# LESSON 20: FLEXIBILITY METHOD FOR ANALYSIS OF INDETERMINATE STRUCTURES

READING: TEXT CH. 11

A.K.A.
FLEXIBILITY METHOD
METHOD OF CONSISTENT DEFORMATIONS
METHOD OF SUPERPOSITION
FORCE METHOD
— LIMITATIONS: LINEARITY
ELASTICITY

KEY CONCEPTS:

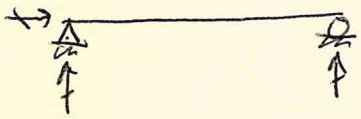
1) EQUILIBRIUM: FORCES ARE BALANCED, STRUCTURE IS NOT ACCELERATING (STATICS)

2) COMPATIBILITY: a) Structure is gapless
b) Structure is consistent with constraints imposed by supports

3) REDUNDANT: Supports in addition to the minimum required for stability

CONSIDER 2 CASES

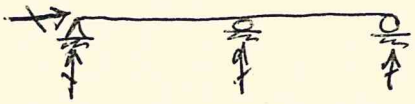
CASE 1



3 SUPPORTS,
3 REACTIONS/UNKNOWNS
↓
3 EQNS. OF STATIC EQUILIBRIUM

DETERMINATE

CASE 2



4 SUPPORTS
4 REACTIONS/UNKNOWNS
↓
3 EQNS OF STATIC EQUILIBRIUM

INDETERMINATE → (1st Degree)

WHAT ELSE CAN WE DO?

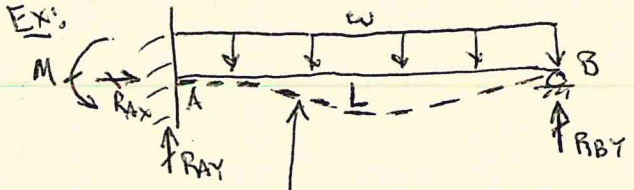
USE EQNS. OF COMPATIBILITY.
↳ FLEXIBILITY METHOD

# How to Apply the Flexibility Method

Step 1) Remove Redundant Restraints

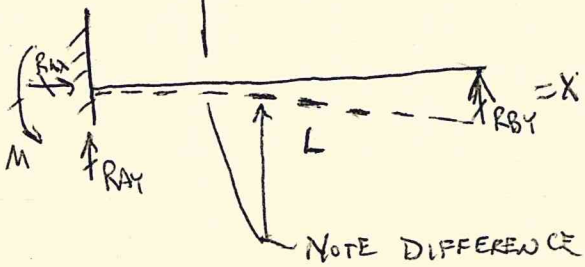
- It is necessary to produce a stable, determinate structure
  → this structure is called, the "RELEASED STRUCTURE"
- Keep all external loads and redundant force (s)

Ex:




EI = Cons.

Released Structure:



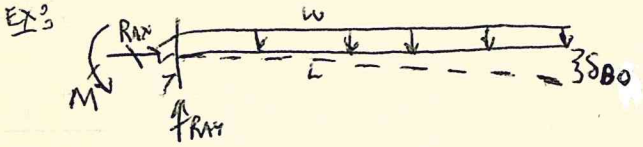

- Remove support at end but keep reaction force.
- Resulting structure is determinate and stable.

NOTE DIFFERENCE IN DEFLECTED SHAPES

Step 2) Analyze Released Structure:

2 Parts: a) Analyze applied loads

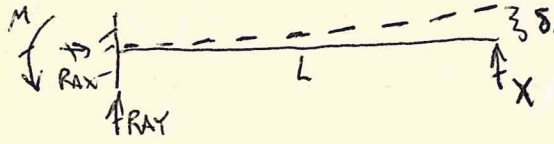
Ex:




$R_{AY} = wL$
$M = \frac{1}{2}wL^2$
$(R_{Ax} = 0)$

$\delta_{B_0} = \frac{-wL^4}{8EI}$

b) Analyze Redundant Reaction Forces




$M = -XL$
$R_{AY} = -X$
$(R_{Ax} = 0)$

$\delta_{B_1} = \frac{XL^3}{3EI}$

NOTE: Deflection at removed redundant is necessary for both systems.

Step 3) Combine the analyses through COMPATIBILITY: (Consistent deformations)

Ex: Deflection at B is zero, add the results from load systems a & b in Step 2 (Principle of superposition)

$\delta_{BO} + \delta_{B1} = 0$ ← pinned connection at B

$$-\frac{wL^4}{8EI} + \frac{XL^3}{3EI} = 0 \Rightarrow X = \frac{3wL}{8} = R_B$$

Use eqns of equilibrium to solve remaining reactions.

→ Why does this work?

Principle of superposition is key

- In linear-elastic structures, summation of effects of applied loads and removed supports may be added.
- Requires linear-elastic structure

→ Easiest when number of redundant supports is small.
→ More steps required for multiple Redundants.

→ Key concepts for future courses in analysis:

Equilibrium
Compatibility

→ Which support to release?
→ up to you.

→ Note: Now, the analysis depends on beam properties (E, I → stiffness)