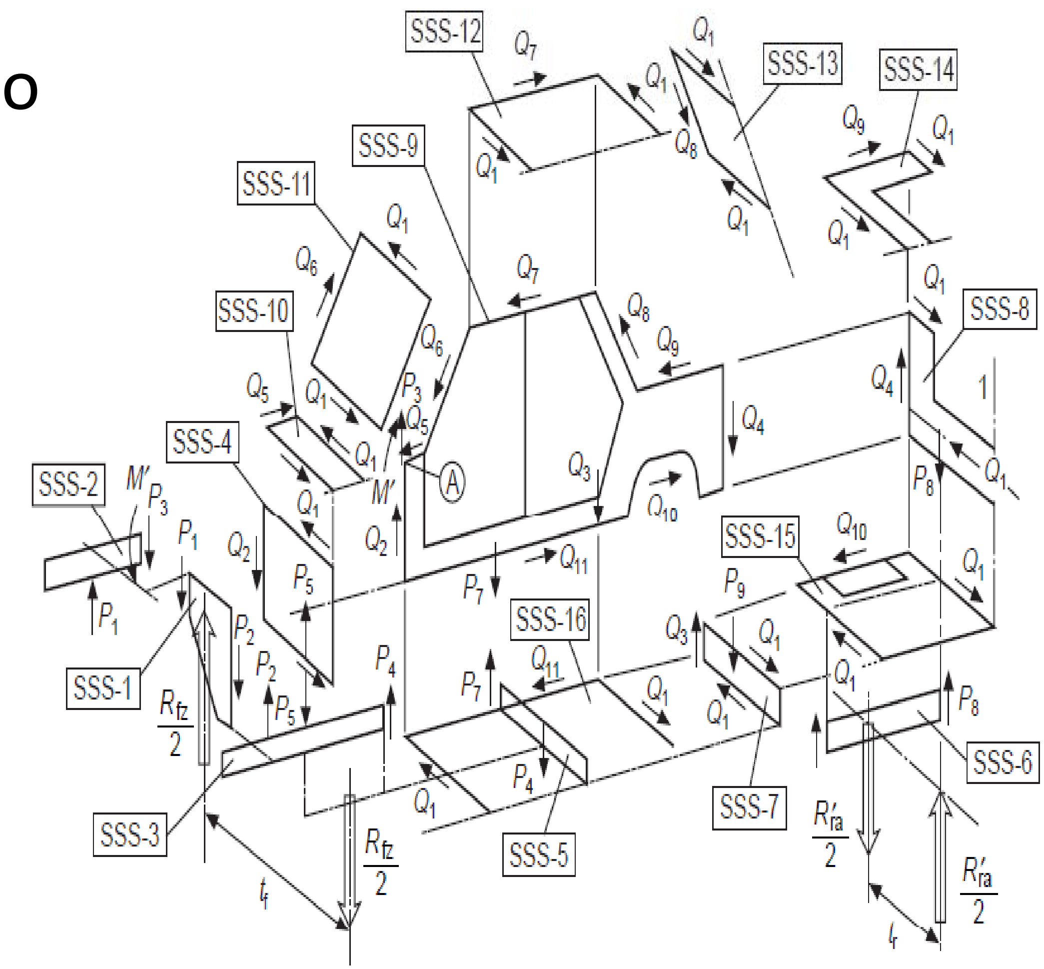
- SSSs 1 to 9 are subject to loads
- The rear boot top frame, rear screen, roof, windscreen, floor panel and boot floor have no loads applied to them
- The side-frame carries the major loads and is the main structural member for determining the bending stiffness and strength of the car.

SSS representation of a saloon car in torsion

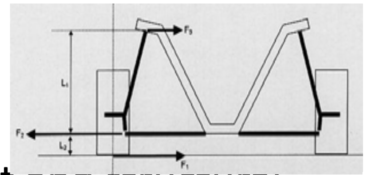
- Front axle is assumed to be lighter than rear.
- Maximum torque that can be applied is:

$$\frac{R_{fz}}{2} * t_f = \frac{R'_{rz}}{2} * t_r$$

- R_{fz} and R'_{rz} are reaction loads at suspension mounting points
- R'_{rz} can be obtained.



- SSS-1 (Strut tower)



  - The car's alignment and structural rigidity depends on the strut tower.

