Steel as a Sustainable Bridging Material

ING - IABSE

MORTH Government of India

PWD UTTARAKHAND

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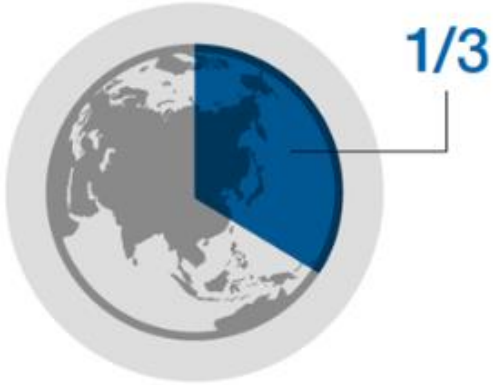
Prof. Dipti Ranjan Sahoo is currently serving as Dean (Infrastructure) and Professor in Department of Civil Engineering at Indian Institute of Technology (IIT) Delhi. He received his Ph. D. in Civil Engineering from IIT Kanpur and worked as a Post-doctoral Fellow at University of Texas, Arlington, USA. His research interests are Performance-based seismic design, Seismic and fire performance of steel structures and Passive vibration control techniques. He has published nearly 300 articles in reputed journals and conferences.

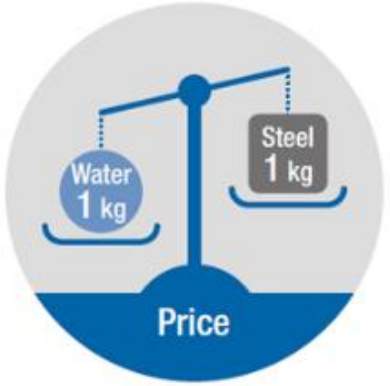
He is a recipient of the prestigious Shanti Swarup Bhatnagar Prize-2022. He is an Elected Fellow of Indian National Academy of Engineering (INAE), Institution of Civil Engineers (UK), Institution of Engineers (India) and Indian Society of Earthquake Technology (Roorkee). He is serving as a member of various committees of Bureau of Indian Standards (BIS) codes, and a member of Working Group for the revision of IS:456, IS:800 and IS:801 codes.

- An abundant, sustainable material

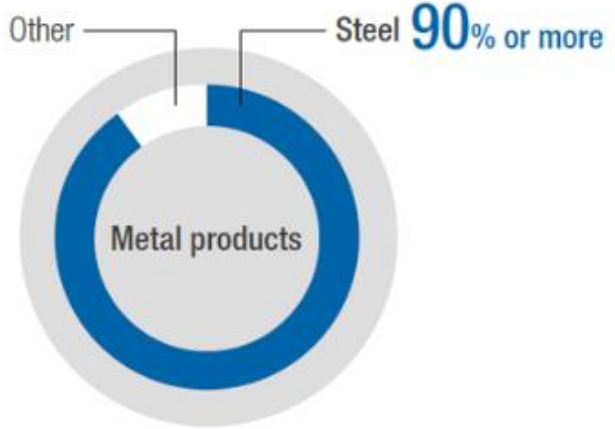
Iron is believed to constitute **one-third** of the Earth's weight.



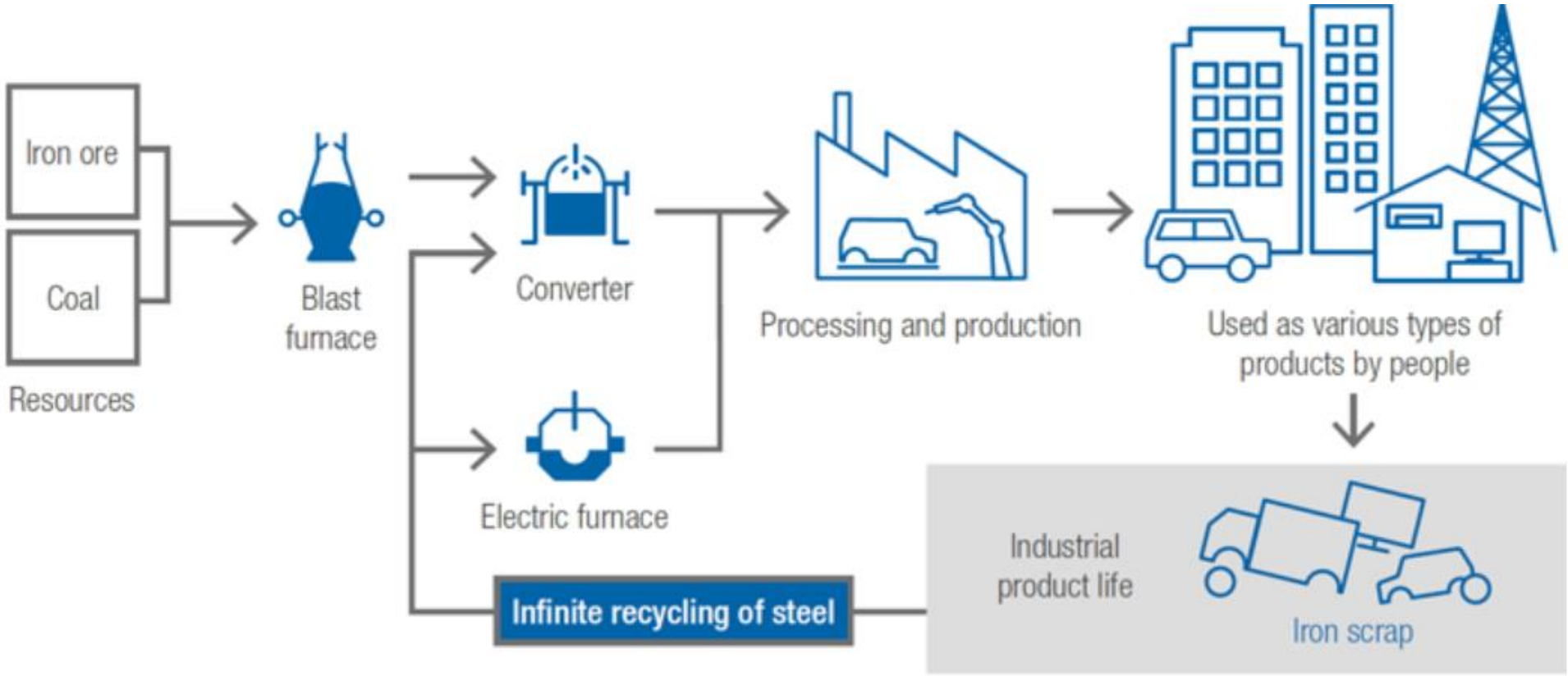
Steel is an **affordable material** and is cheaper than water in a plastic bottle (in comparing price per unit weight).



