Pavement Materials & Design

4.1_Review of Materials Mechanical behavior

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Mechanical behavior of materials

Key Factors Influencing Mechanical Behavior

- Mechanical behavior refers to how materials respond to external loads.
- Factors that influence material response
  - *The magnitude and type of load*
  - *The geometry of the element.*
  - ***Its properties***

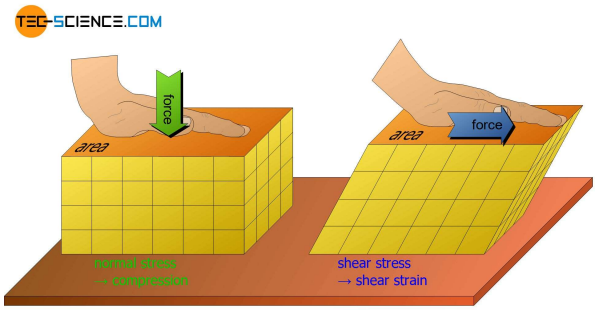

Image source: https://www.open.edu/openlearn/science-maths-technology/science/chemistry/introduction-polymers/content-section-5.2.1

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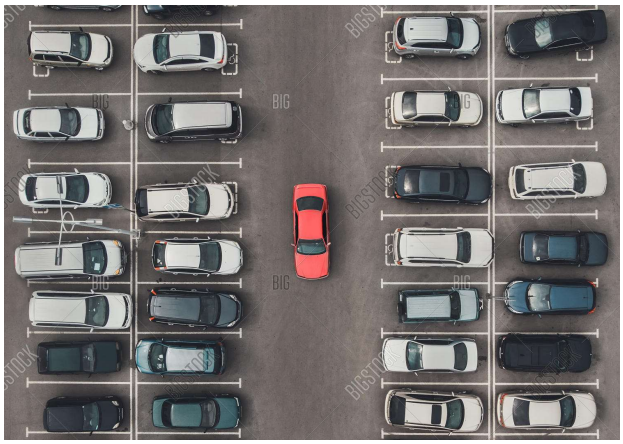
Mechanical behavior of materials

Loading Conditions

- The two basic types of loads are static and dynamic
- **Static loading**
  - *implies a sustained loading of the structure over a period of time.*
  - *Generally, static loads are slowly applied such that no shock or vibration is generated in the structure.*
  - *Once applied, the static load may remain in place or be removed slowly.*
  - *Loads that remain in place for an extended period of time are called sustained (dead) loads.*



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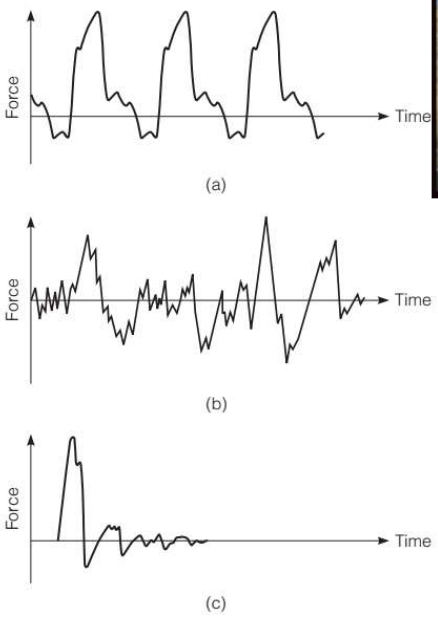
Mechanical behavior of materials

Loading Conditions

- Dynamic loads
  - *implies Loads that **generate** a shock or vibration `*
- Dynamic loads can be classified as
  - ***Periodic :** such as a harmonic or sinusoidal load repeats itself with time*
  - ***Random** : the load pattern never repeats, such as that produced by earthquakes*
  - ***Transient load** : is an impulse load that is applied over a short time interval, after which the vibrations decay until the system returns to a rest condition*



Types of dynamic loads: (a) periodic, (b) random, and (c) transient

Image source: https://www.open.edu/openlearn/science-maths-technology/science/chemistry/introduction-polymers/content-section-5.2.1

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Mechanical behavior of materials

Stress–Strain Relations

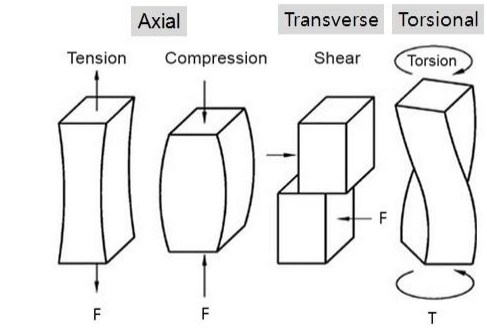
- Much useful information about the material can be determined by plotting the stress–strain diagram.

