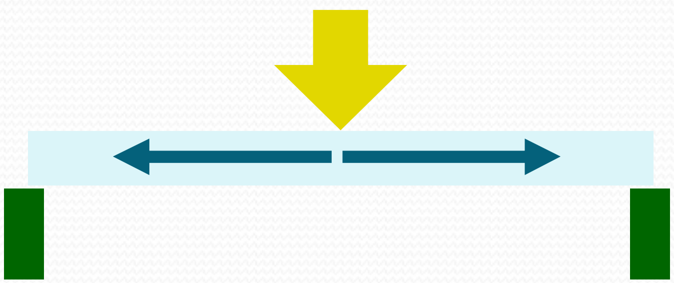
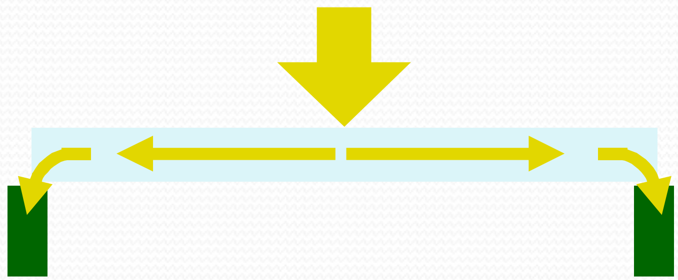
Beams

- Extremely common structural element

- In buildings majority of loads are vertical and majority of useable surfaces are horizontal



Beams



devices for transferring vertical loads horizontally

action of beams involves combination of

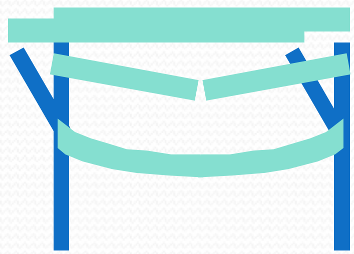
bending and shear

What Beams have to Do

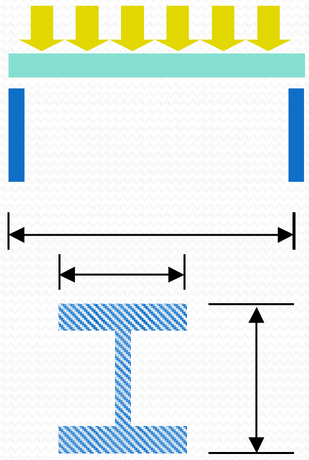
- Be strong enough for the loads
- Not deflect too much
- Suit the building for size, material, finish, fixing etc

Checking a Beam

- **what we are trying to check (test)**
  - **stability - will not fall over**
  - **adequate strength - will not break**
  - **adequate functionality - will not deflect too much**

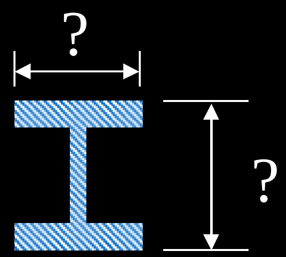


- **what do we need to know**
  - **span - how supported**
  - **loads on the beam**
  - **material, shape & dimensions of beam**
  - **allowable strength & allowable deflection**

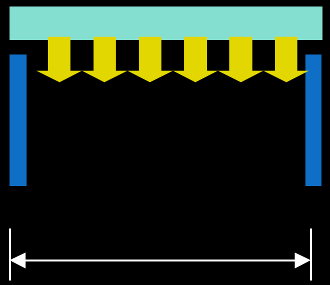


Designing a Beam

- **what we are trying to do**
  - **determine shape & dimensions**

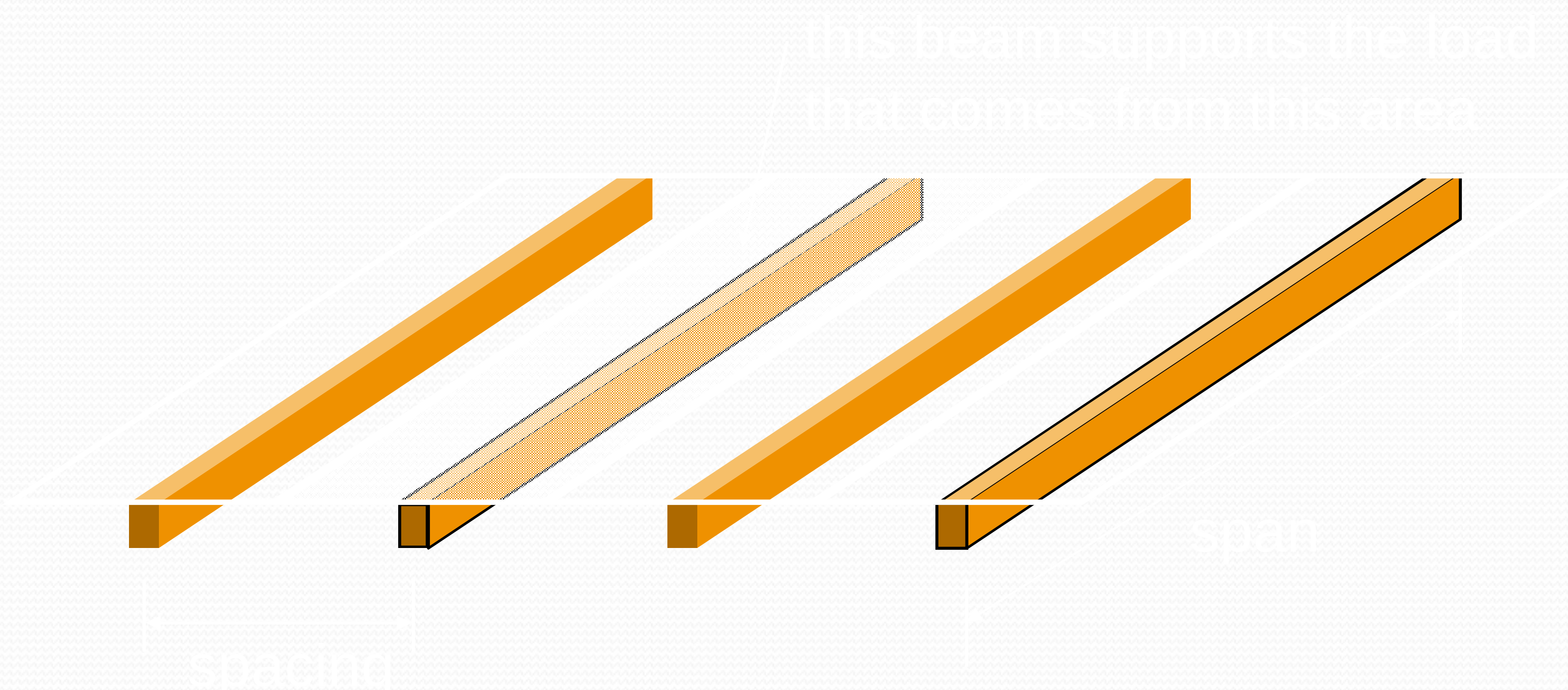


- **what do we need to know**
  - **span - how supported**
  - **loads on the beam**
  - **material**
  - **allowable strength & allowable deflection**



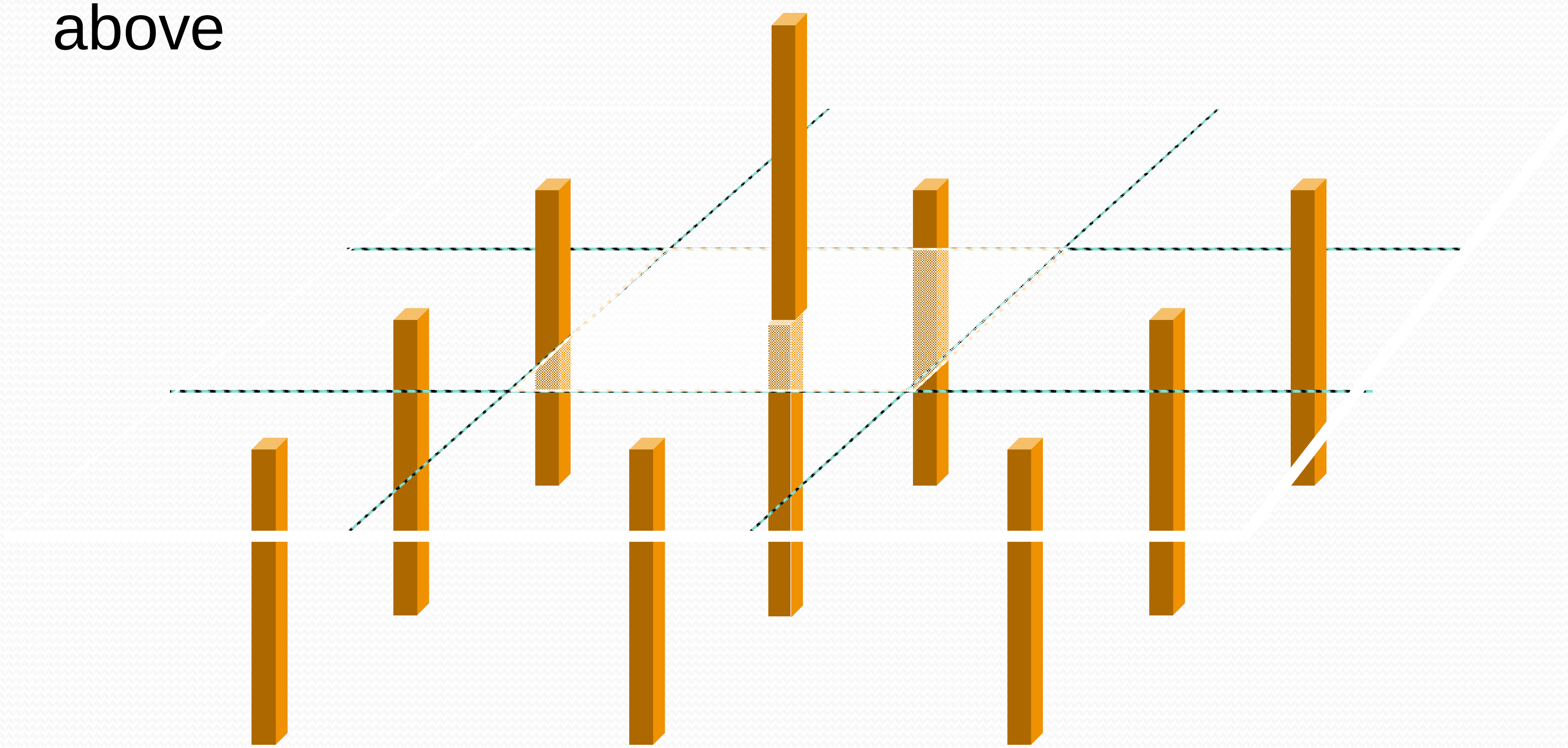
Tributary Areas

- A beam picks up the load halfway to its neighbours
- Each member also carries its own weight

