Terminology and Overview of Vehicle Structure Types
Basic Requirements

- **Purpose of structure**
  - To maintain the shape of the vehicle.
  - To support the various loads applied to vehicle.

- **Design aim**
  - To achieve sufficient levels of *strength and stiffness* with a minimum *mass*
  - To achieve acceptable *crash* performance
Strength

“no part of the structure will lose its function when it is subjected to road load”

Loss of structural function

- Instantaneous overloads due to extreme load cases
  - Overstressing
  - Buckling
  - Failure of joint

- Material fatigue
**Strength**

- **Definition:**
  Maximum force which the structure can withstand

- **Note**
  - Different load cases cause different local component loads.
  - The structure must have sufficient strength for all load cases.
The stiffness of the structure, \( (K) \) relate the deflection produced \( (\Delta) \) when load is applied:

\[
P = K \Delta
\]

- The stiffness of a vehicle structure has important influences on its handling and vibrational behavior.

- The two stiffness definitions are:
  - Bending stiffness, \( K_B \)
  - Torsional stiffness, \( K_T \)
**Stiffness**

- **Bending stiffness,** $K_B$
  - Relates the symmetrical *vertical deflection* of the point near the center of the wheelbase to *multiples static loads* on the vehicle.

- **Torsional stiffness,** $K_T$
  - Relates the *angular deflection* ($\theta$) to an applied *pure torque* about the longitudinal axis of the vehicle.

  *Torsion case usually difficult to design for, so that the torsional stiffness is often used as a benchmark of vehicle structure.*
Selection of vehicle type & concept

- Satisfactory Structure
  - Most appropriate structural type for intended application.
  - Correct layout of structural elements. *(satisfactory load paths, without discontinuities)*
  - Appropriate size of panels and sections.
  - Good detail design for joints.
Assumption

- Satisfactory load paths are performed (i.e. if equilibrium of edge force, (SSS))
- Foundation for sufficient structural stiffness
  - (bending, torsion)
- Estimates of interface loads between major body components calculated (simplified methods)
- Early estimates of stiffness using FEM can be obtained
Types of automotive structure

- **Body-on-frame**
  - Mounting a separate body to a rigid frame which supports the drivetrain was the original method of building automobiles, and its use continues to this day.
  
  - The original frames were made of wood (commonly ash), but steel *ladder frames* became common in the 1930s.
Body frame integral

- It has become the main technique for chassis assembly for most vehicles except trucks and large sport utility vehicles, replacing the traditional approach of body-on-frame (BOF).

- The main advantage of this is that soft mounts are used to reasonably isolate the body from the vibrations endured by both the frame and the suspension system.
Monocoque

- (French for "single" (mono) and "shell" (coque)) is a construction technique that supports structural load using an object's external skin.

- This stands in contrast with using an internal framework (or truss) that is then covered with a non-load-bearing skin.
- **Structural skin** is another term for the same concept
- **Unibody, or unitary construction**, is a related construction technique for automobiles in which the body is integrated into a single unit with the chassis rather than having a separate body-on-frame.
- The welded "Unit Body" is the predominant automobile construction technology today.
A space frame or space structure
- is a truss-like, lightweight rigid structure constructed from interlocking struts in a geometric pattern.
- They derive their strength from the inherent rigidity of the triangular frame; flexing loads (bending moments) are transmitted as tension and compression loads along the length of each strut.
The closed tube torsion structure has been used in more modern time. *(thinner walled member)*

- **Torsional constant, J**
  - For thin wall closed section

\[
J = \frac{4A_E^2 t}{S}
\]

- \(A_E\) is the enclosed area
- \(t\) is the wall thickness
- \(S\) is distance around section perimeter
Torsional stiffness, $K_T$

\[ K_T = \frac{GJ}{L} \]

- $G$ is material shear modulus
- $L$ is length of member

\[ T = K\theta \]

- $T$ is applied torque
- $\theta$ is torsional deflection

- Hence there is a great advantage in increasing the breadth and depth of the member.
Backbone structure

Lotus

Alpine Renault A310

Backbone chassis
Made of triangulated tubes
Triangulated tube structure

- add roll cage to passenger compartment.
- more increase in the torsional stiffness.

- Coachwork can consist of thin sheet metal cladding, attached directly to the framework.
Monocoque
Punt structure

- Floor member are of large closed section with good joints between member.
- In many case the upper body is treated as structural insignificant.

Lotus Elise

Ford GT 40
Perimeter space frame

- Small section tubular members are built into ring-beam.
- Each ring beam must be stiff locally at the corner.
- Ring-beam are moderately effective at carrying local in-plane shear.
Integral or unitary body structure
Modern integral body-in-white