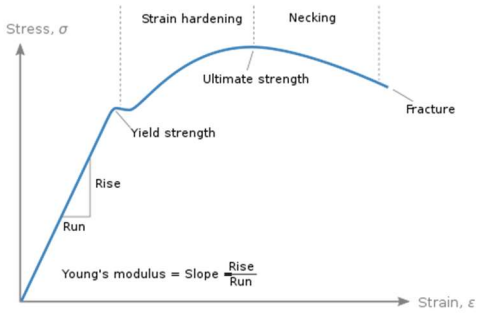
Stress

$$Stress = \frac{Force\ (or\ load)}{Area} \qquad \sigma = \frac{F}{A}$$

Strain

$$Strain = \frac{Length\ of\ Stretch}{Original\ Length} \qquad \varepsilon = \frac{\delta}{L}$$





Stress–strain curve typical of a low-carbon steel

Image source: https://www.open.edu/openlearn/science-maths-technology/science/chemistry/introduction-polymers/content-section-5.2.1

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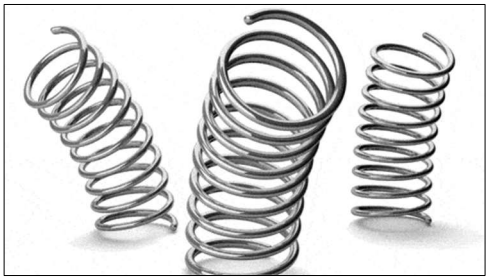
Materials Physical form

Liquid

Solid



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Mechanical behavior of materials

Elastic Behavior

- Elastic materials return to their original shape after being deformed
- It must have an **instantaneous** response (deformation) to load
- Shape deformation does not change with time
- e.g, Spring, rubber

Image source: https://www.open.edu/openlearn/science-maths-technology/science/chemistry/introduction-polymers/content-section-5.2.1 https://transcendfit.co/blogs/fascia/viscoelasticity/

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Mechanical behavior of materials

Elastic Behavior

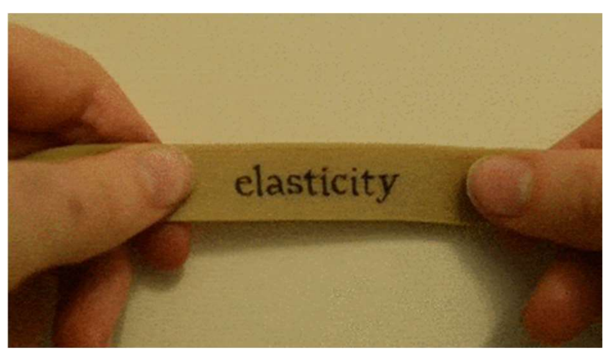

Image source: https://www.open.edu/openlearn/science-maths-technology/science/chemistry/introduction-polymers/content-section-5.2.1 https://transcendfit.co/blogs/fascia/viscoelasticity/

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Mechanical behavior of materials