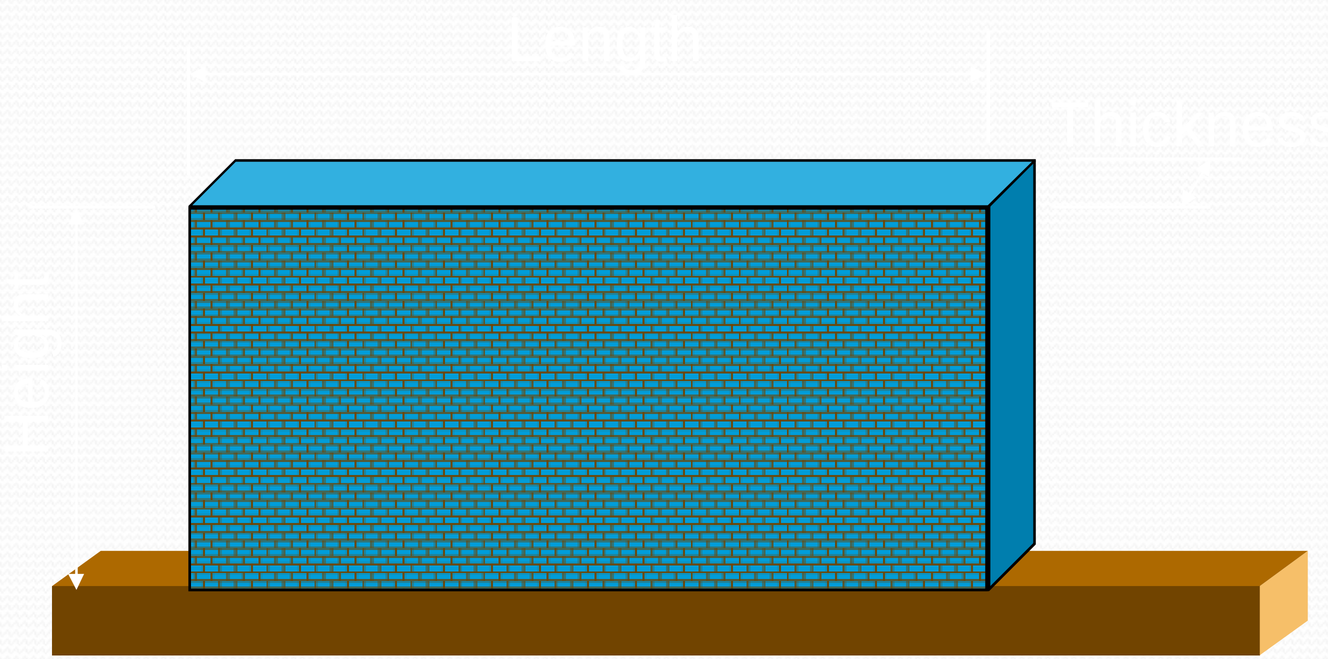


Tributary Areas (Cont. 1)

- A column generally picks up load from halfway to its neighbours
- It also carries the load that comes from the floors above



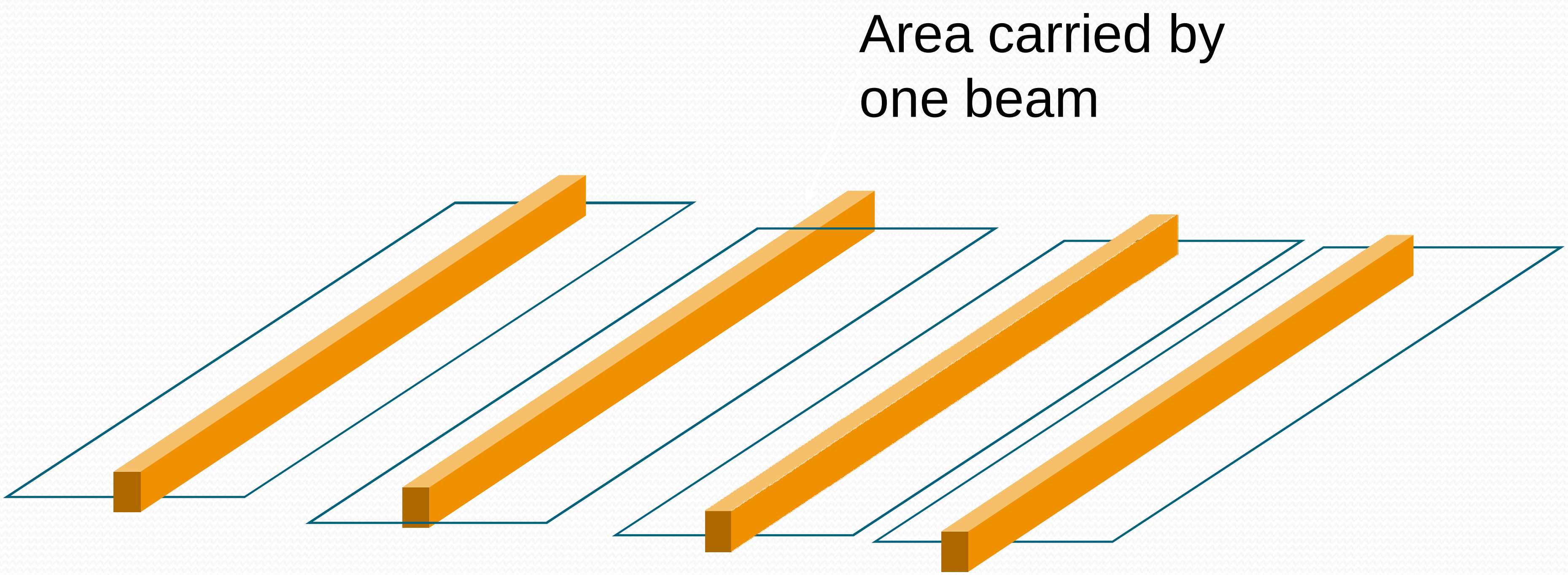
Dead Loads on Elements



Load =

Surface area x
Wt per sq m,
or
volume x
wt per cu m

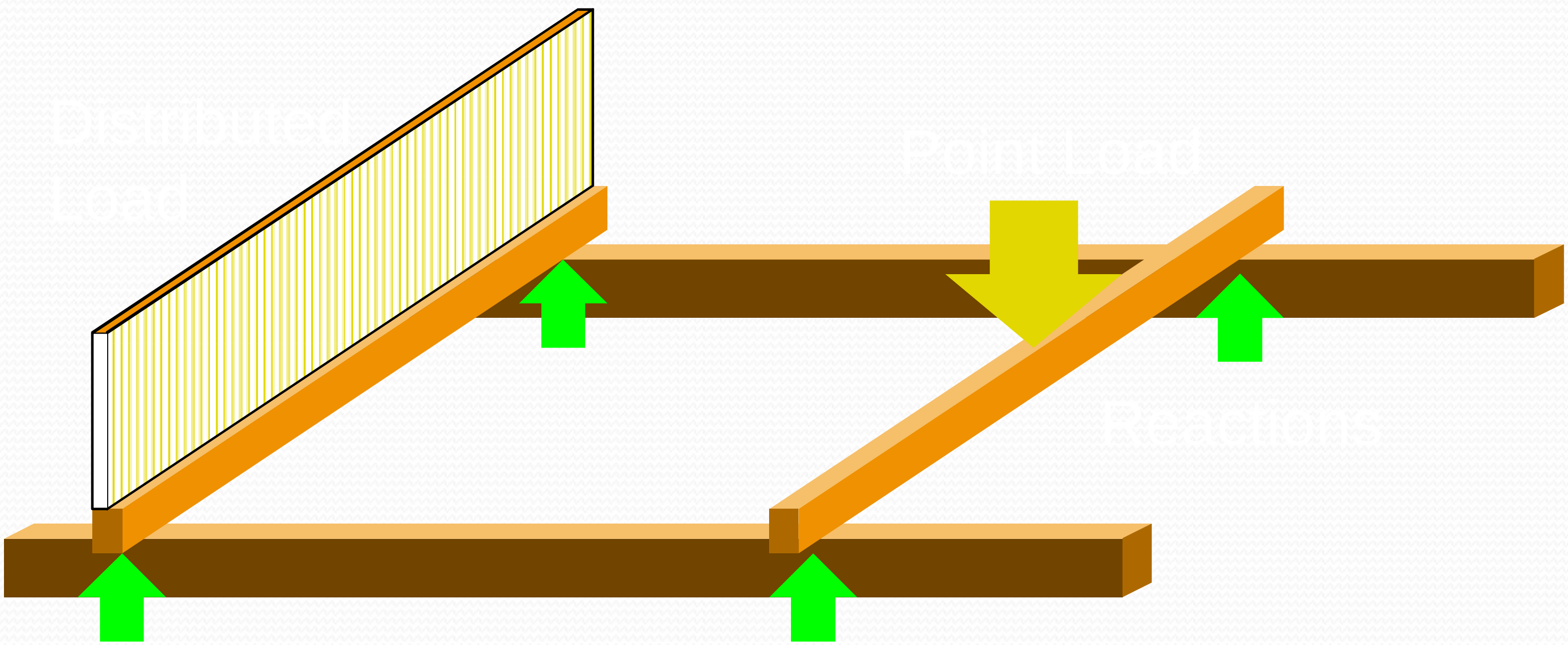
Live Loads on Elements



Total Load = area x (Live load + Dead load) per sq m
+ self weight

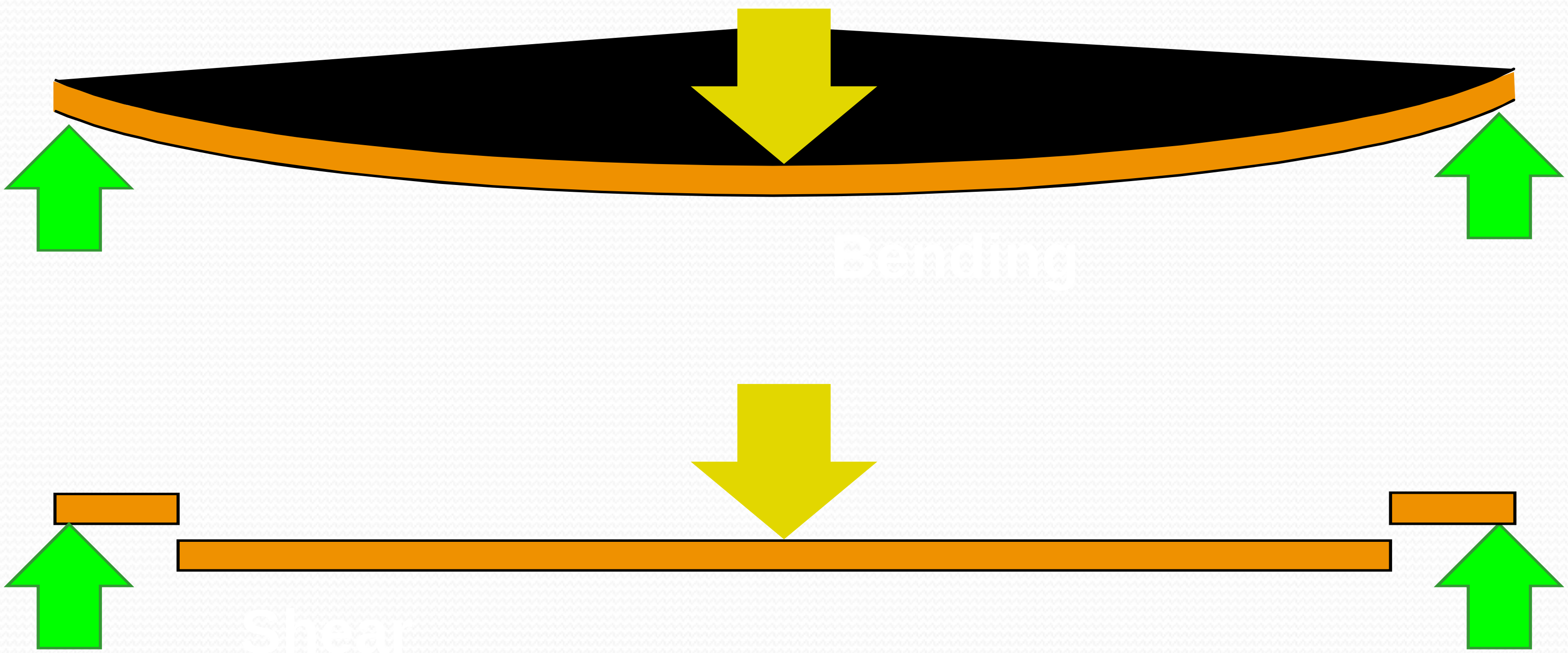
Loads on Beams

- Point loads, from concentrated loads or other beams
- Distributed loads, from anything continuous