Steel represents **90% or more** of metal products, as steel being abundant, low-priced, and having good workability, and has a wide range of applications.



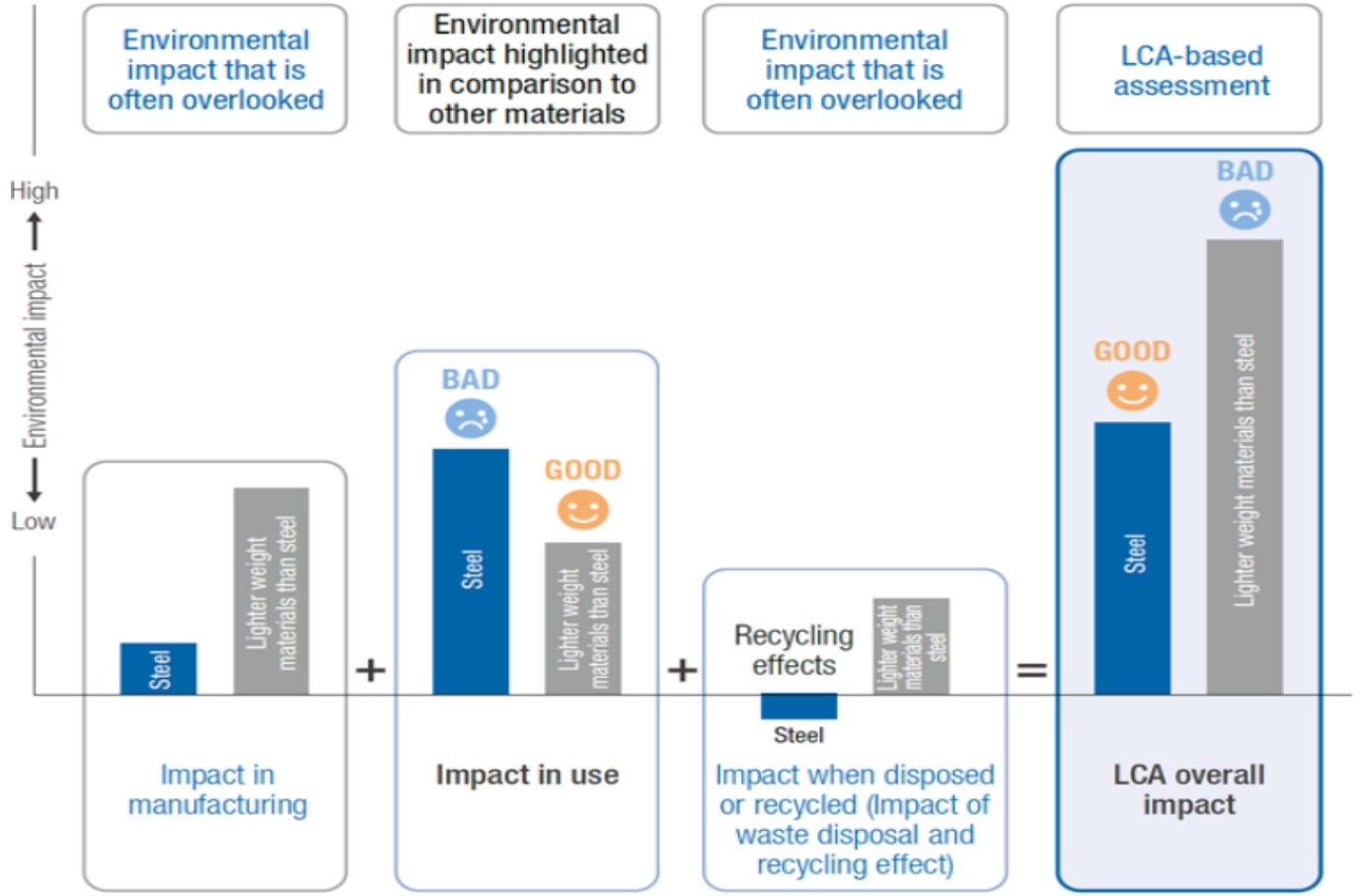
- A material that can be reborn endlessly