Elastic Behavior under creep loading

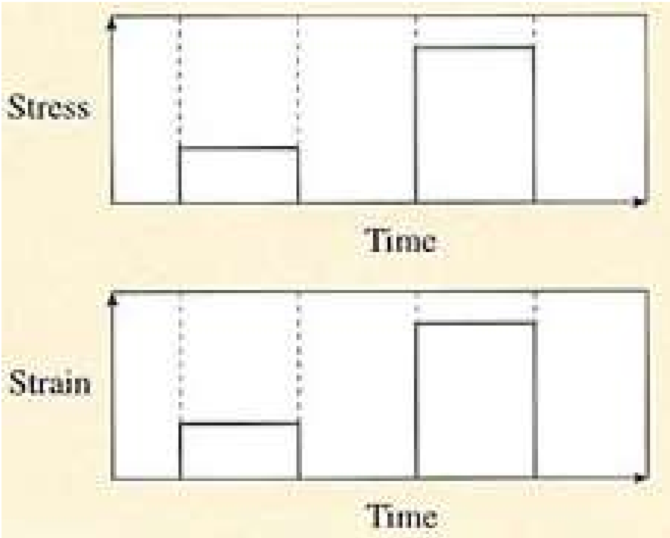

Image source: https://www.open.edu/openlearn/science-maths-technology/science/chemistry/introduction-polymers/content-section-5.2.1 https://makefastworkshop.com/hacks/?p=20181112

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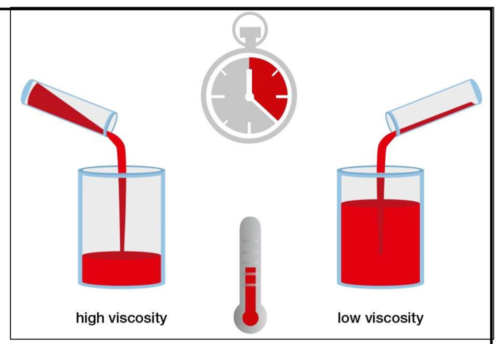
Mechanical behavior of materials

Viscous behavior

- ❑ Viscosity measures a fluid's resistance to flow, like honey or oil



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Mechanical behavior of materials

Viscous behavior

- Viscous Materials
  - *its original shape can be easily changed*
  - *Can deform easily*
- Viscous flow is not recoverable;
  - *When the stress is removed from a viscous fluid the strain remains*
- Have delayed response

Image source: https://www.wikiwand.com/en/Dashpot

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Mechanical behavior of materials