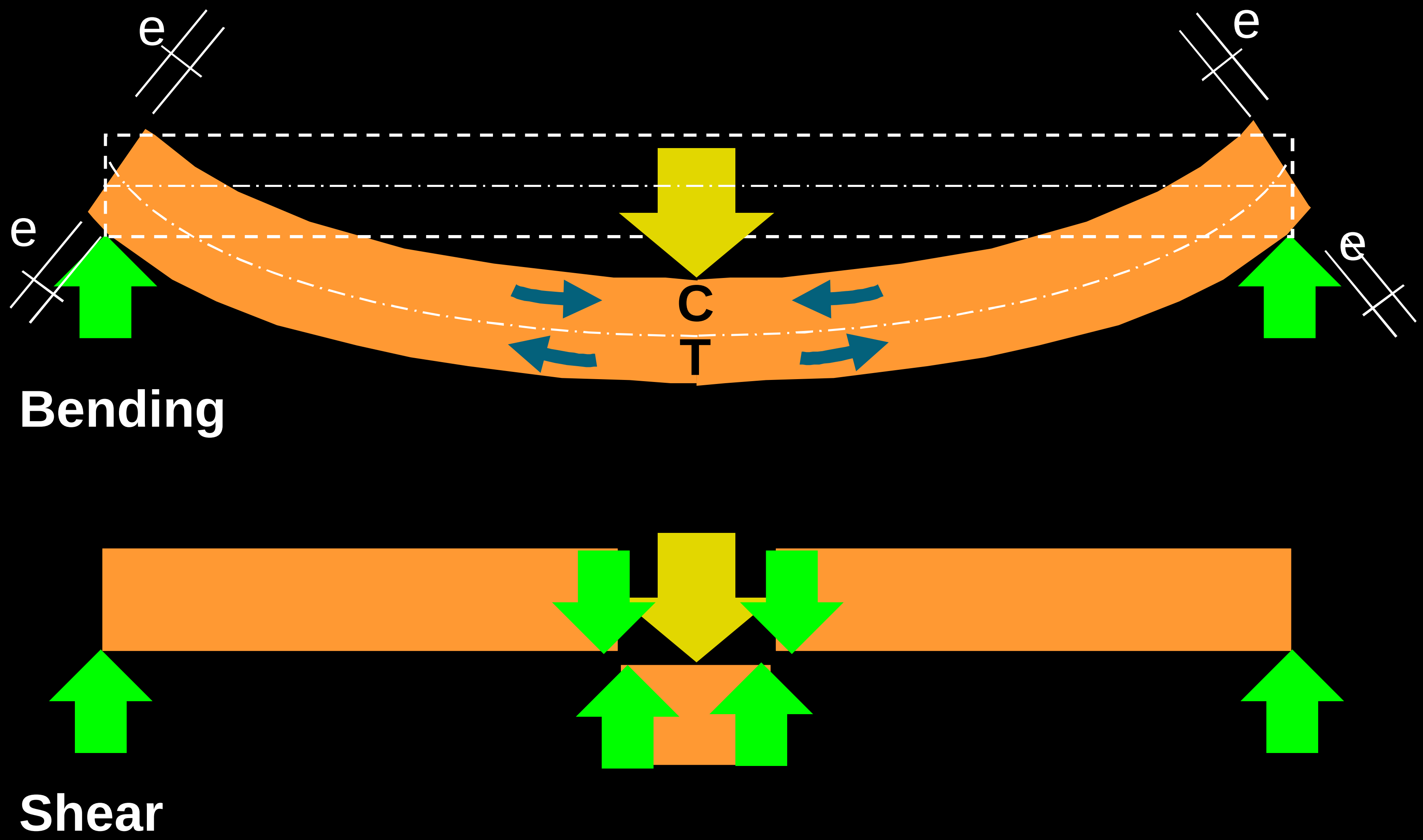


What the Loads Do

- The loads (& reactions) bend the beam, and try to shear through it



What the Loads Do (cont.)



Designing Beams

- in architectural structures, bending moment more important
  - importance increases as span increases

- short span structures with heavy loads, shear dominant
  - e.g. pin connecting engine parts

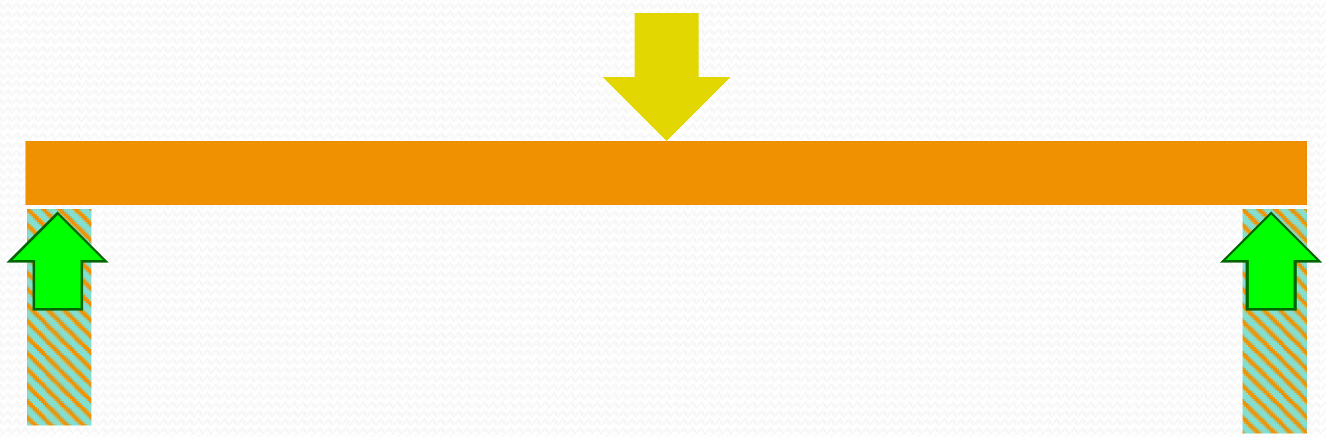
beams in building designed for bending checked for shear

How we Quantify the Effects

- First, find ALL the forces (loads and reactions)

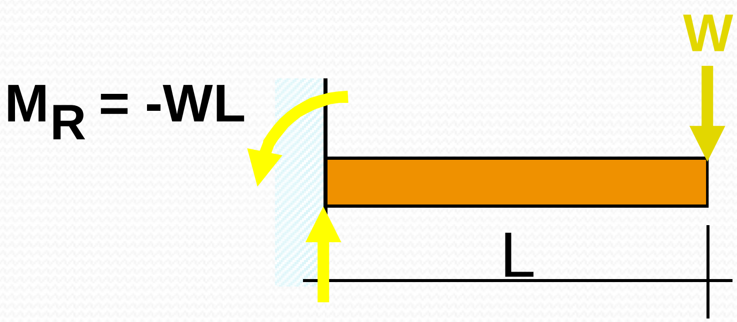
- Make the beam into a freebody (cut it out and artificially support it)

- Find the reactions, using the conditions of equilibrium



Example 1 - Cantilever Beam Point Load at End

- Consider cantilever beam with point load on end



vertical reaction, R = W
and moment reaction M_R = - WL

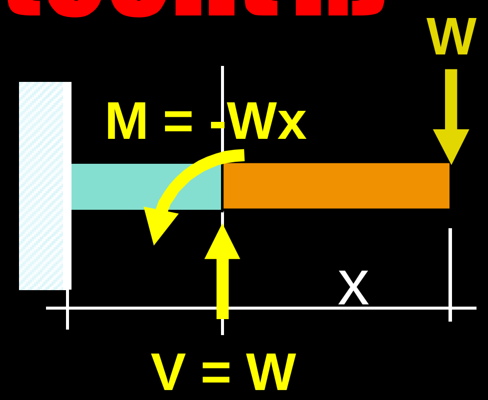
- **Use the freebody idea to isolate part of the beam**

- **Add in forces required for equilibrium**

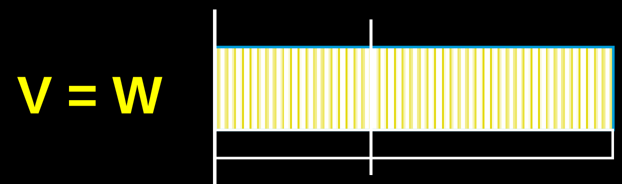
Example 1 - Cantilever Beam Point Load at End (cont1.)

