Introduction to the simple structural surfaces (SSS) method

Definition of a simple structural surfaces (SSS)
Equilibrium conditions
Examples of simple box structure

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Objectives

- To introduce the concept of modeling and to show its usefulness.
- To understand the definition and limitations of a SSS.
- To illustrate the SSS method on a simplified box or van structure.
- To show examples of SSS methods representing vehicle structures.
Simple Structural Surfaces (SSS) Methods

- Easy to understand
- May be used as a preliminary step prior to carrying out FEA
- Particularly useful in assessing possible load paths

Idea:
- Vehicle structures / panels can be represented approximately by plane surfaces.
A plane structural element (or subassembly) that can be considered as rigid only in its own plane. (i.e. flexible to out-of-plane load)

- Plates may be considered similar to beams, however:
  - Plates can bend in two directions and twist
  - Plates must be flat (or else they are shells)
resistance to bending of the surface is largely determined by the values of

\[
\begin{align*}
I_{xx} &= \frac{1}{12} at^3 \\
I_{yy} &= \frac{1}{12} tb^3 \\
I_{zz} &= \frac{1}{12} bt^3
\end{align*}
\]

\[
M = \sigma \cdot I \\
M \quad y \quad \gg \quad M \quad x \quad \gg \quad M \quad z
\]

- Structural surfaces are **rigid** in their plane but **flexible** with respect to forces normal to it.
Examples of SSS Structures

Panel

Pin jointed framework

Windscreen frame

Swaged panel

Bus sideframe

Passenger car sideframe
Examples of SSS Structures

Swaged panel

Panel with reinforced hole

- Stiffening of the panel by **swaging** or a reinforced **hole** can increase the load capacity.
Examples of SSS Structures

Pin jointed framework

- The pin-jointed framework will also provide suitable structural properties for the loads Q1 and Q2.

A ring frame (windscreen) provides its sufficient corner joint stiffness and sidebeam stiffness.

Windscreen frame
Examples of non-SSS Structures

- Pin jointed mechanism
- Discontinuous rigid
- Panel with large cutout
 Modifications Made in Practice

A thin flat panel is very prone to buckling.

**Boom-panel assembly**

- Reinforce panels by swaging grooves in them or by adding some type of stiffeners at the edges.

- The structure consists of a thin rectangular sheet to which a rod is bonded along each edge.

**Consideration**

- A cantilever supported at the Rt with a vertical load \( F_z \) at Lt end.
- The vertical boom distributes the \( F_z \) into the panel.
- We assume that panel carries only shear load.
Modifications Made in Practice

**Boom–panel assembly**

**Equilibrium equations**

- **Vertical boom** \( F_z - Q_2 = 0 \) \( \Rightarrow Q_2 = F_z \)
- **Panel** \( Q_1 b - Q_2 a = 0 \) \( \Rightarrow Q_1 = Q_2 \frac{a}{b} = \frac{F_z a}{b} \)
- **Top boom** \( Q_1 - K_1 = 0 \) \( \Rightarrow K_1 = Q_1 \)
- **Bottom boom** \( Q_1 - K_2 = 0 \) \( \Rightarrow K_2 = Q_1 \)

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INSPIRING CREATIVE AND INNOVATIVE MINDS
Floor Panel with auxiliary beam

An auxiliary beam is added to carry the vertical load $F_z$.

**Equilibrium equations**

Floor panel

$$Q_3 w_1 - Q_4 l = 0$$

Cross beam

$$K_3 + K_4 - F_z = 0$$

$$K_3 w_1 - F_z \left( w_1 - w_2 \right) = 0$$
Edge Load distribution: Floor Panel

\[ \delta_c = \delta_L \]
\[ 2K_1 + K_2 + K_3 = F_{zl} \]
\[ K_2a = K_3b \]

Solve

\[ K_1 = \frac{8a^2b^2I_cF_{zl}}{I_l(a+b)w^3 + 16a^2b^2I_c} \]
\[ K_2 = \frac{F_{zl}w^3I_la}{I_l(a+b)w^3 + 16a^2b^2I_c} \]
\[ K_3 = \frac{F_{zl}w^3I_lb}{I_l(a+b)w^3 + 16a^2b^2I_c} \]
Example: A Simple Box Structure

The most simple type of structure is a closed box, such as a freight container.

- **Bending Load Case**

- Each of these members is subject to *shear and bending* load which are functions of their length.

- The *floor* and *roof* panels have no loads acting in their planes.
Example: A Simple Box Structure

Bending Load Case

Note:
Roof panel (No.3) carries no loads.

Equilibrium equations

1. \[ 2K_1 - F_z = 0 \]
2. \[ K_2 + K_3 - K_1 = 0 \]
3. \[ K_1 a - K_3 l = 0 \]
4. \[ 2R_f - 2K_2 = 0 \]
5. \[ 2R_f - 2K_3 = 0 \]
Example: A Simple Box Structure

- **Pure Torsion Load Case**

- The load on a rear panel must be correct as the reacted moment from the suspension forces $R_r$.

- The floor, roof, Lf and Rt hand side wall panel are loaded in complementary shear.

- If the rear panel is removed, it must be replaced by a ring structure or door frame (*resist the torsional load*)

INSPIRING CREATIVE AND INNOVATIVE MINDS
Example: A Simple Box Structure

- **Pure Torsion Load Case**

  Equilibrium equations:

  \[ R_f^t - R_r^t r = 0 \]

  \[ Q_6 w + Q_4 l = 0 \]

  \[ Q_5 l - Q_6 h = 0 \]

  \[ R_f^t + Q_4 h - Q_5 w = 0 \]

  \[ Q_3 w - Q_4 h = 0 \]
Example: A Simple Box Structure

Box van with missing SSS (torsion)
Roles of SSS Method in Load Path/Stiffness Analysis

- Modelling vehicles with SSS method has revealed problem in the design concept.
  - Flexibility in the rear door frame of a simple box results in the torsion moment being carried entirely in the floor or chassis frame.
  - If the surrounding frame has low stiffness the glass may be loaded excessive. (glass cracking)
Other Examples of Missing SSSs and Solutions

(a) Lack of upper dash in horizontal plane
Rotation of inner wing panels due to out-of-plane loads on dash panel

(b) Upper dash with cross-beam in the horizontal plane
Solution to (a). Horizontal forces from inner wing reacted into floor and upper dash
Example of Missing SSSs and Solutions

Rotation of engine rails due to out-of-plane loads on dash panel

Solution to (c) by using torsion boxes (four small SSSs)

Engine rails do not continue under floor