Viscous Behavior under creep loading

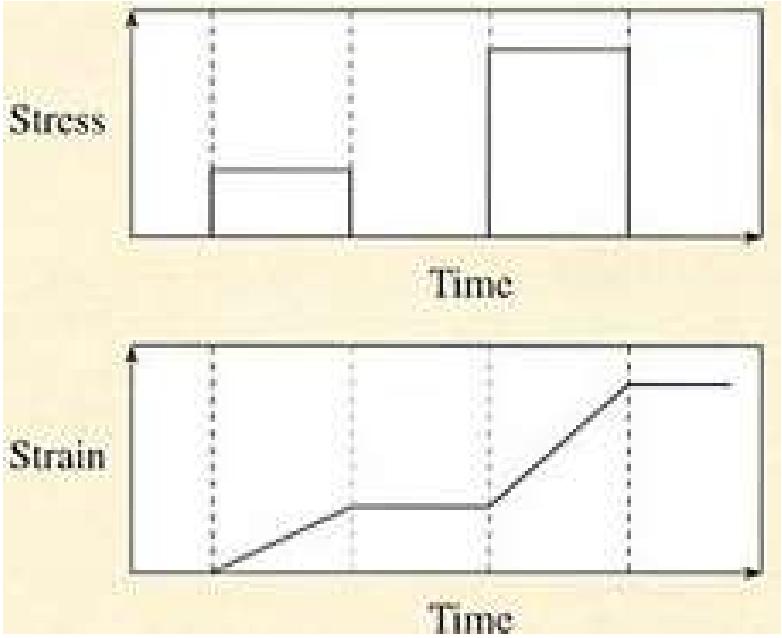

Image source: https://www.wikiwand.com/en/Dashpot

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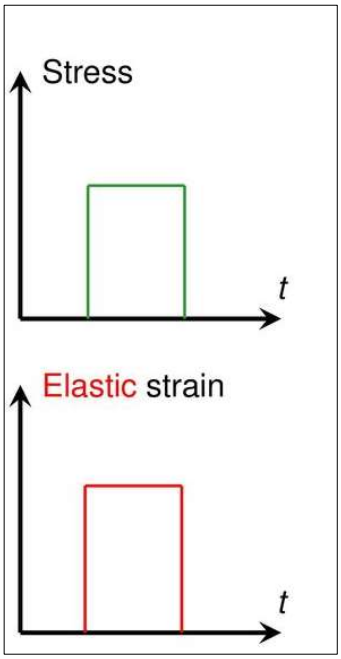
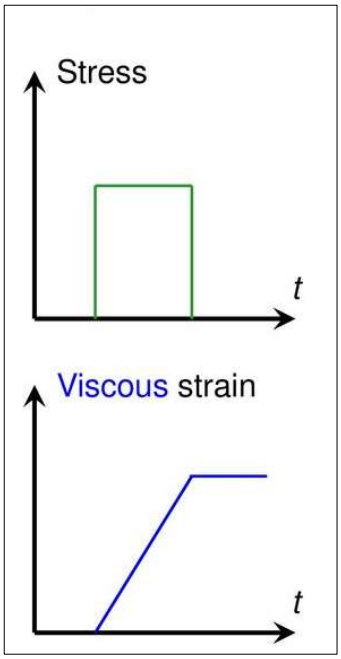
Mechanical behavior of materials

Viscous Vs. Elastic Behavior





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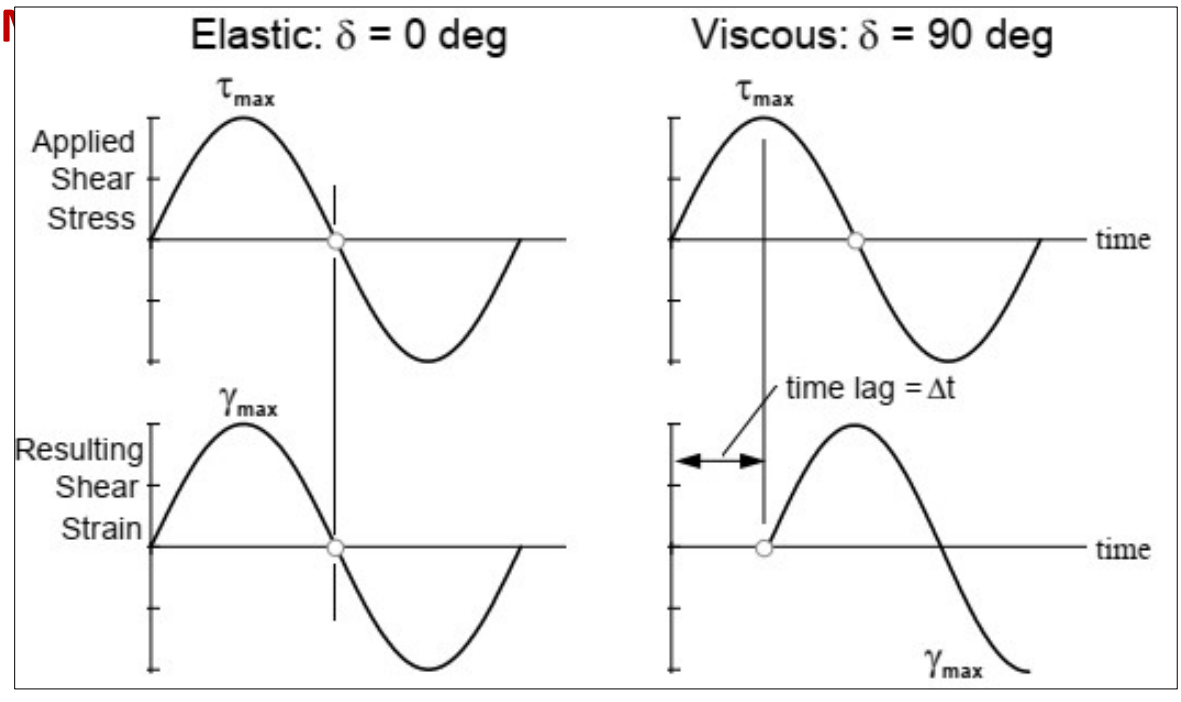