- A material with diverse properties and infinite potential

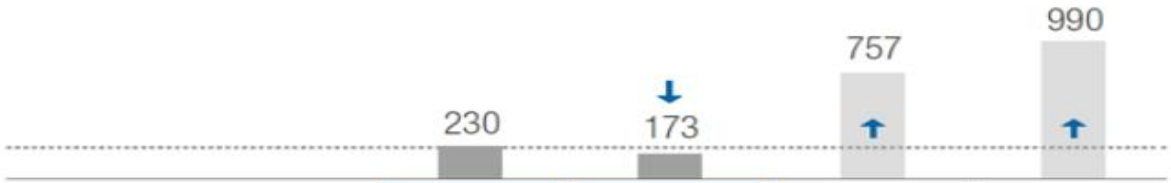
Strength	Weldability	Heat resistance
Toughness	Paintability	Cold resistance
Robustness	Magnetism	
Workability	Corrosion resistance	Weather resistance

- An outstanding material from the Life Cycle Assessment (LCA) perspective



- Life Cycle Assessment (LCA) perspective

Comparison of GHG (Green House Gas) emission in producing an automotive part that has the same strength as conventional steel (kg-CO_2e)



	Conventional steel materials	High-tensile steel	Aluminum	Carbon fiber reinforced plastics
Functional equivalent weight (kg)	100	75	67	45
GHG emissions per unit (kg-CO_2e/kg)	2.3	2.3	11.3	22.0

Based on the public data of WorldAutoSteel

Steel's environmental impact in production is extremely lower than other materials, some of which are lighter than steel.

Note: Moreover, high-tensile steel is about 25% lighter than conventional steel and has a lower environmental impact.

- Strategies
  - Increase production of sustainable steel
  - Improve environmental, social and governance (ESG) performance
    - *Enhanced Waste And Energy Management*
  - Embrace digitization to unlock value
  - Collaborate with all stakeholders to accelerate the transition to improve output quality
  - Assess and adopt clean technologies, promoting a balance of risk, capital cost and quality

Assess and adopt clean technologies

- **Carbon capture**
  - Top gas recycling can recycle up to 90% of the exhaust gas from blast furnaces
  - remaining highly CO_2-concentrated 10% reuse for combustion

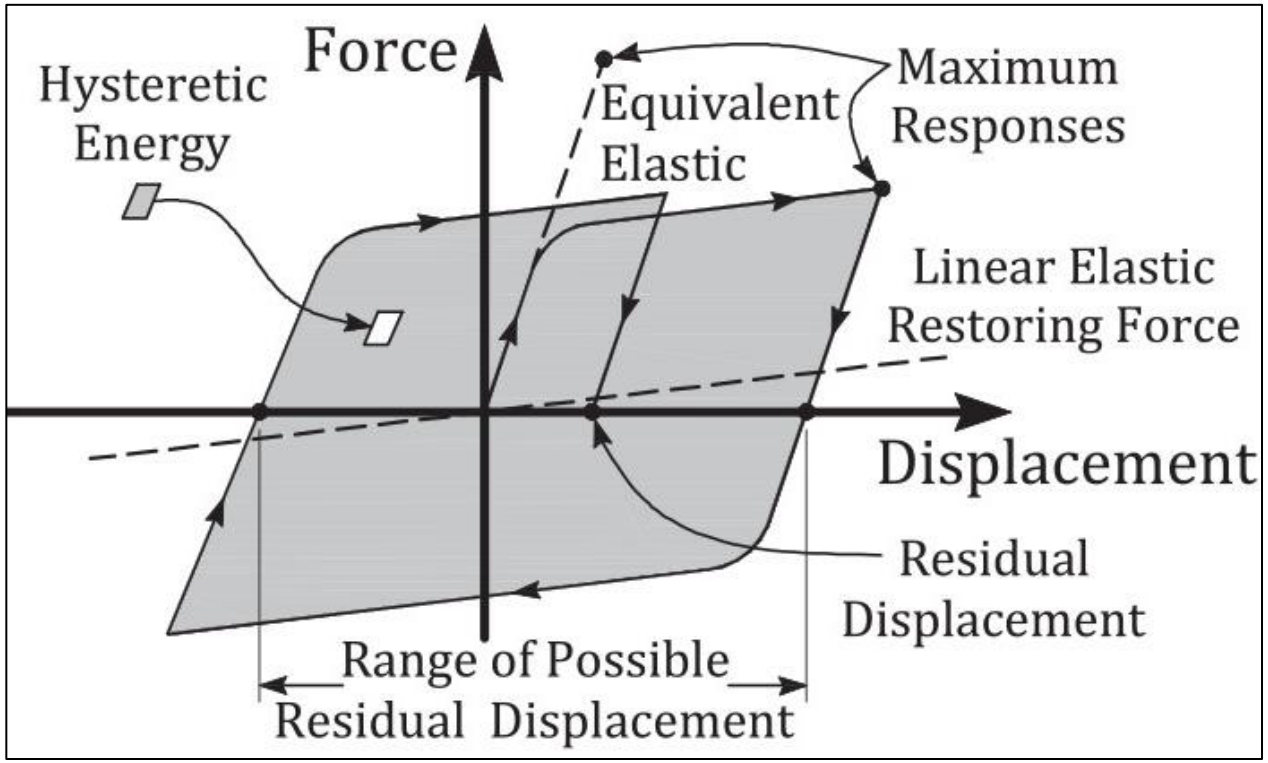
- **Innovations in product mix**
  - Moving to scrap-based Electric Arc Furnace production should reduce emissions
  - Availability of scraps and desired quality of the end product ??