Take section anywhere at distance, x from end

Add in forces, V = W and moment M = - Wx

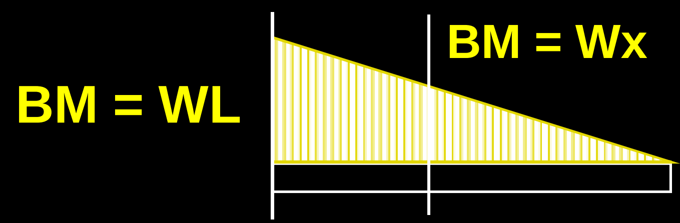


Shear V = W constant along length (X = 0 -> L)



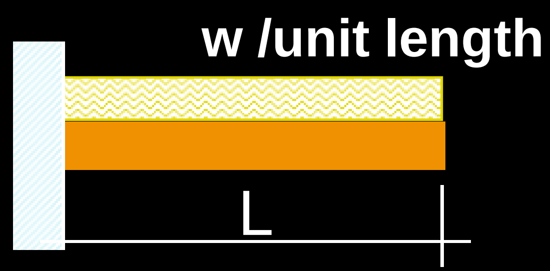
Shear Force Diagram

Bending Moment BM = W.x
when x = L BM = WL
when x = 0 BM = 0

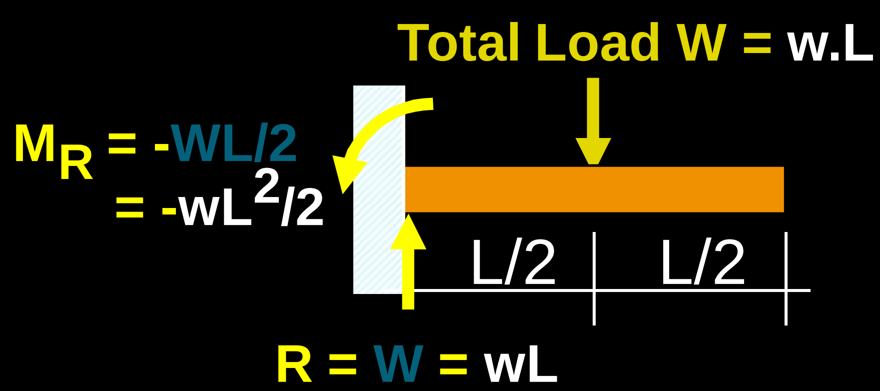


Bending Moment Diagram

Example 2 - Cantilever Beam Uniformly Distributed Load



For maximum **shear V** and **bending moment BM**



vertical reaction, $R = W = wL$

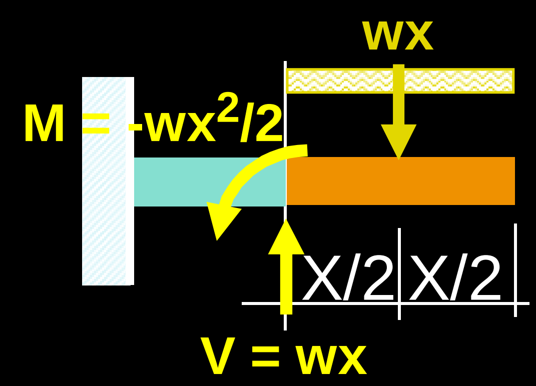
and moment reaction $M_R = -WL/2 = -wL^2/2$

Example 2 - Cantilever Beam Uniformly Distributed Load (cont.)

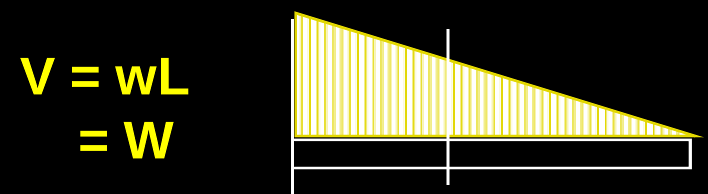
For distributed V and BM

Take section anywhere at distance, x from end

Add in forces, $V = w.x$ and moment $M = - wx.x/2$

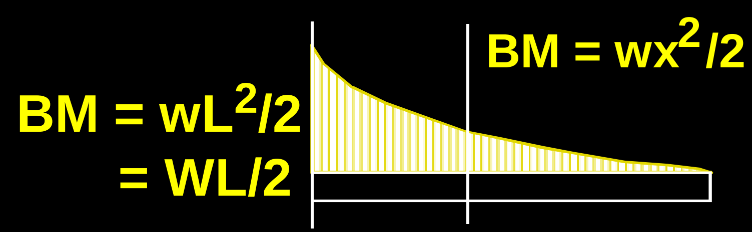


Shear $V = wx$
when x = L $V = W = wL$
when x = 0 $V = 0$



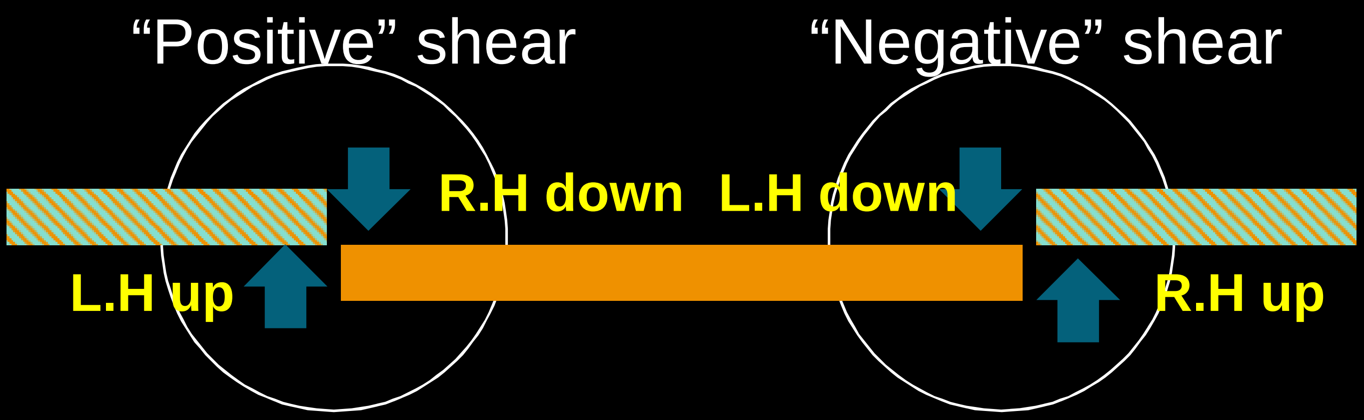
Shear Force Diagram

Bending Moment $BM = w.x^2/2$
when x = L $BM = wL^2/2 = WL/2$
when x = 0 $BM = 0$
(parabolic)



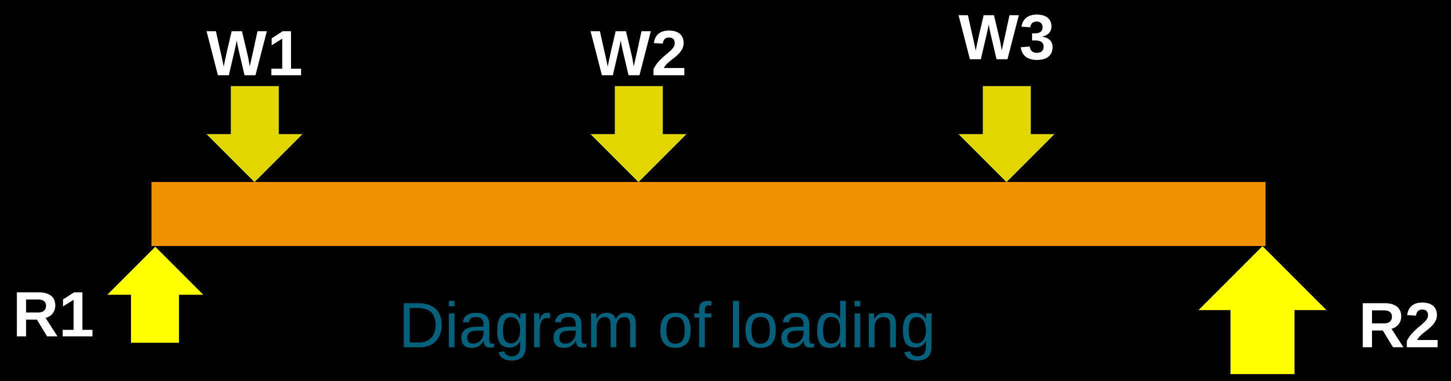
Bending Moment Diagram

Sign Conventions
Shear Force Diagrams

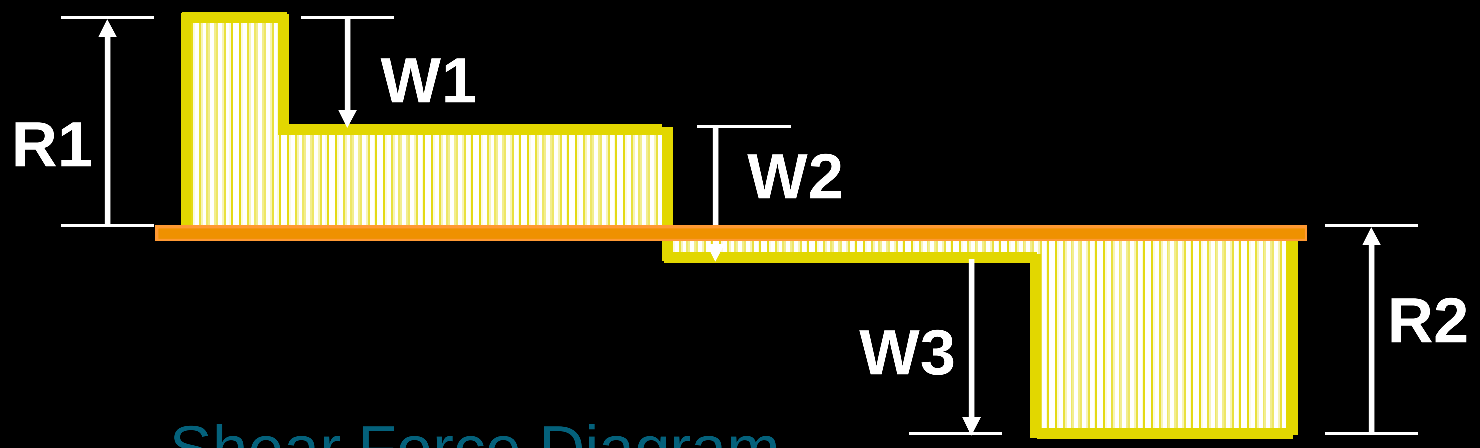


- **The opposite convention is equally valid, but this one is common**
- **There is no difference in effect between positive and negative shear forces**