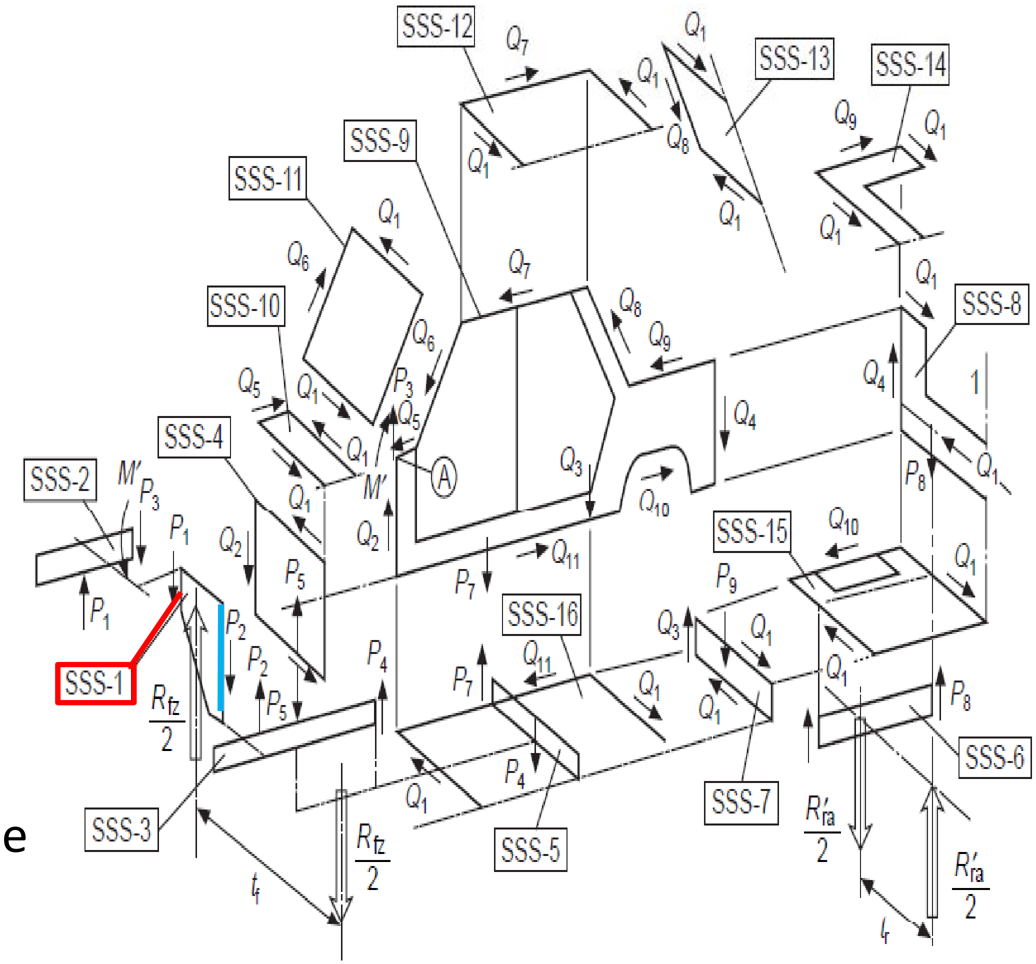
- Resolving forces:
  - Forces are not balanced .

$$P_1 + P_2 - \frac{R_{fz}}{2} = 0$$

- Moment balance
  - Taking moment about the medial edge

$$P_1 = \frac{R_{fz}}{2} * \frac{w_2}{(w_2 + w_1)}$$

- P_1 and P_2 can be determined from the above equations.
- As this is a half model , loads on the left strut tower (SSS-1’) will be equal but opposite in direction



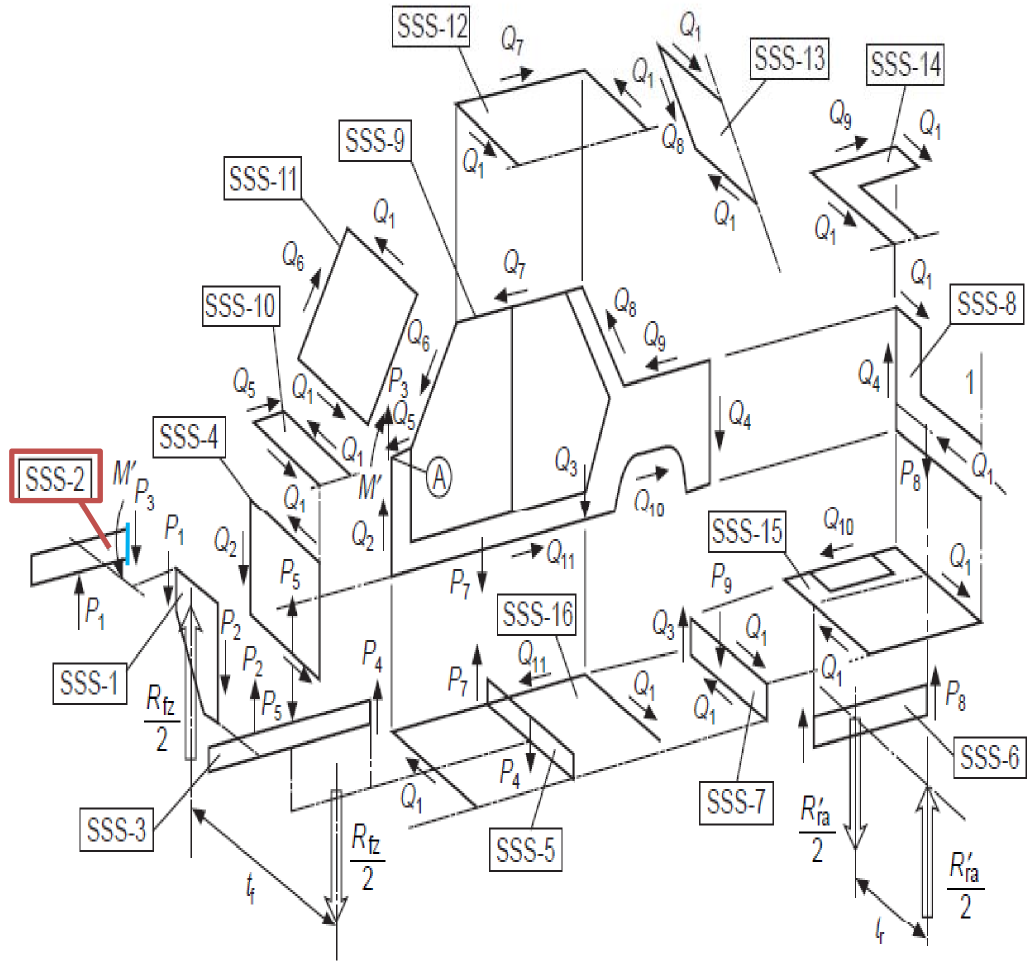
- SSS-2 (Upper front longitudinal)
  - Load P_1 from strut tower is transmitted.
- Force balance

$$P_3 - P_1 = 0$$

- Moment balance
  - P_1 is equal to P_3
  - creates a moment in clockwise direction
  - moment M’ balances
  - Moment taken wrt rear edge

$$M' - P_1 l_3 = 0$$

- SSS-2’ have equal but opposite loads.
- P3 and M’ can be found.