Assess and adopt clean technologies

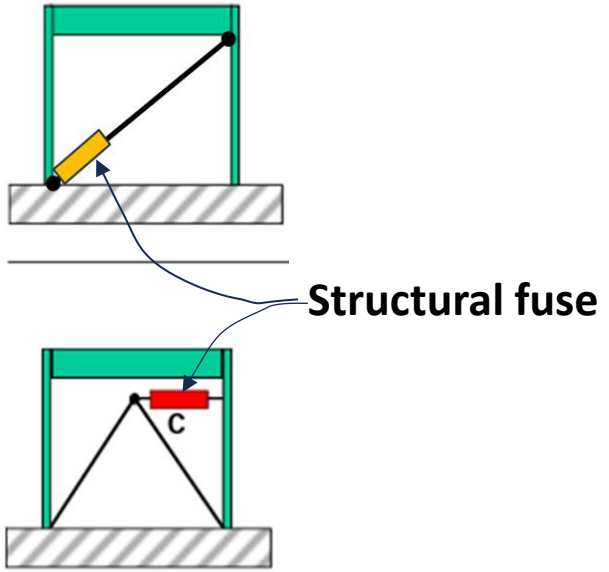
- Green Hydrogen
  - Use of green hydrogen with direct reduced iron and Electric Arc Furnace
  - Feasibility and scalability of hydrogen availability ??

- Alternative smelting reduction processes
  - Energy-Efficient Production Methods
  - EAFs are more energy-efficient and primarily use recycled steel scrap to produce new steel
  - Biomass, a substitute for coal in the iron reduction process, is carbon neutral .

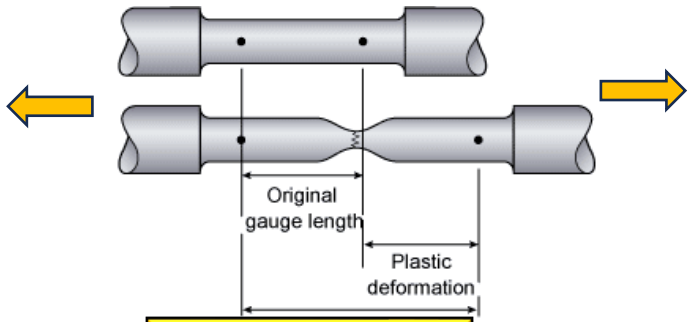
- Ductility-based Design
  - Damage control (life Safety level of protection)



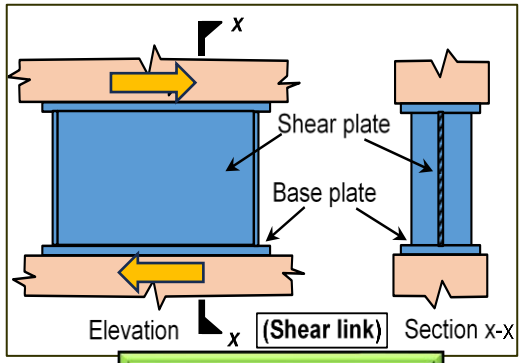
- Yielding Steel
  - **Advantages**
    - Stable material properties
    - Not a mechanical device
    - No special maintenance
    - Reliable long-term performance
    - Resistance of aging
  - **Energy dissipation Devices**
    - **Structural fuses**
    - **Damping devices**