Plotting the Shear Force Diagram



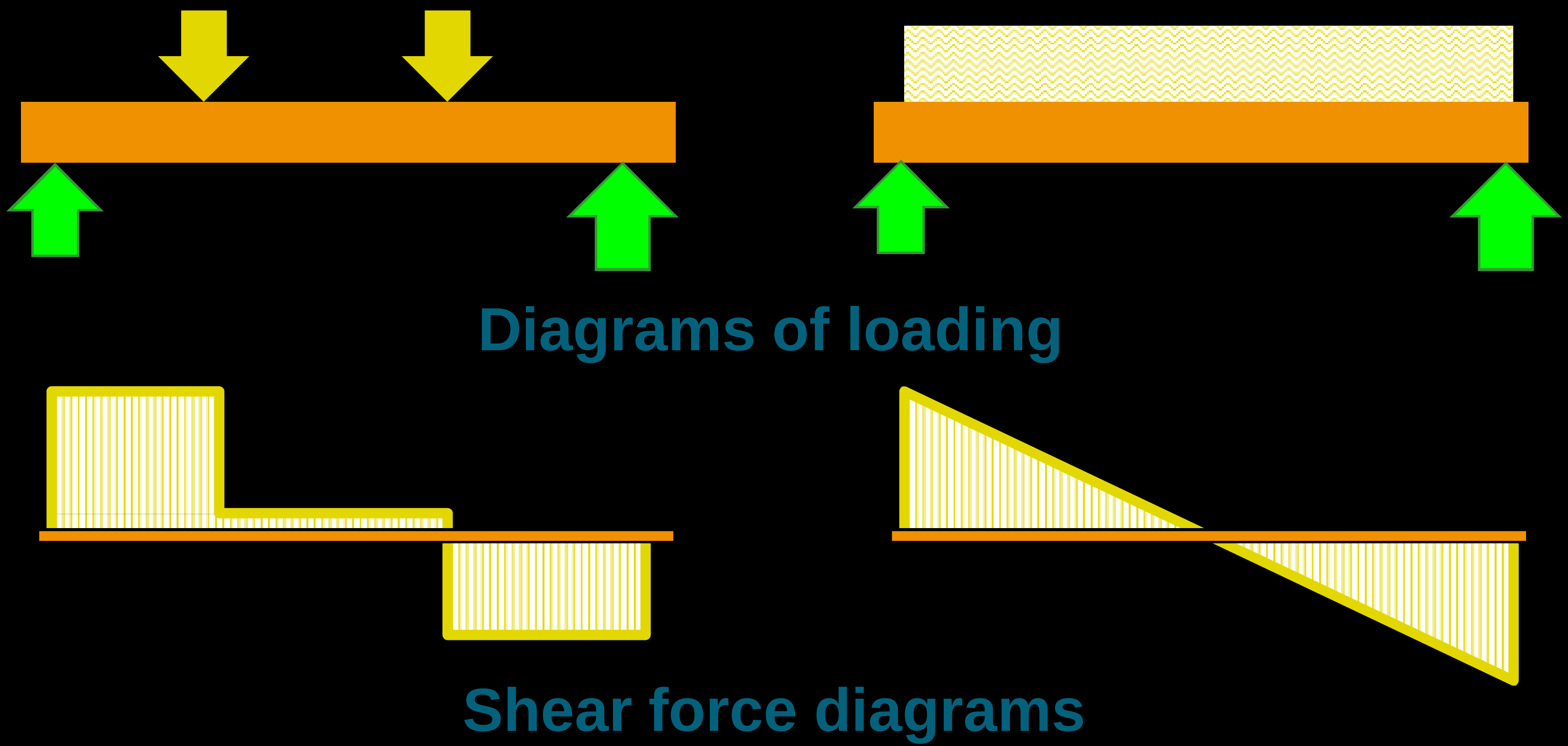
- up or down



Shear Force Diagram

Shape of the Shear Force Diagram

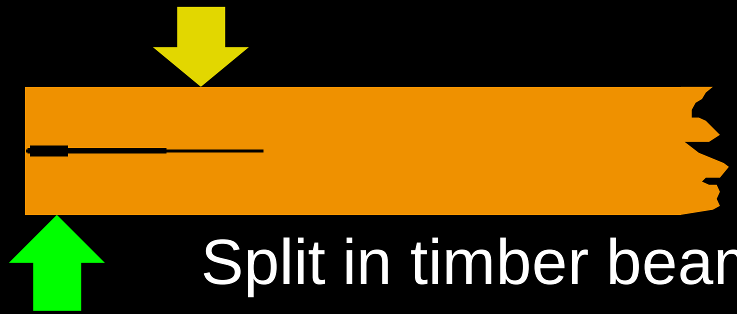
-
- Uniformly distributed loads produce triangular diagrams



What Shear Force does to the Beam

- forces stresses

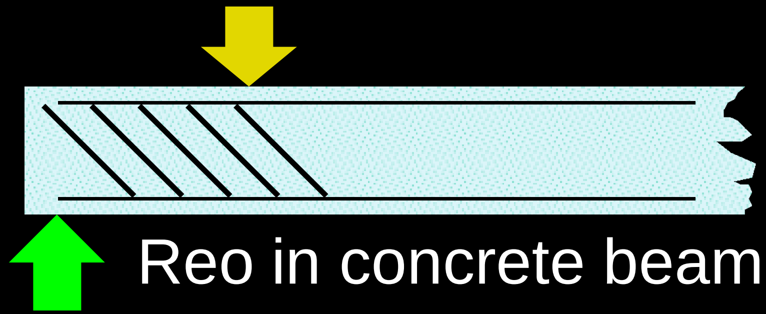
- Timber may split horizontally along the grain



Split in timber beam

- Shear is seldom critical for steel

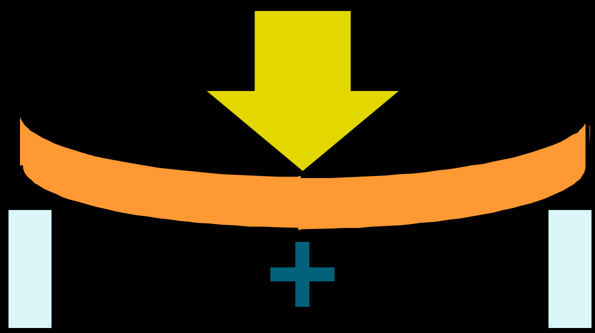
- Concrete needs special shear reinforcement (45º or stirrups)



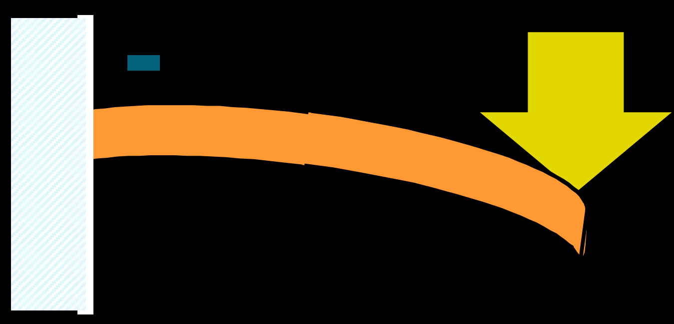
Reo in concrete beam

Sign Conventions
Bending Moment Diagrams

Sagging
POSITIVE



Hogging
NEGATIVE

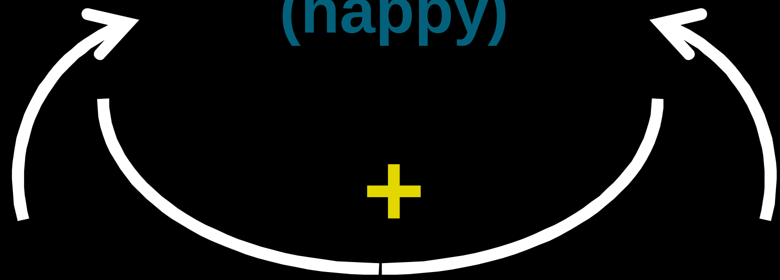


- **This convention is almost universally agreed**

Sign Conventions
Bending Moment Diagrams (cont.)

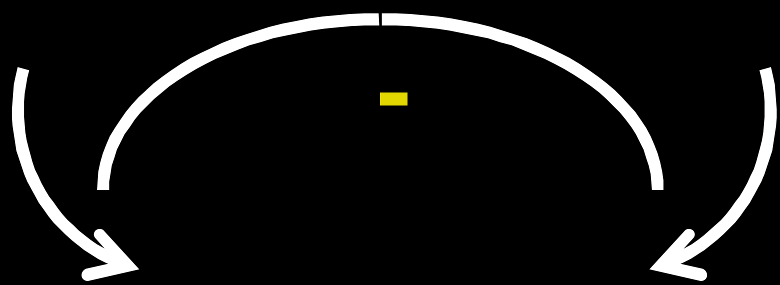
Sagging bending moment is POSITIVE

(happy)



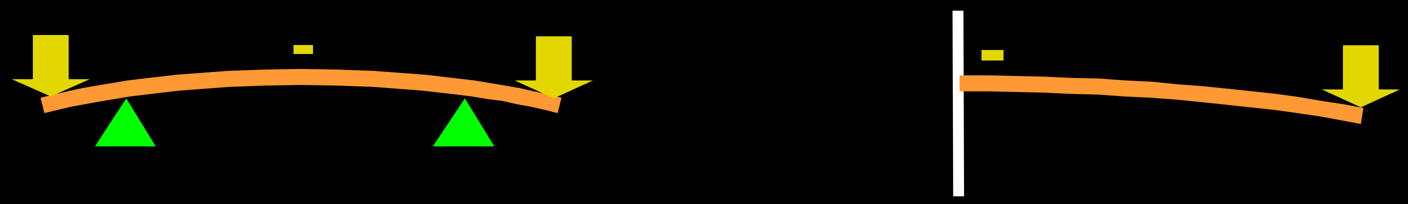
Hogging bending moment is NEGATIVE

(sad)