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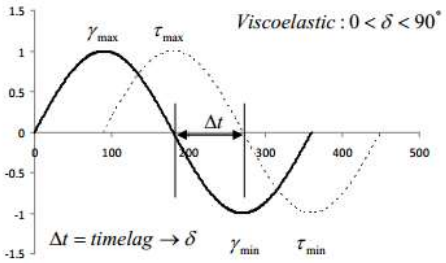
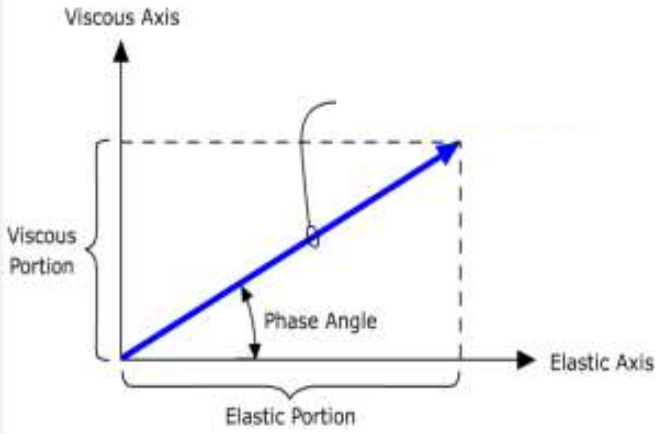
Mechanical behavior of materials

Lag time = Phase angle





https://www.researchgate.net/publication/275353265_Predicting_Complex_Shear_Modulus_Using_Artificial_Neural_Networks

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What do you think ?

Based on this video , is this material elastic or viscous ?

Image source: https://wiki.anton-paar.com/hu-hu/a-viszkozimetria-alapjai/

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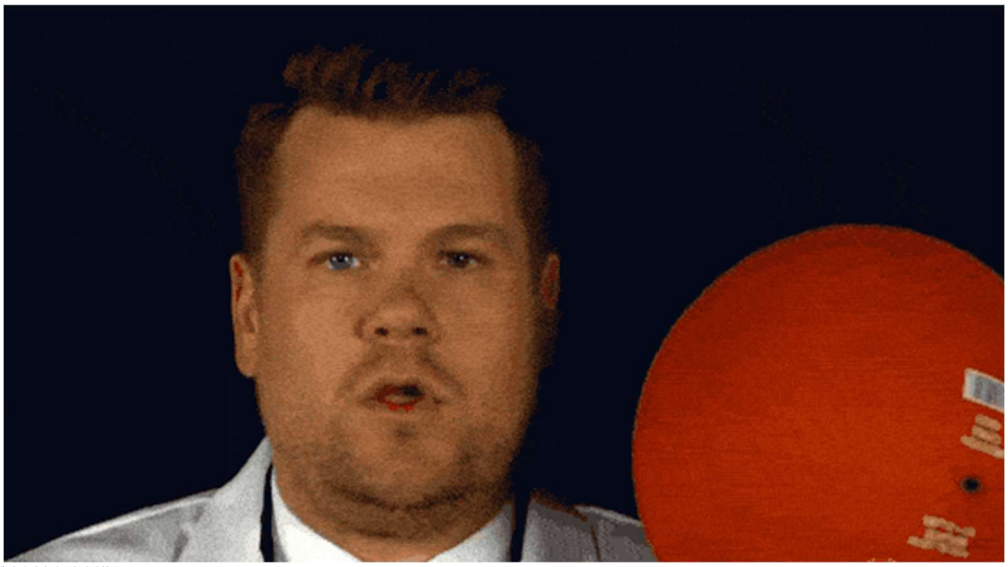

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What do you think ?

is this dough follows an elastic or viscous behavior ?

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What do you think ?

is this dough follows an elastic or viscous behavior ?

