Introduction to Structural Instabilities

What makes structures unstable? Why is it important to study them?

Solid Mechanics III - Methods of Solving Problems

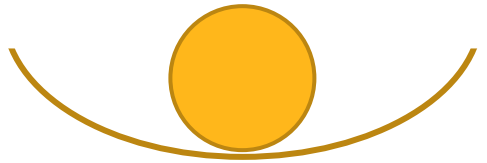
Structural Instabilities

Structural Stability

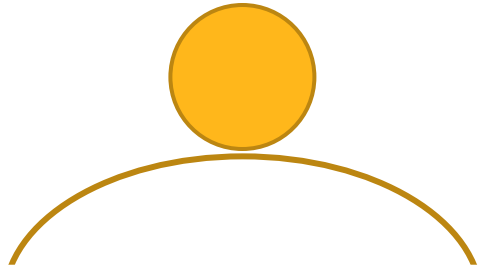
- When a force is applied on any structure, it either moves or it deforms. In some cases it does both.
- In all the cases, every point in a body undergoes certain amount of displacement under the applied force.
- In some cases the displacements are large and in other cases it is small.
- Gradual increase is load generally results in a gradual change in displacement.
- If a structures undergoes very large change in displacement for a very small change in applied force, then the structure is identified as structural unstable.
- In this section we will study what makes structures unstable.

Simple Example

- Consider a ball resting on two smooth surfaces: convex upwards, and convex downwards.
- Let's give the ball a small nudge (displacement) and see how it behaves.
- In case I, after a small nudge, the ball will oscillate about its original position and eventually comes to rest in its original state. This is a stable structure.
- In case II, after a small nudge, the ball will continue to fall under gravity as there's no other restoring force pulling it back. This is unstable structure.



Stable



Unstable

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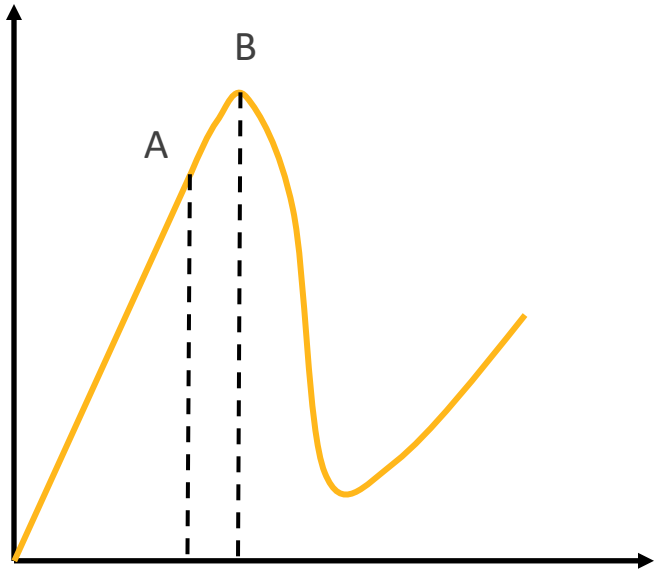
- Studying the force displacement curve of a structure tells us when a structure is becoming unstable.
- For instance, in this chart there’s a gradual change in displacement with applied force until point A
- At point B, the structure loses its ability to support the load and there’s a rapid change



Structures that undergo rapid displacement are unstable.

Types of Instability

- There are many forms of instability.
- For our discussion we will categorize them as
  1. Dynamic instability
  2. Buckling
- This classification is inspired from the terms in the governing equations that are responsible for the instability.

Why Study Instabilities?

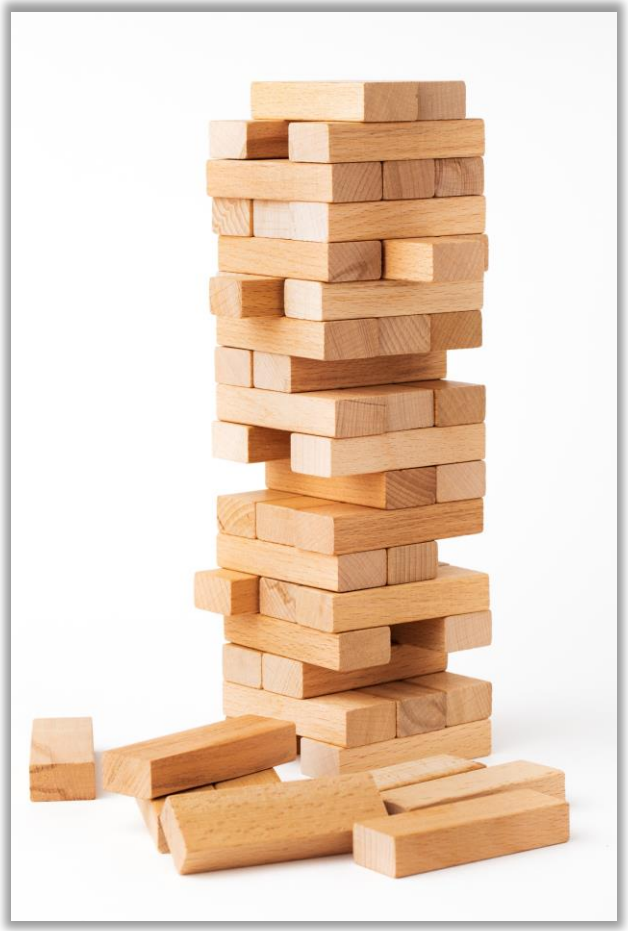
- Most structures are prone to structural instabilities and studying them is crucial for success of any design.
- Designs for every major construction such as bridges, and buildings must be assessed for their instabilities.
- A famous case for one such design failures is the Tacoma Narrows bridge which was constructed in 1940 and collapsed soon after the inauguration.
- This design suffered from a form of dynamic instability called as aeroelastic flutter.
- This collapse did not result in any human causalities, but it did serve as a wake-up call in studying the vibrational characteristics of all suspension bridges before constructing them.

Cont’d…

- Pressure vessel are used in several applications such as boilers, oil & gas industry, chemical plants, processing industry, etc.,
- If the structure of the vessel is not strong enough to withstand the high internal pressure the structure can collapse into itself and release the pressure.
- This can be a catastrophic failure.
- It is crucial to study the critical pressure that a vessel can support and establish whether it is suitable for the operating conditions.

Cont’d…

- Apart from these two examples, instabilities are standard occurrences and are often included as part of the design too.
- A simple snap-fit mechanism that’s commonly used in most electronics enclosures experience instability now of engagement due to loss of contact.
- A game of wooden blocks is played by strategically introducing instability of the structure.
- Even the act of us leaning over carefully to look over heights is our instinct of maintaining a stable foot.
- In this section, we’ll learn the different aspects of structural stability and how we use them or avoid them in different applications.

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