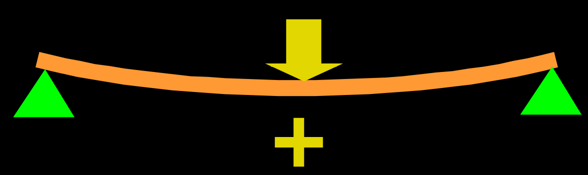
Positive and Negative Moments

- **Cantilevers produce negative moments**

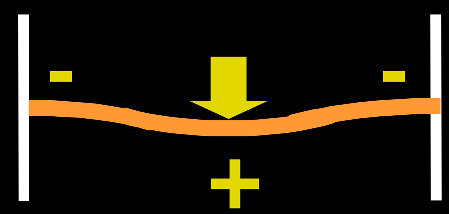


Cantilevers

- **Simple beams produce positive moments**



Simple beam



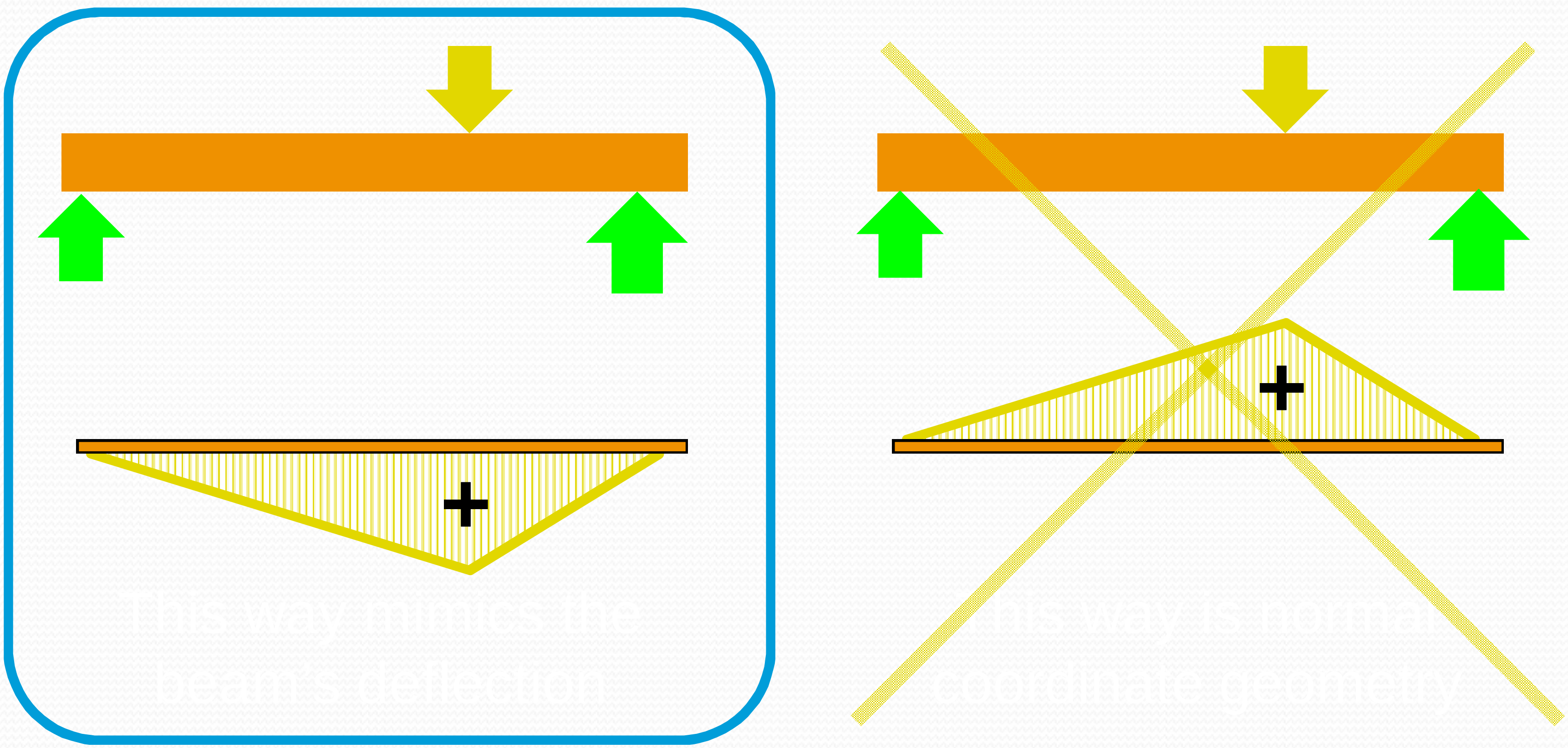
Built-in beam

- **Built-in & continuous beams have both, with negative over the supports**

Where to Draw the Bending Moment Diagram

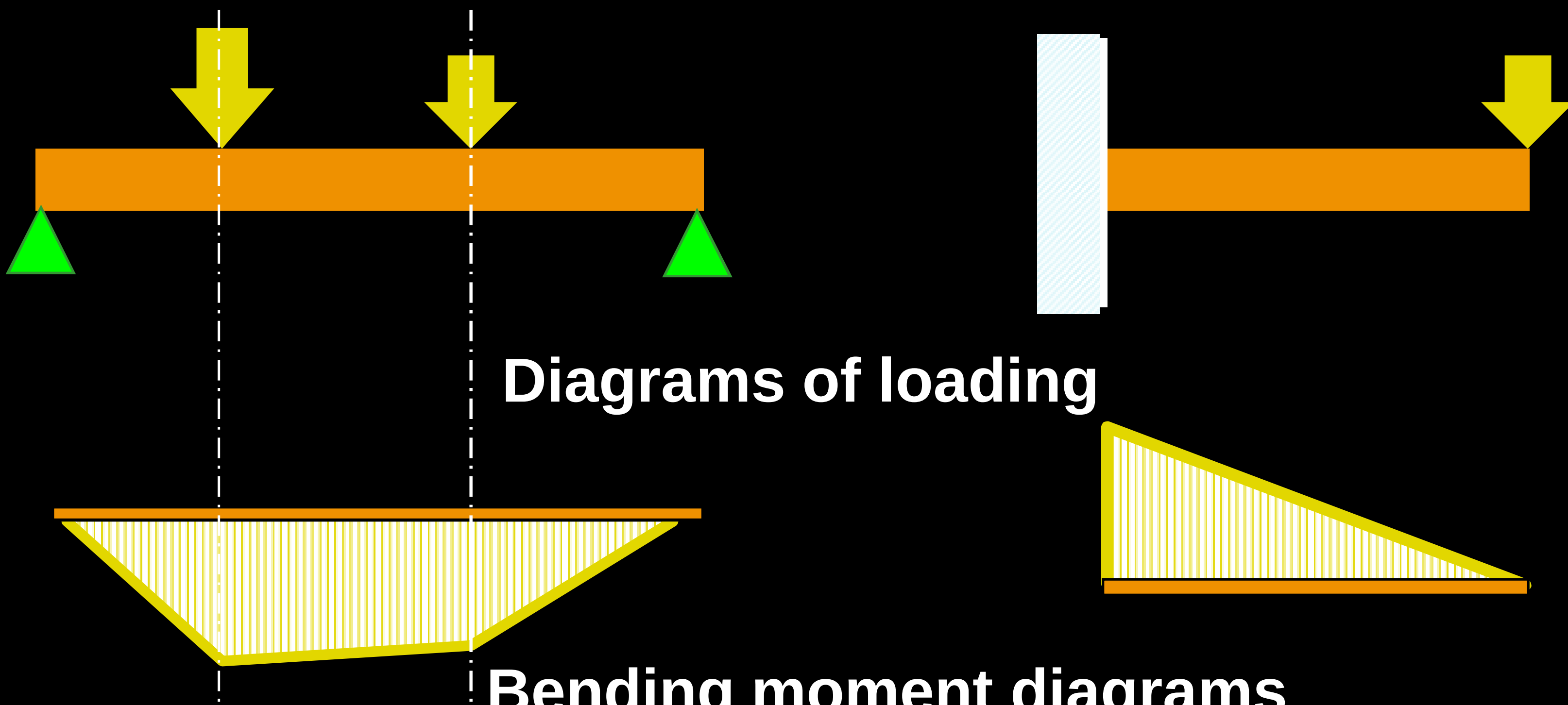
- Positive moments are drawn downwards

(textbooks are divided about this)



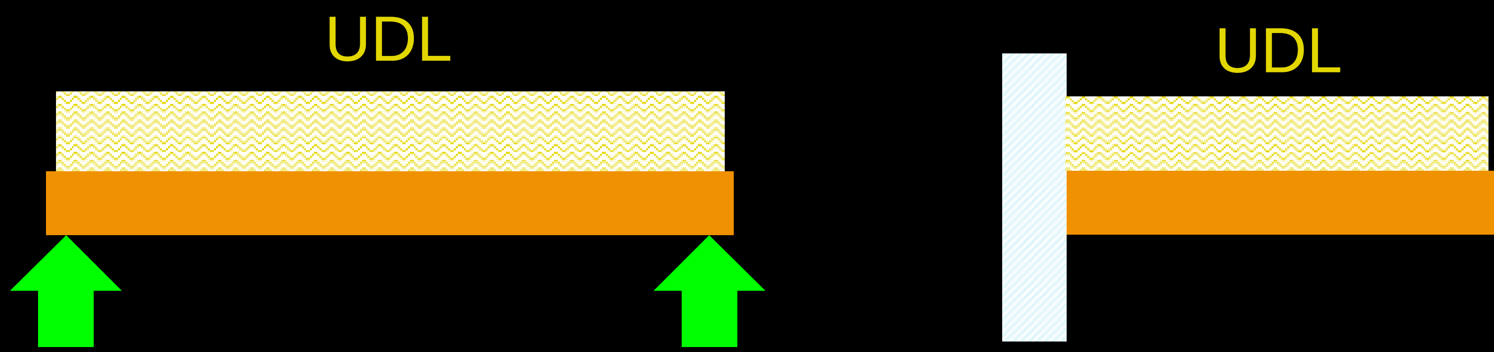
Shape of the Bending Moment Diagram

- triangular



Shape of the Bending Moment Diagram (cont1.)

- **Distributed loads produce parabolic diagrams**

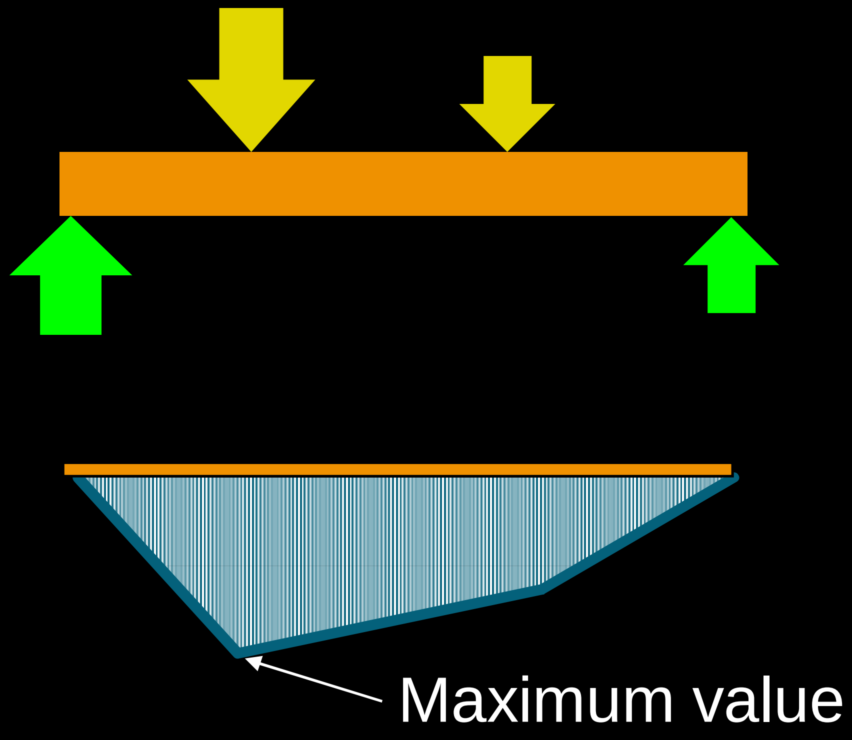


Diagrams of loading

Bending moment diagrams

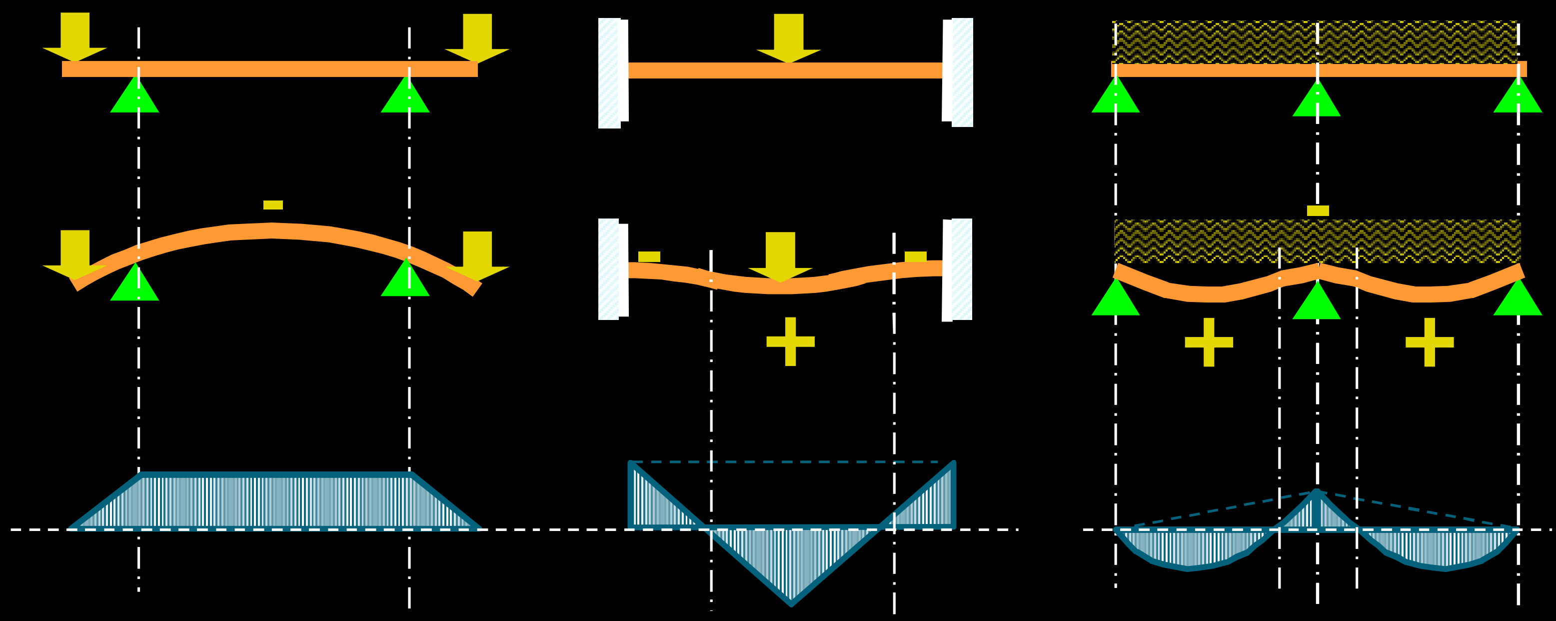
Shape of the Bending Moment Diagram (cont.2)