Image source: https://wiki.anton-paar.com/hu-hu/a-viszkozimetria-alapjai/

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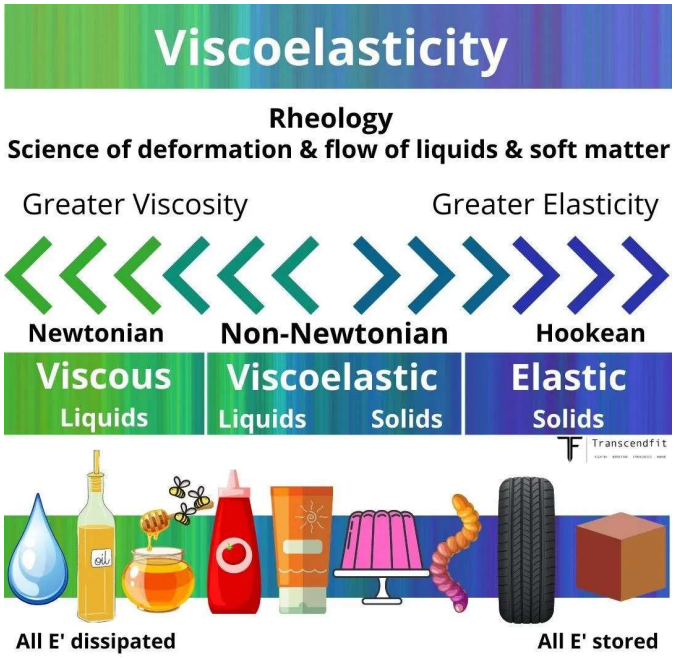
Mechanical behavior of materials

- According to Rheology,
  - *most materials are viscoelastic*
    - have both viscous & elastic components.
- Materials with the highest viscous portion are called Viscous/Newtonian **liquids**
  - *no matter how they are stressed, their viscosity never changes*
  - *e.g water/ salad oil*
- Materials with the highest elastic portion are called Elastic/Hookean **solids**
  - *they show the same level of stiffness unless they are destroyed*
  - *e.g. Rubber/ steel*



https://transcendfit.co/blogs/fascia/viscoelasticity/

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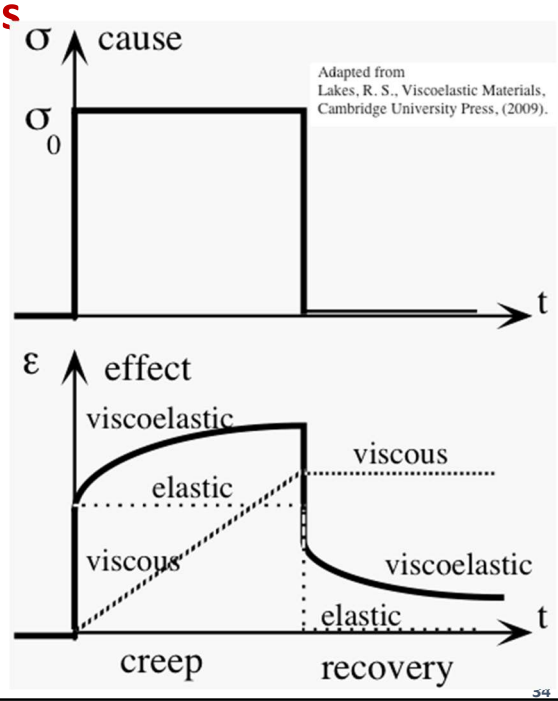
Mechanical behavior of materials

Viscoelastic Behavior

- Viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation
- Viscoelastic Materials
  - *Have both elastic and viscous response*
  - *Have delayed response*
  - *Deformation depends on*
    - Applied load
    - Duration of Load
    - Rate of Loading
    - Temperature



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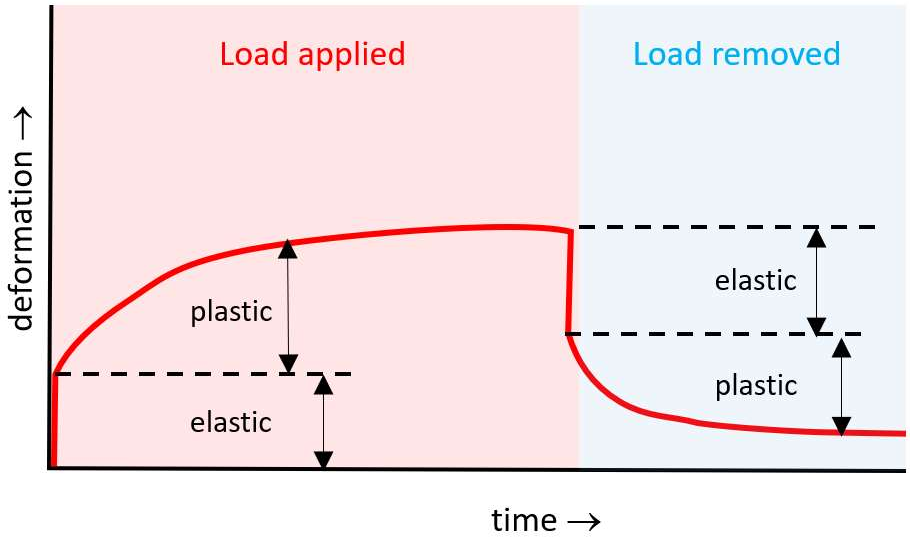
Mechanical behavior of materials