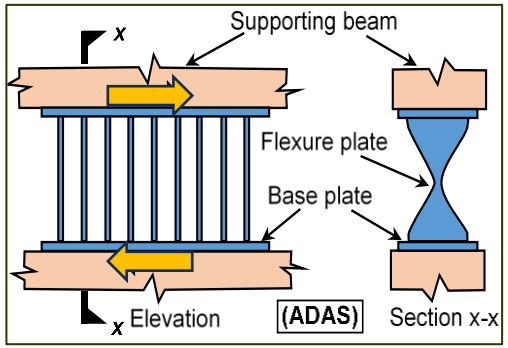
- Yielding Steel



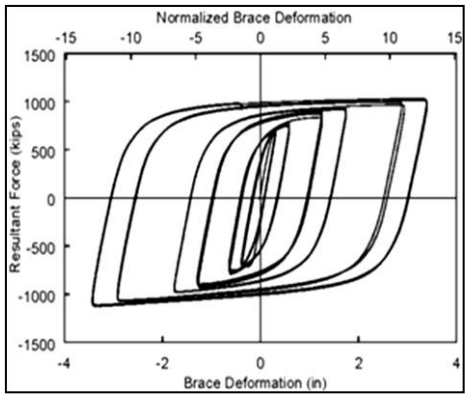
Axial yielding

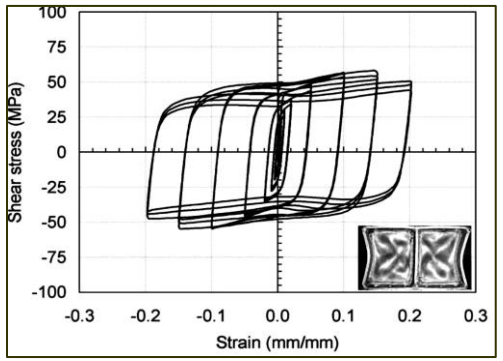


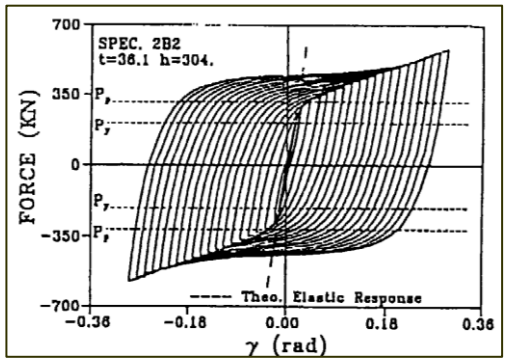