- **We are mainly concerned with the maximum values**

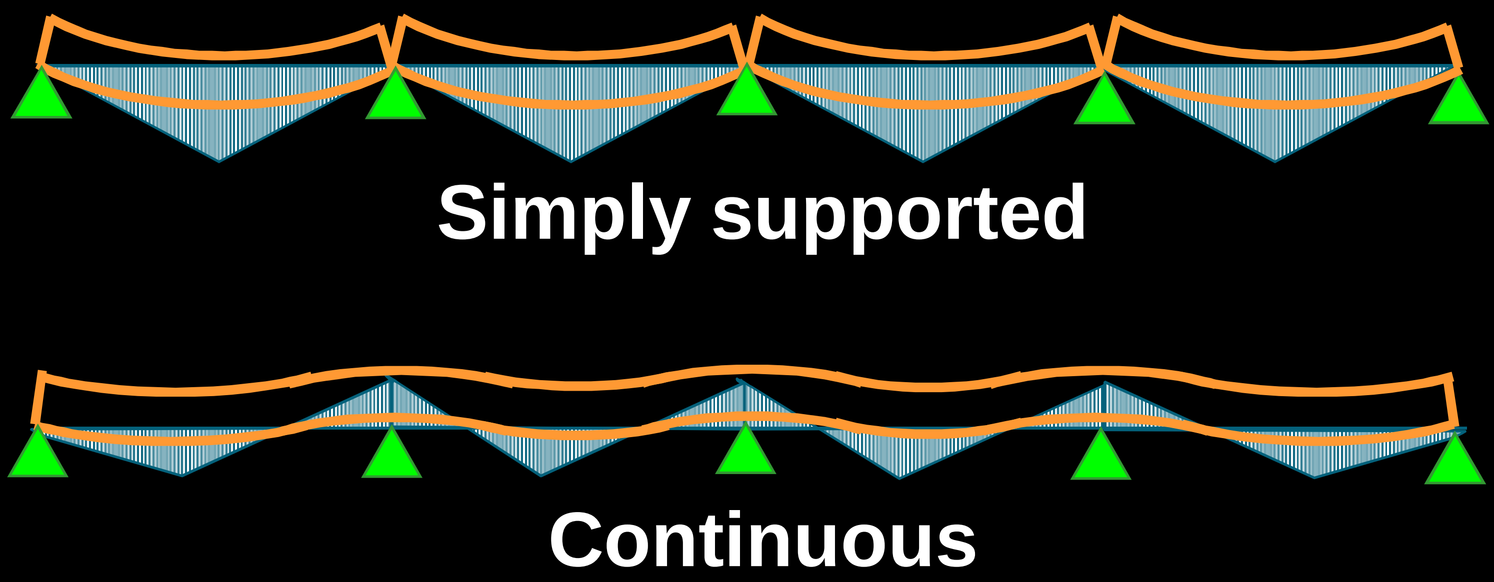


Shape of the Bending Moment Diagram (cont.3)

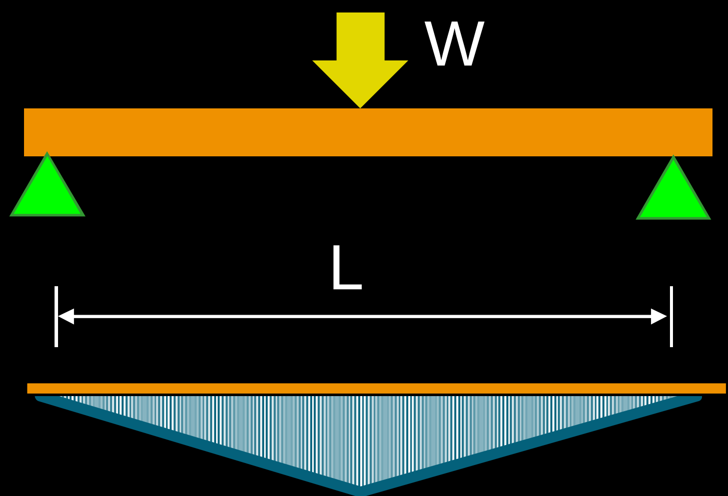
- Deflected Shape
- **Use the Deflected shape as a guide to where the sagging (+) and hogging (-) moments are**

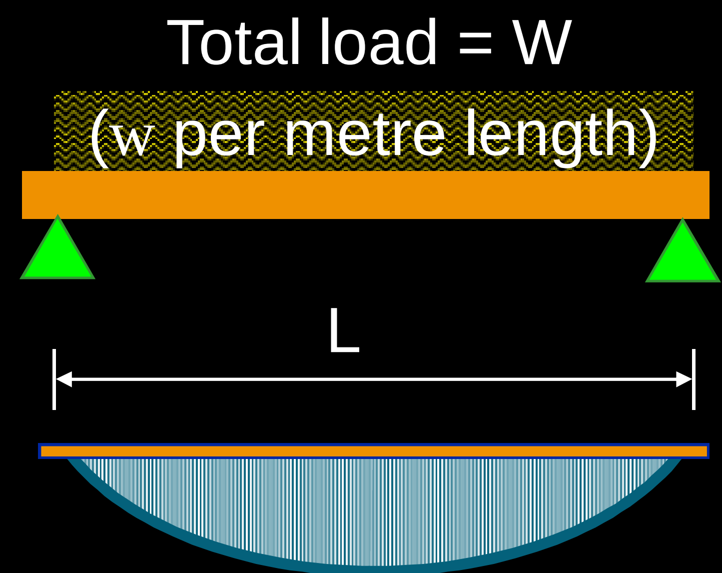


Can we Reduce the Maximum BM Values?