Viscoelastic Behavior under creep loading



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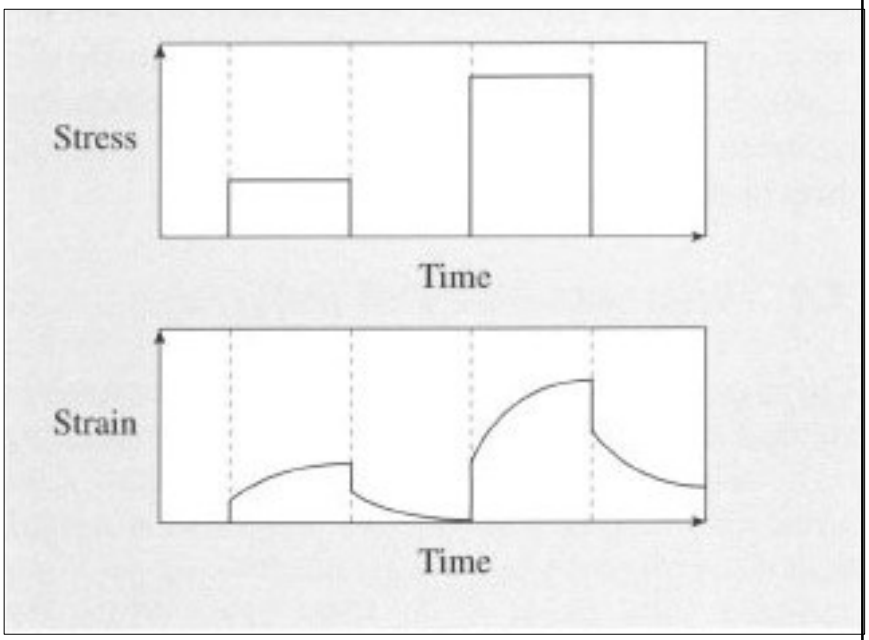
Mechanical behavior of materials

Viscoelastic Behavior under creep loading



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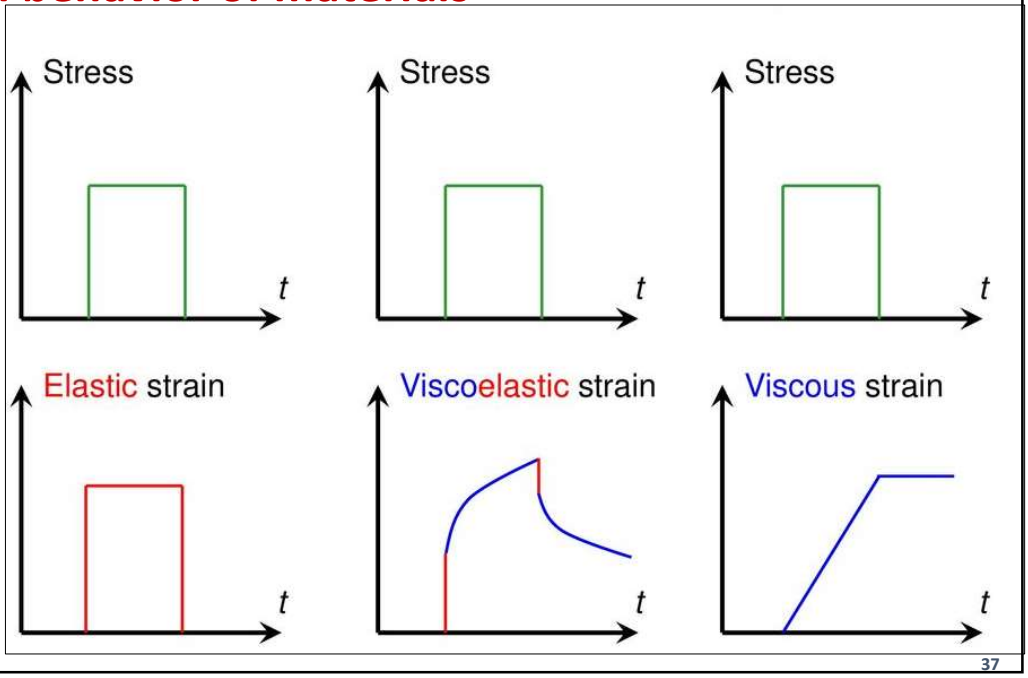
Mechanical behavior of materials

Viscoelastic Behavior



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What do you think ?