Shear yielding



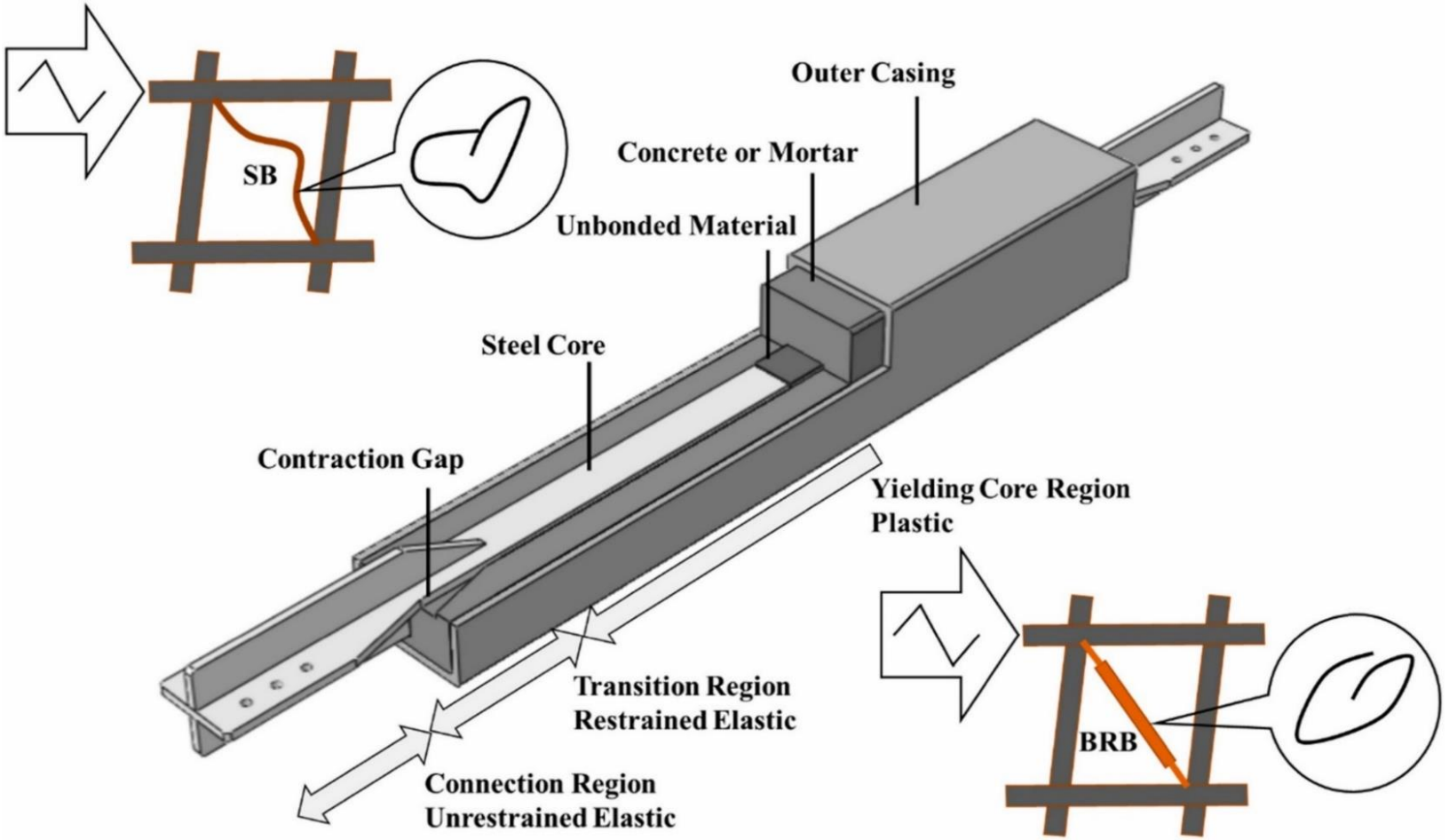
Flexural yielding



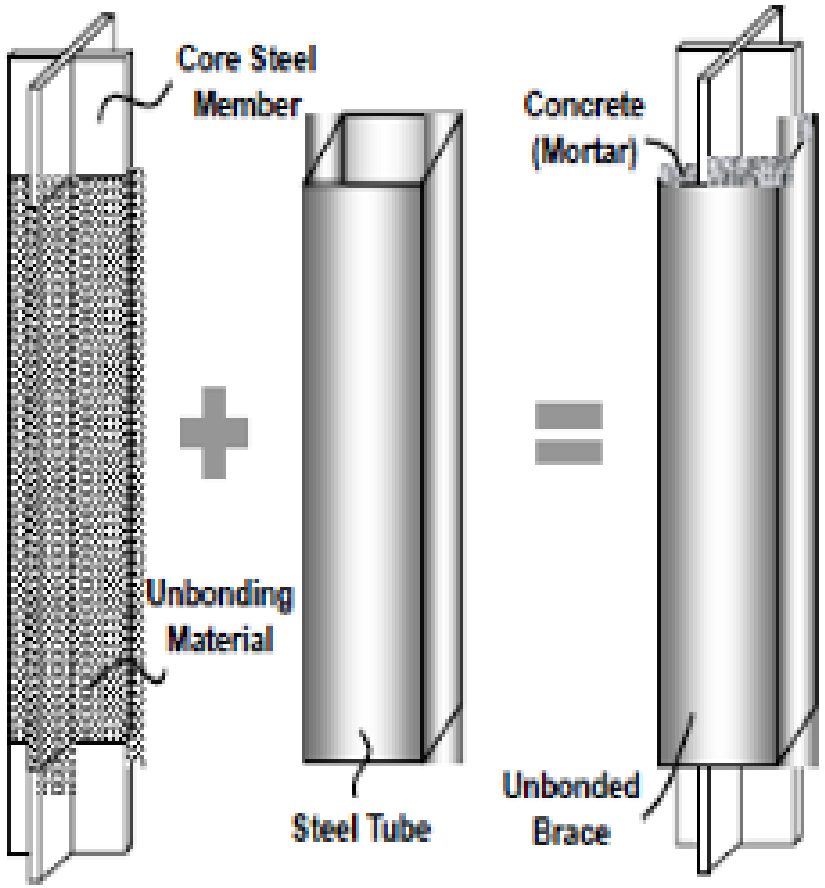


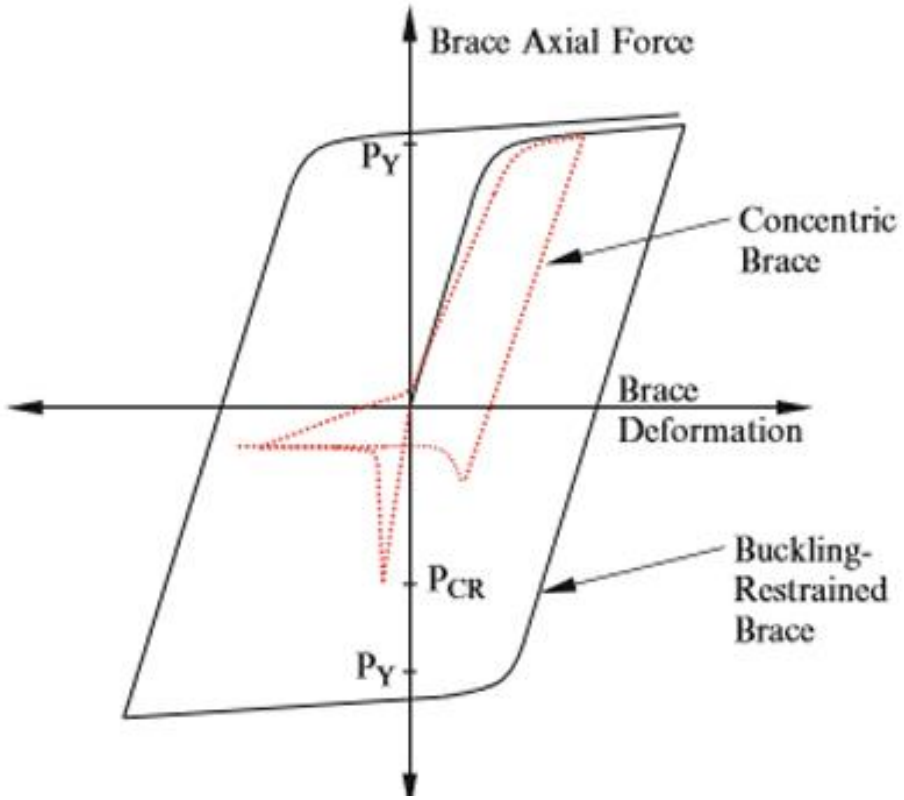


- **Concepts**

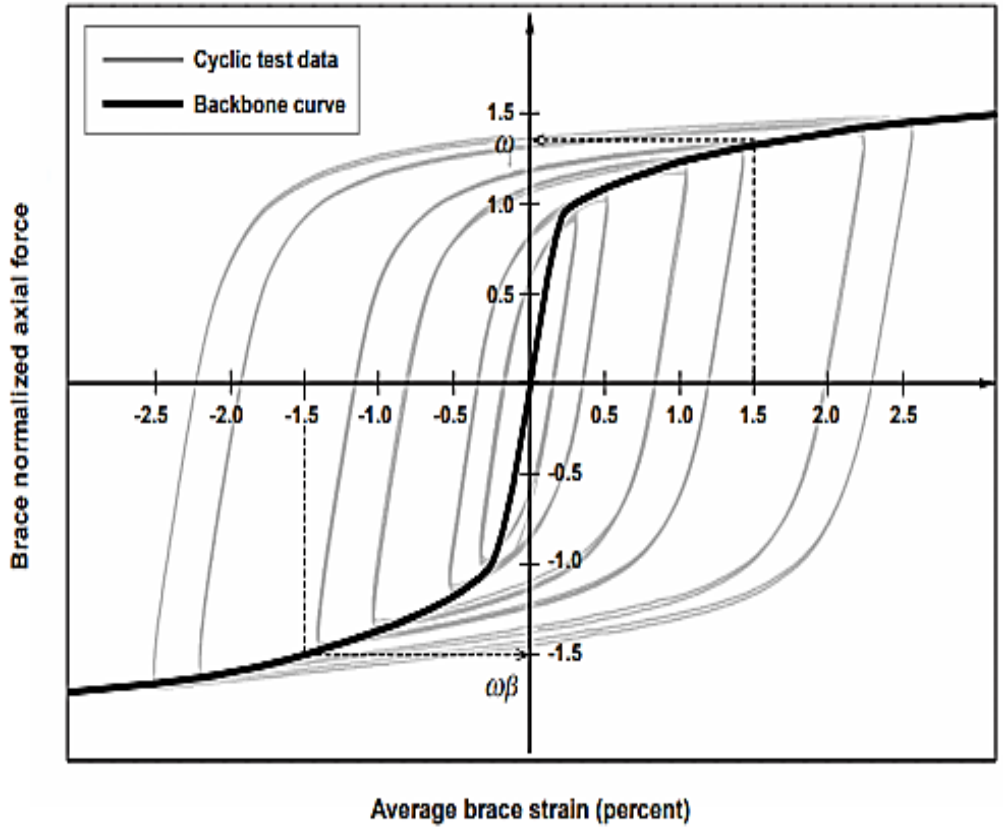

SB
Outer Casing
Concrete or Mortar
Unbonded Material
Steel Core
Contraction Gap
Yielding Core Region
Plastic
Transition Region
Restrained Elastic
Connection Region
Unrestrained Elastic
BRB