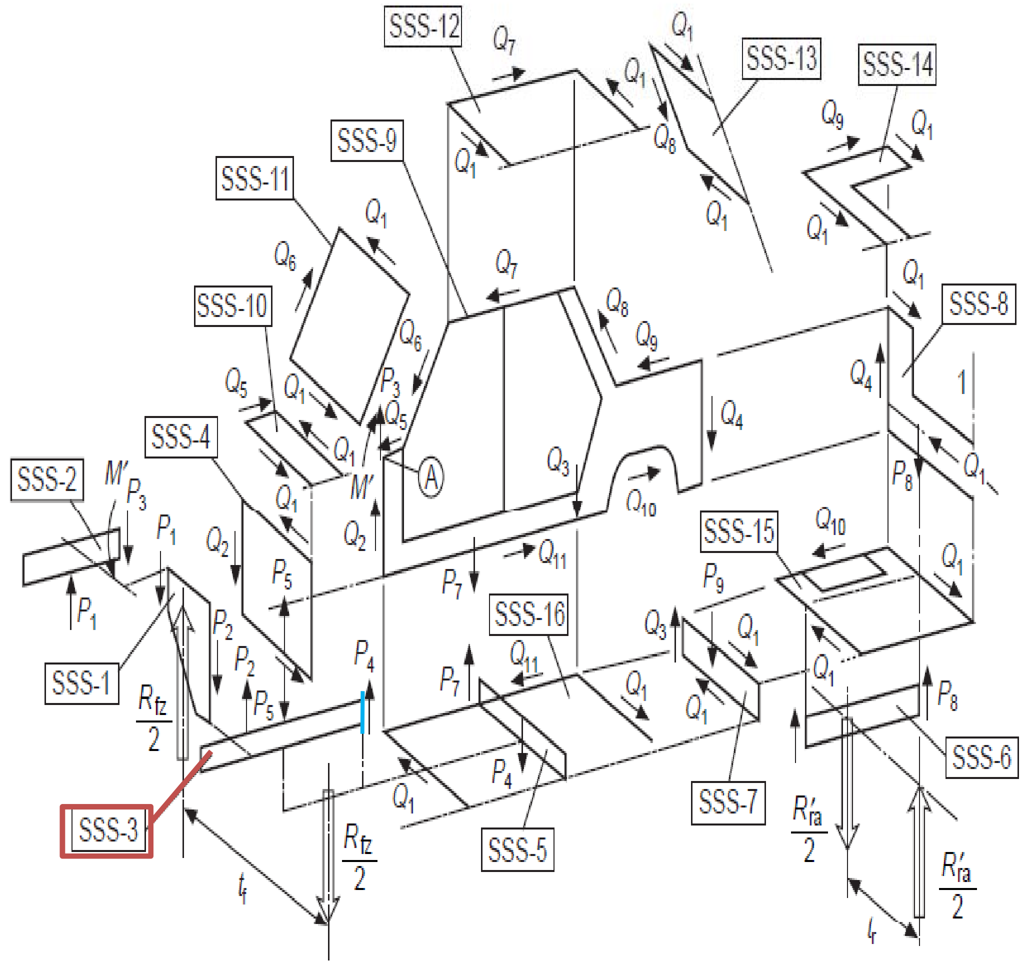
- SSS-3 (Lower front longitudinal)
  - P_2 from strut tower is transmitted
- Force balance:

$$P_2 + P_4 - P_5 = 0$$

- Moment balance:
  - Taken wrt rear edge

$$P_5 = \frac{p_2 l_4}{(l_4 - l_5)}$$

- SSS-3' have equal and opposite loads.
- P4 and P5 can be found.



- SSS-5 (Floor cross beam)
- Moment balance:

$$P_4(t_f - 2w_2) - P_7 w = 0$$

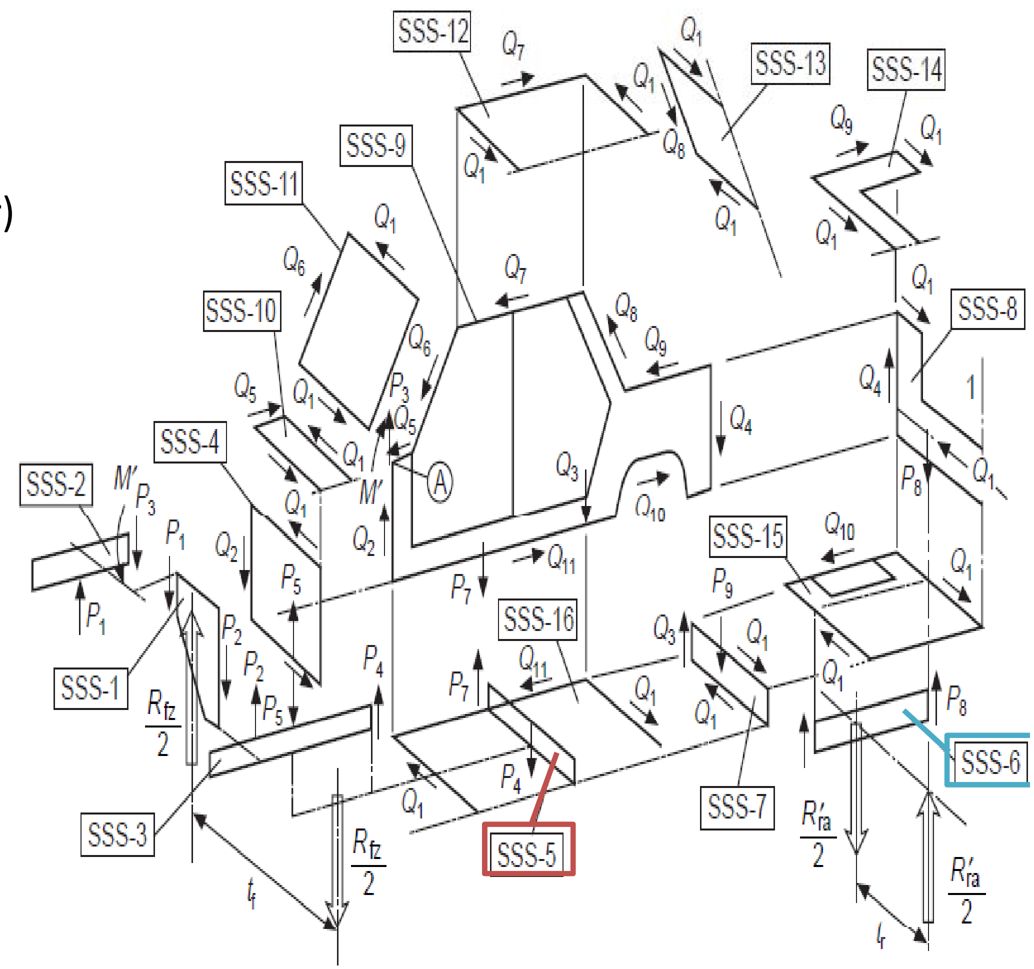
- SSS-6 (Longitudinal under boot floor)
- Force balance:

$$P_9 + P_8 - \frac{R'_{rz}}{2} = 0$$

- Moment balance:

$$P_8 = \frac{R'_{rz} * l_6}{2 * (l_6 + l_5)}$$

- SSS-6' will have equal and opposite loading
- P_7, P_8 and P_9 can be found.



- # SSS-4 (Engine firewall)
- Moment balance:

$$P_5(t_f - 2w_2) - Q_1 h_1 - Q_2 w = 0$$

- # SSS-7 (rear floor cross beam)
- Moment balance:

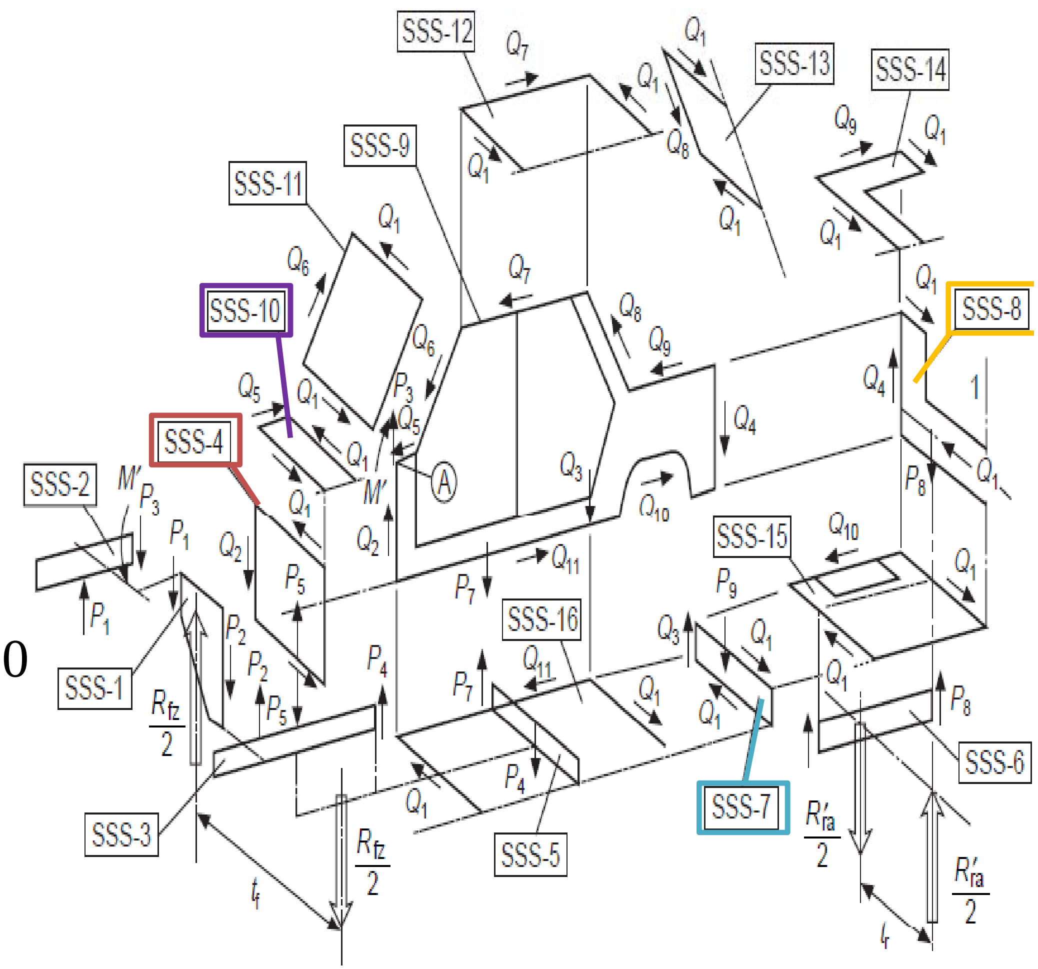
$$P_9 t_r - Q_1 h_2 - Q_3 w = 0$$

- # SSS-8 (rear floor cross beam)
- Moment balance:

$$P_8 t_r - Q_1(h_3 - h_2) - Q_4 w = 0$$

- # SSS-10 (rear floor cross beam)
- Moment balance:

$$\frac{Q_1(h - h_1)}{\cos\alpha} - Q_6 w = 0$$



- SSS-12 (Roof panel)
- Moment balance:

$$Ql_8 - Q_7 w = 0$$

- SSS-13 (Back-light frame)
- Moment balance:

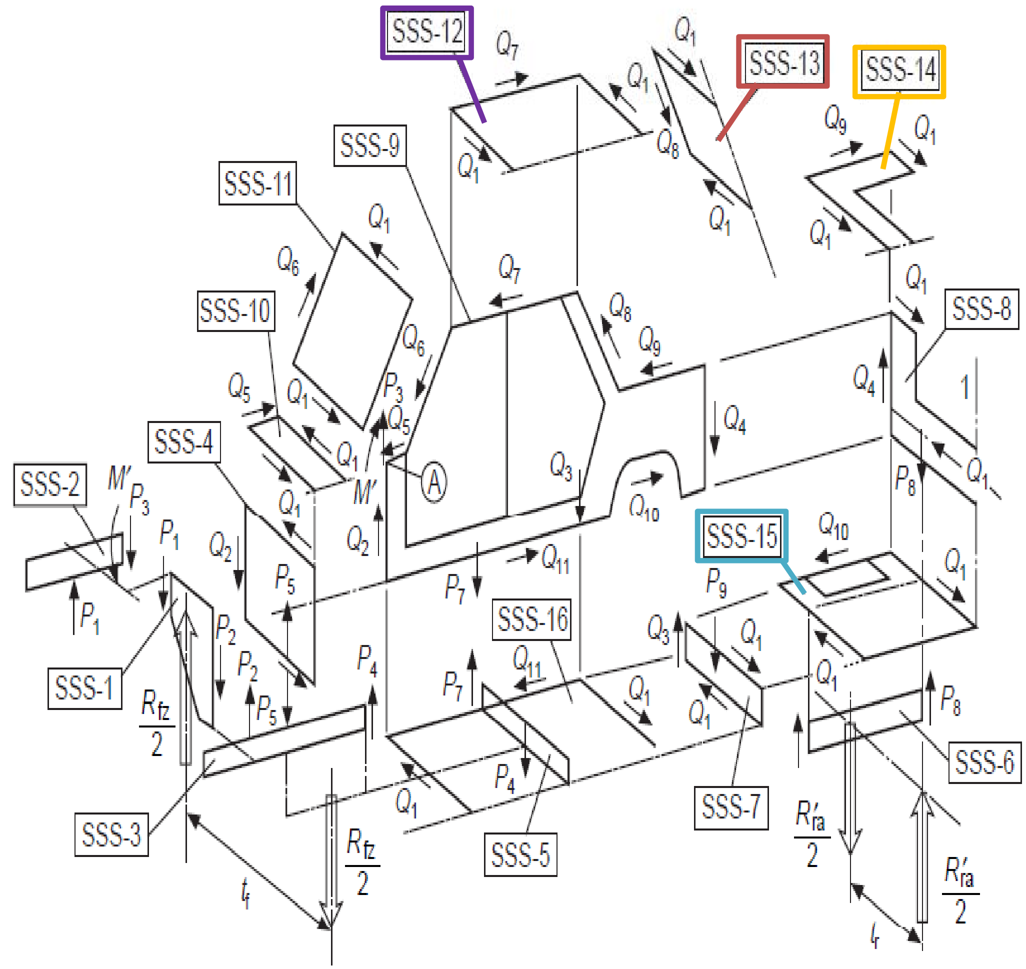
$$\frac{Q_1(l - h_3)}{\cos\beta} - Q_8 w = 0$$

- SSS-14 (Trunk top frame)
- Moment balance:

$$Ql_7 - Q_9 w = 0$$

- SSS-15 (rear floor cross beam)
- Moment balance:

$$Q_1(l_5 + l_6) - Q_{10} w = 0$$



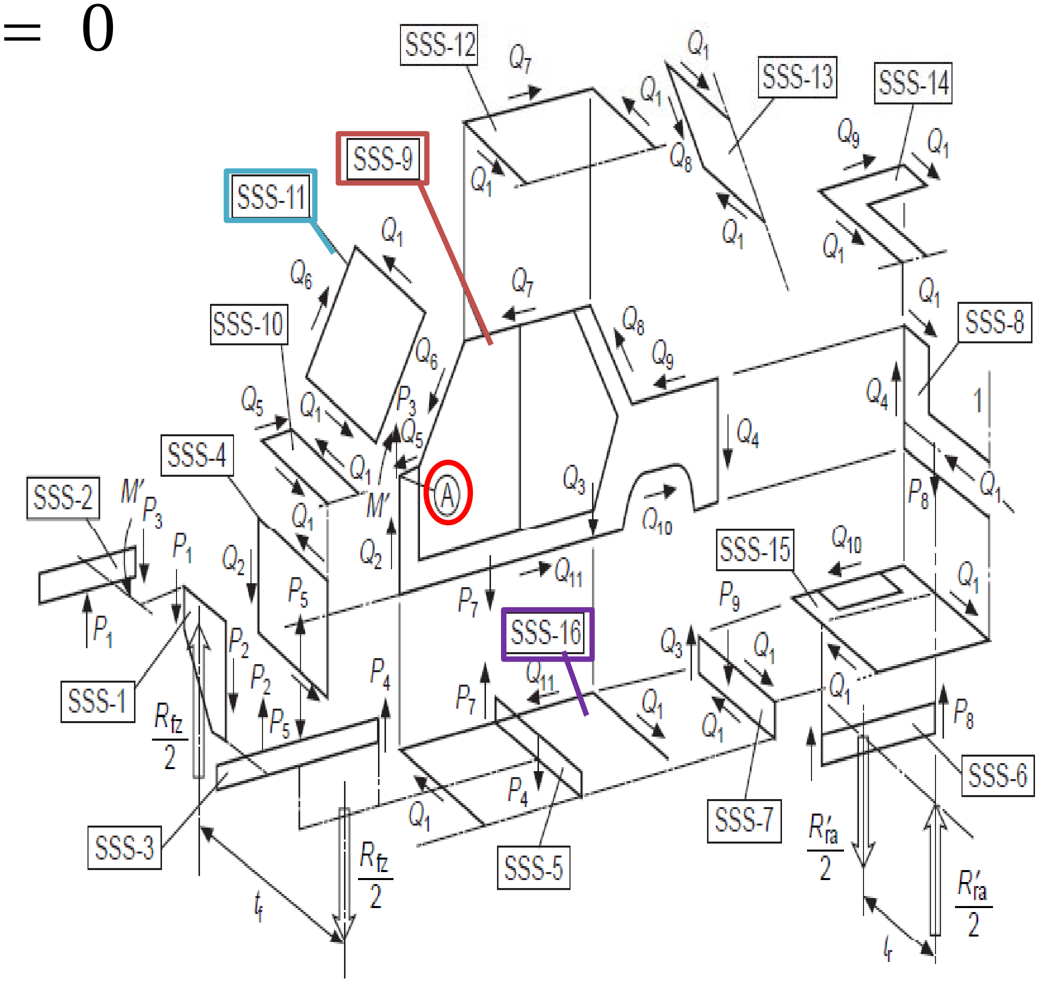
- SSS-16 (Main floor)
- Moment balance:

$$Q_1(L - l_5 - l_3) - Q_{11}w = 0$$

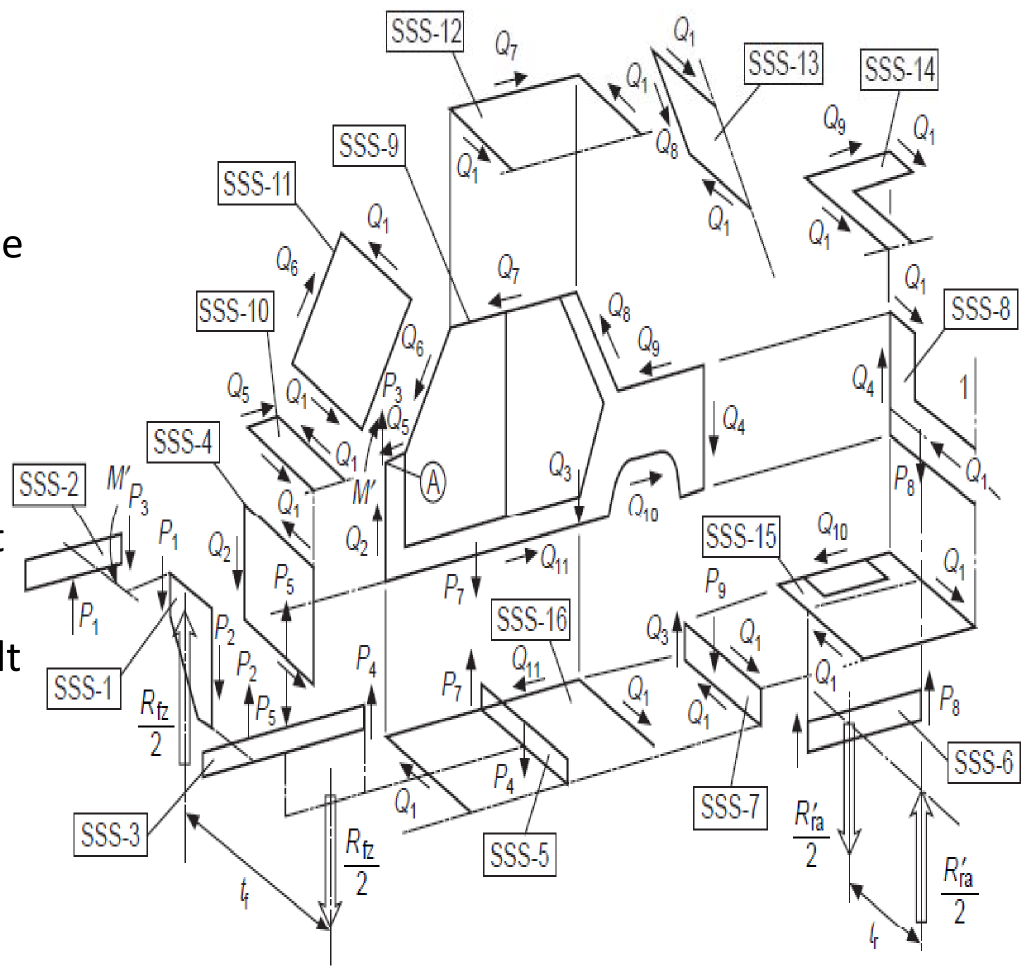
- SSS-11 – SSS-16 are in complimentary shear
- SSS-9 (side frame)
- Moment about A:

$$Q_4(L+l_6-l_3)+Q_3(L-l_5-l_3)+P_7(l_4-l_3)$$
$$+M'+Q_6(l_9\cos\alpha)-Q_7(h-h_1)$$
$$-Q_8\cos\beta(L+l_6+l_7-l_3)-Q_8\sin\beta(h_3-h_1)$$
$$-Q_9(h_3-h_1)-Q_{10}(h_1-h_2)-Q_{11}(h_1)=0$$

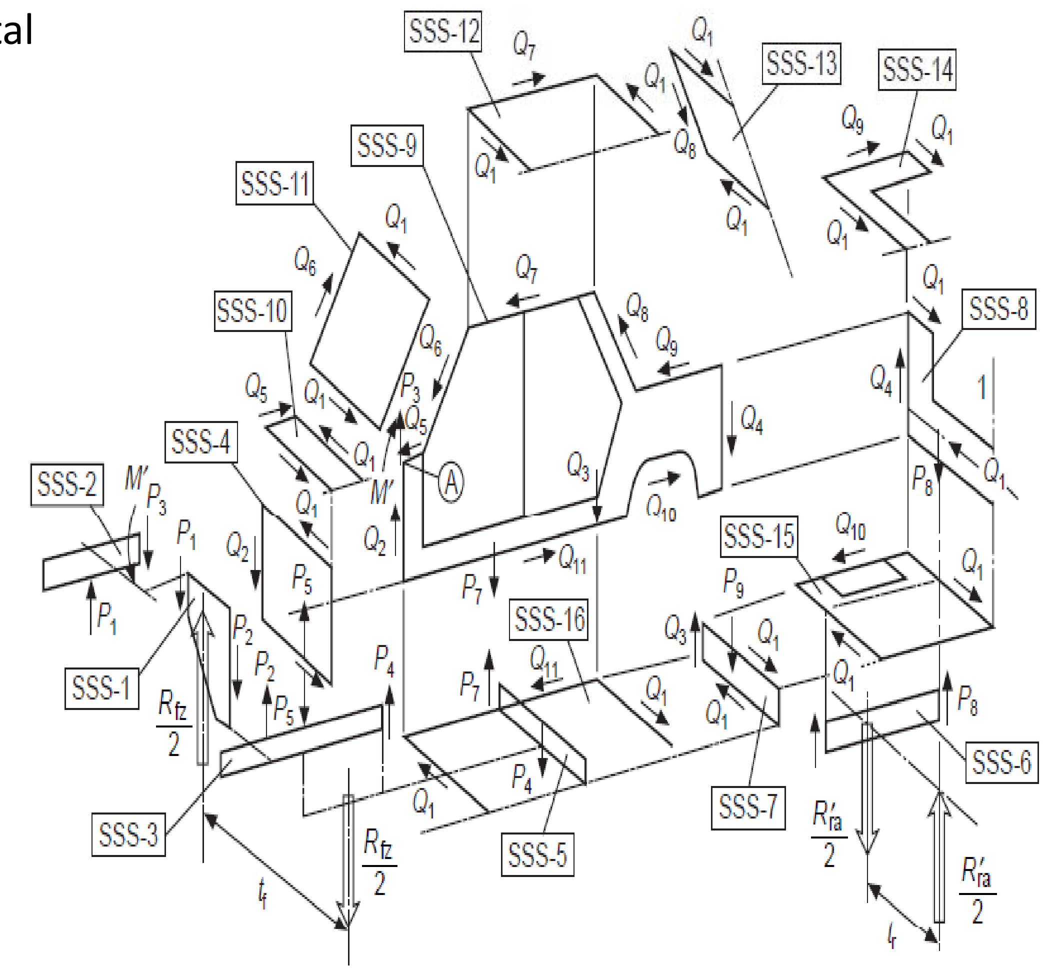
- 11 equations and 11 unknowns
- $Q_1 \ldots Q_{11}$ can be solved.