Standard BM Coefficients
Simply Supported Beams



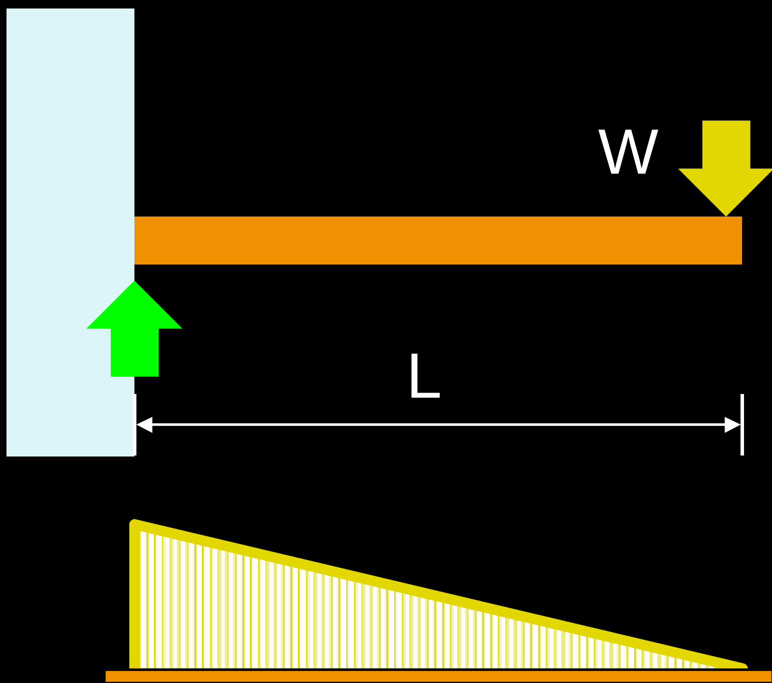


Central point load
Max bending moment
= **WL/4**

Uniformly distributed load
Max bending moment
= **WL/8** or **wL²/8**

where W = wL

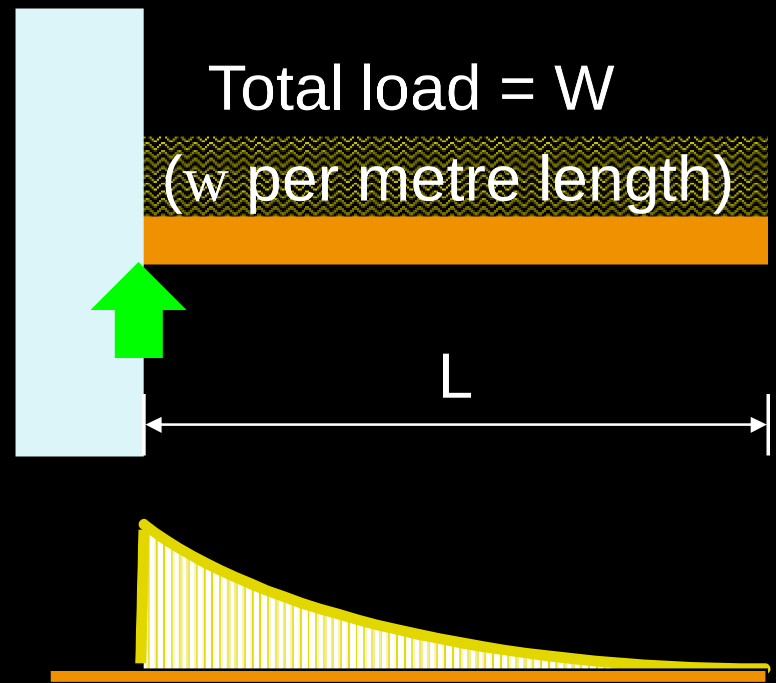
Standard BM Coefficients Cantilevers



End point load

Max bending moment

= **-WL**



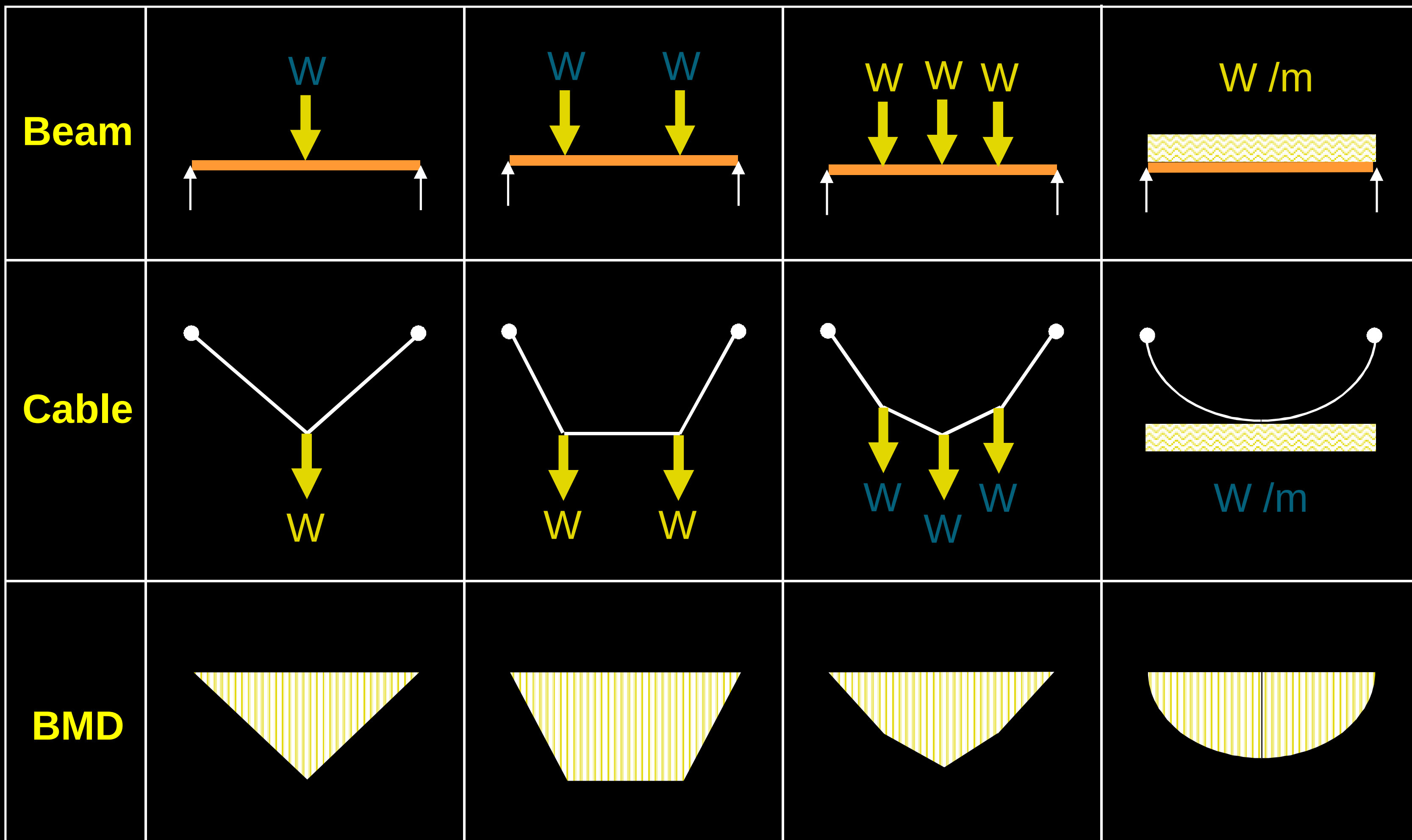
Uniformly Distributed Load

Max bending moment

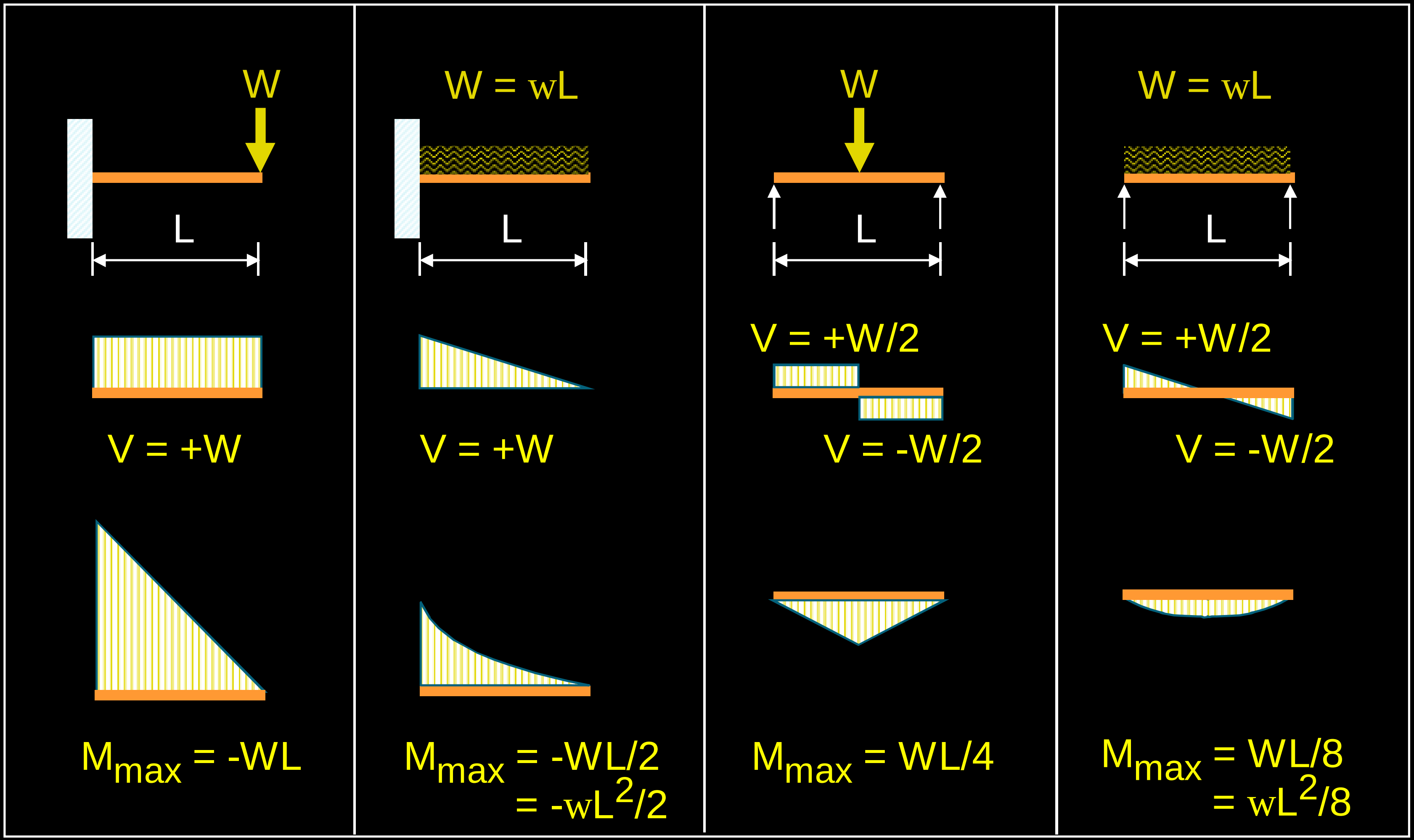
= **-WL/2 or -wL^2/2**

where W = wL

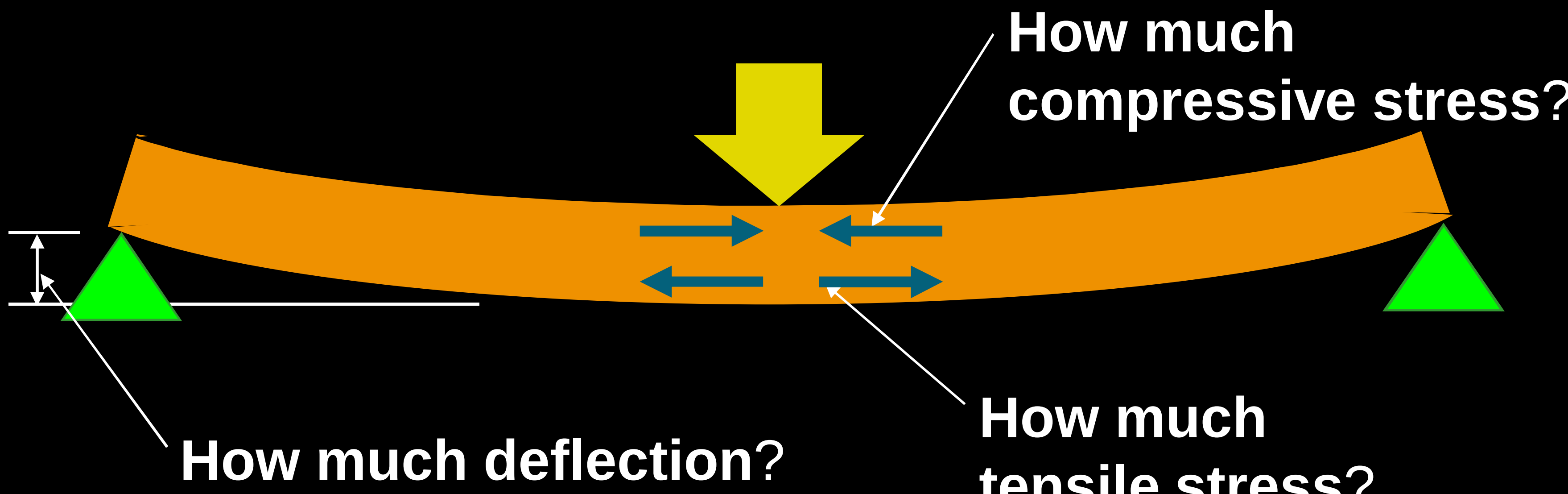
Standard BM Coefficients Simple Beams



SFD & BMD Simply Supported Beams



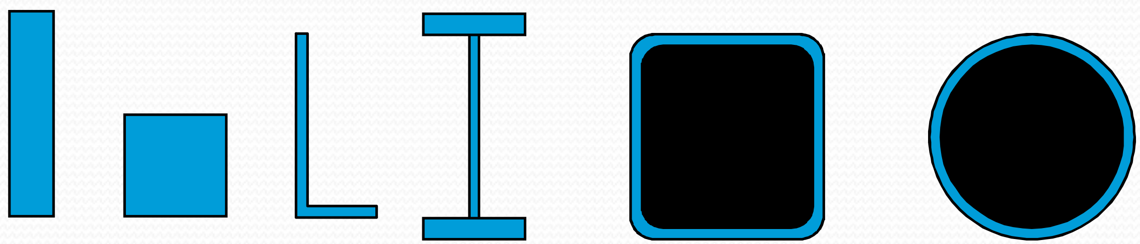
What the Bending Moment does to the Beam



How to Calculate the Bending Stress

- It depends on the beam cross-section

- **We need some particular properties of the section**



how big & what shape?

is the section we are using as a beam

What to do with the Bending Stress

- Codes give maximum allowable stresses
- Timber, depending on grade, can take 5 to 20 MPa
- Steel can take around 165 MPa
- Use of Codes comes later in the course

Finding Section Properties

we need to find the
Section Properties

next lecture