Based on the following conditions, which behavior is more prominent in a Viscoelastic Material ?

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What do You think ?

Image source : https://in.pinterest.com/pin/433541901607683832/

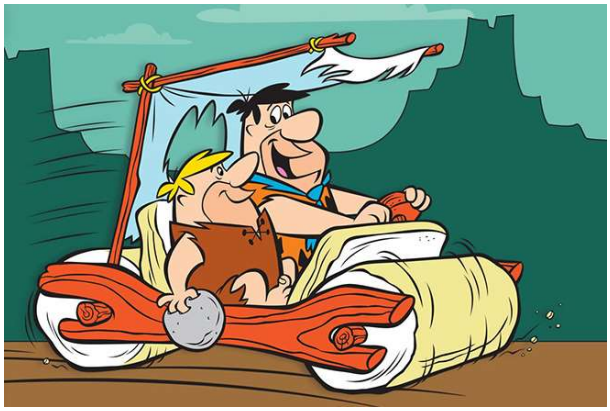

Image source : https://www.whichcar.com.au/car-style/12-cartoon-cars

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What do You think ?

Image source : https://giphy.com/explore/towing

Image source https://www.behance.net/gallery/67086875/Iconic-Cars-Animated-GIF

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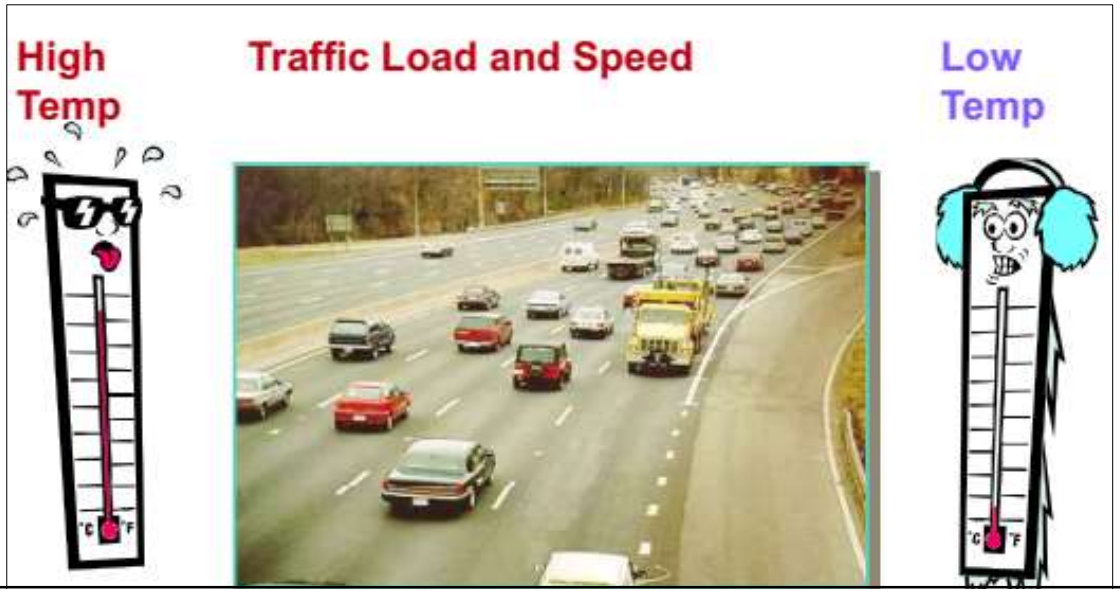
Based on these conditions, which behavior is more prominent in rubber?



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What do You think ?

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What do You think ?

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What do You think ?

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