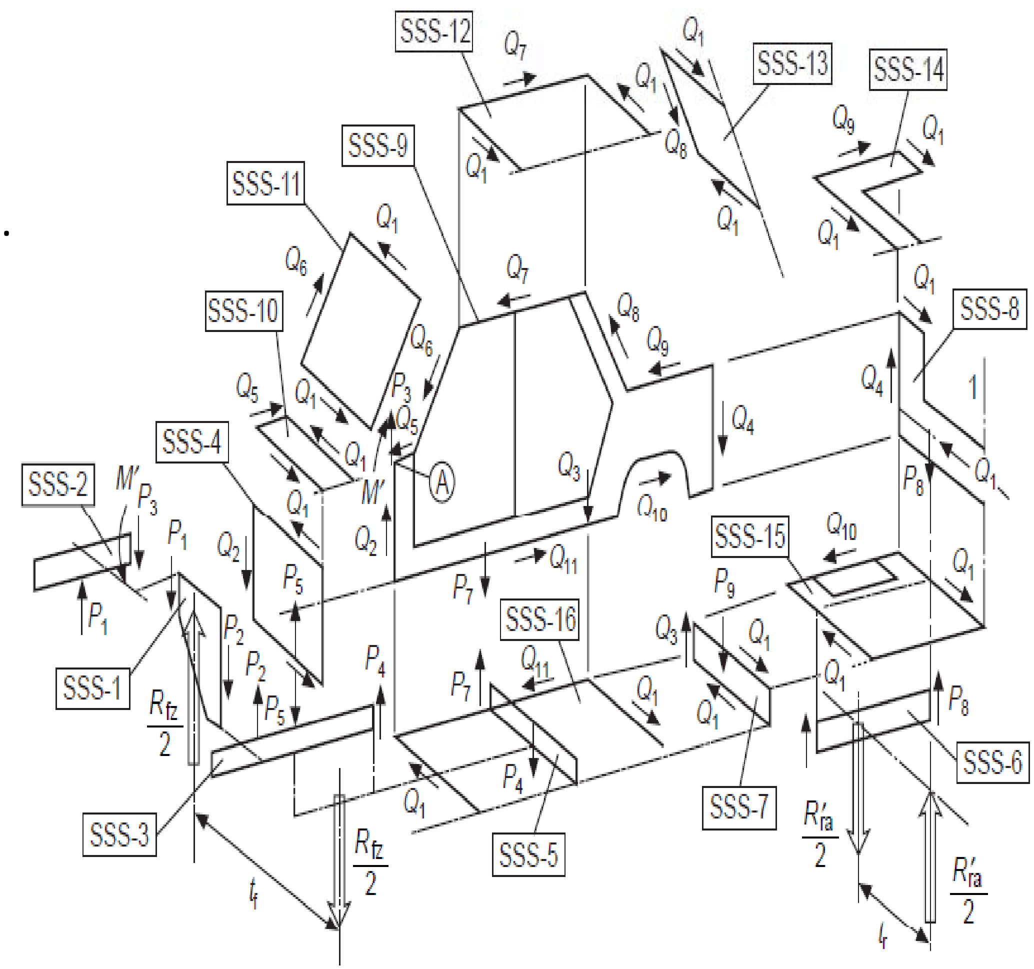
- Examination of figure reveals:
  - Shear force is applied to all panels
  - Including windscreen frame, backlight frame, trunk frame, rear panel, floor panel and trunk floor panel
  - Should have good shear stiffness
  - Floor panel requires swaging to prevent buckling.
  - Windscreen frame and backlight frame must be constructed with stiff corner joints
  - This ensures shear is transferred to roof.
  - In other words these frames must not shear.
  - A single poor frame stiffness will result in poor vehicle torsional stiffness



- Examination of figure reveals:
  - Windscreen frame and backlight frame are stiffened by glass, which acts as shear panel
  - Glasses are bonded to frames
  - This ensures glass is retained in frontal impacts
  - Glass is subjected to shear stress
  - If surrounding frames are less stiff glass may crack
  - Rear panel and trunk top frame are subjected to shear.
  - These 2 components are not very good SSSs due to large discontinuity caused by trunk lid.
  - Overcome by high sill or lift over
  - This makes poor access for loading luggage

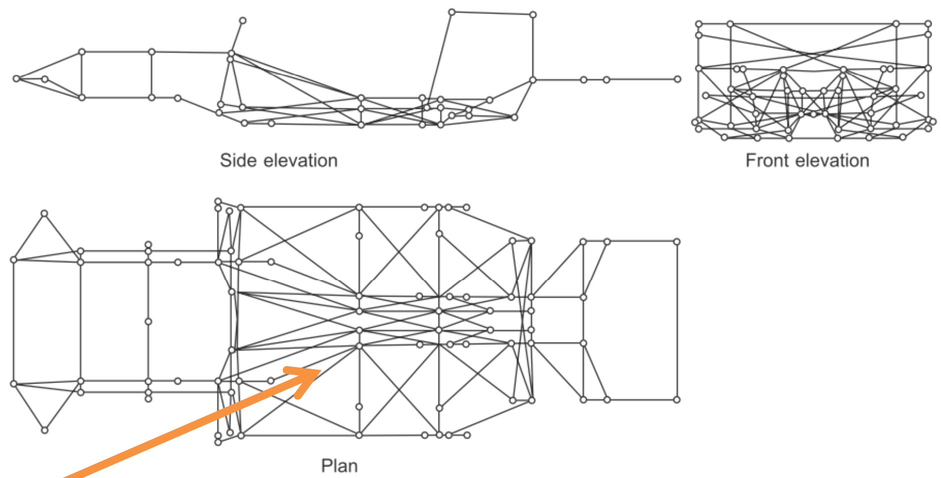


- Examination of figure reveals:
  - Side rear panels which houses rear lights are made wide like the sides of the trunk top frame.
  - A better structure will incorporate a panel or cross brace in the plane of rear sear back.
  - Most of the modern car do not have this as customers prefer folding seats.



Computational methods

- Structural analysis is now fundamental in vehicle design process
- Finite element method (FEM) is a promising tool in structural analysis
- Vehicle structures are divided into small elements
- Finite elements deforms while in SSS structures are assumed to be rigid
- Static and/or dynamic equilibrium equations along with material constitutive equations are solved using linear algebra
- Complexity of FEM increased as detail of vehicle model increases
- Beam elements represent sills, window pillars, engine rails and floor cross beams
- Floor, roof, bulkheads can be modeled by equivalent beams that have stiffness equivalent to shear panels



Computational methods

- Recent models use plate and shell elements to accurately represent sheet metal components
- Number of loads and number of elements results in a very large data set.
- Long model preparation time and long computer solving time
- Initial loading to FEM can be derived using rigid body methods like SSS.