- **Traditional BRBs**

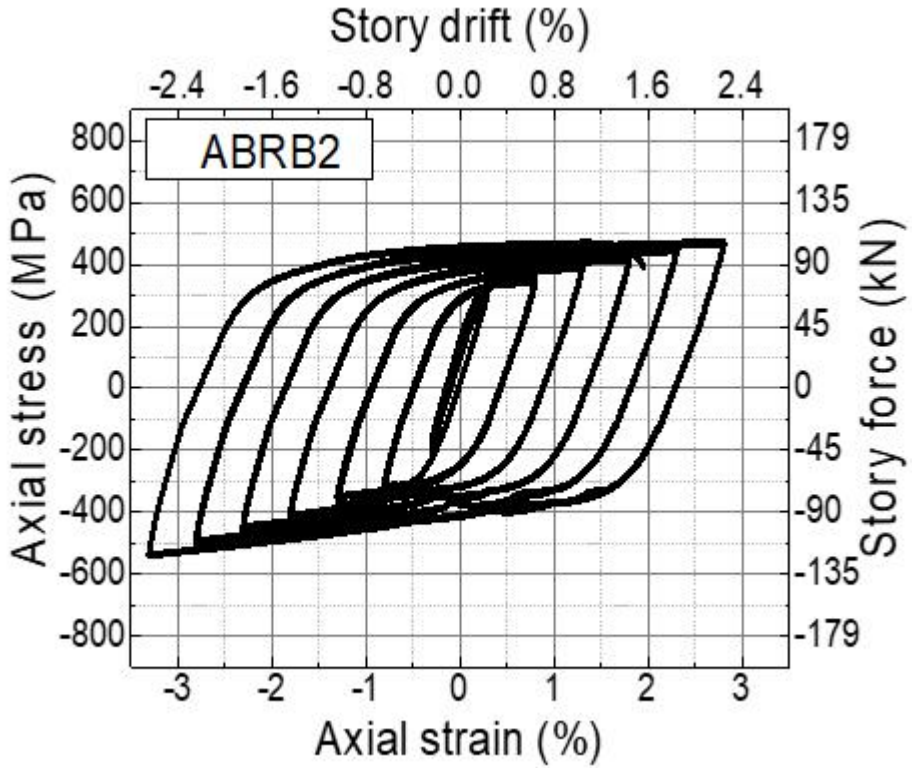




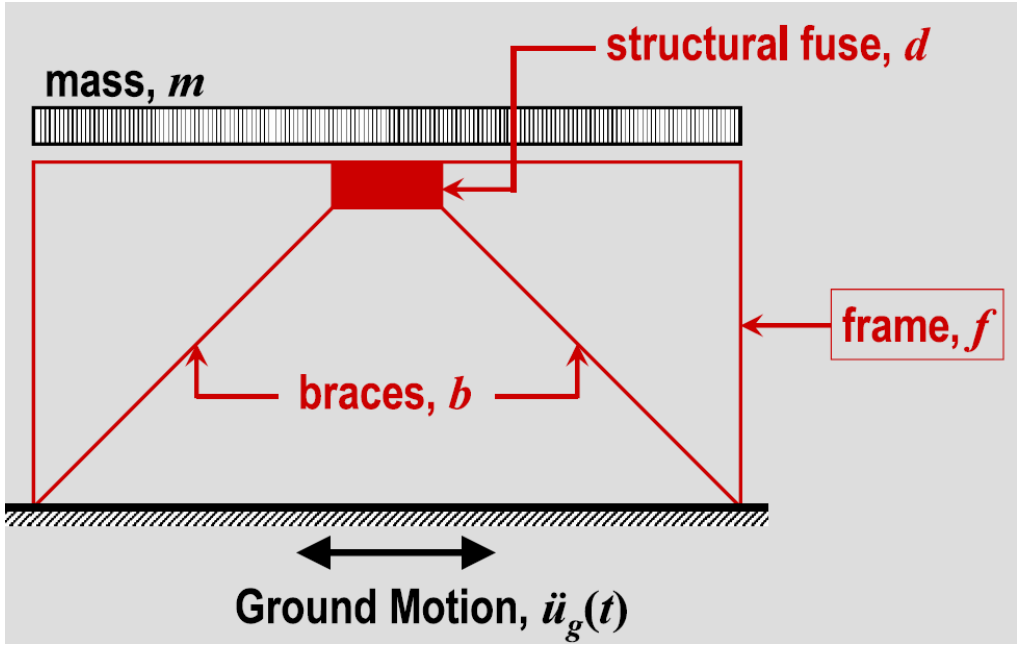
- **Hysteretic Response**



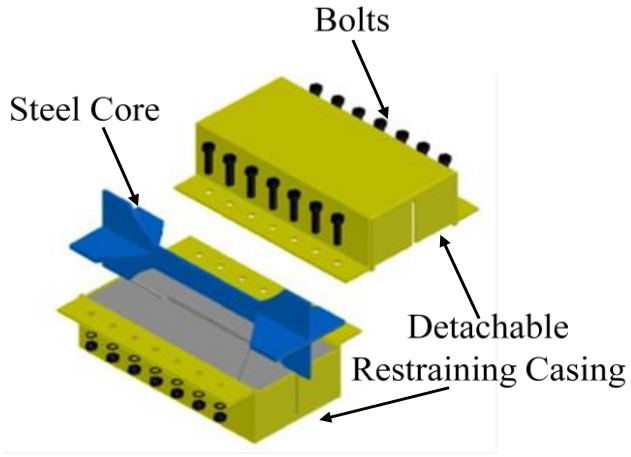
- **All-steel BRBs**

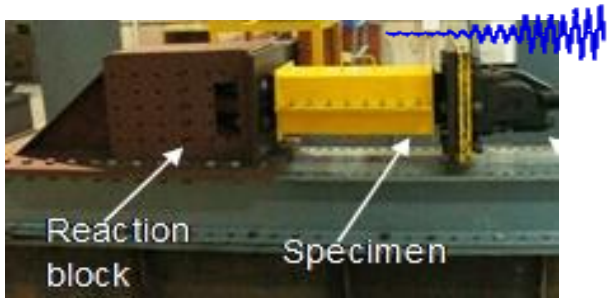


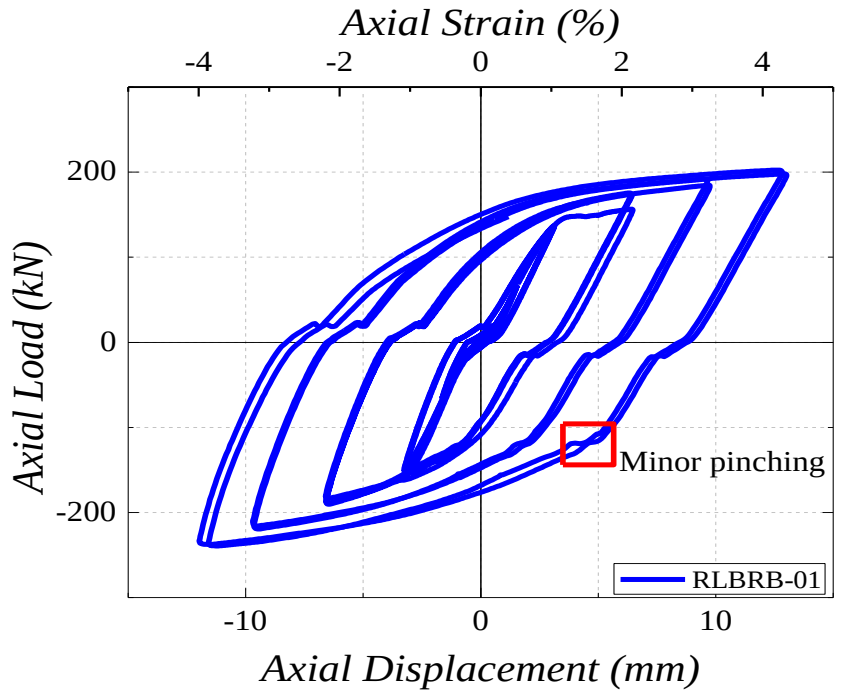
- **Concept**
  - Based on hysteretic damping and energy dissipation
  - To concentrate damage in specially designed elements
  - Replaceable after seismic events



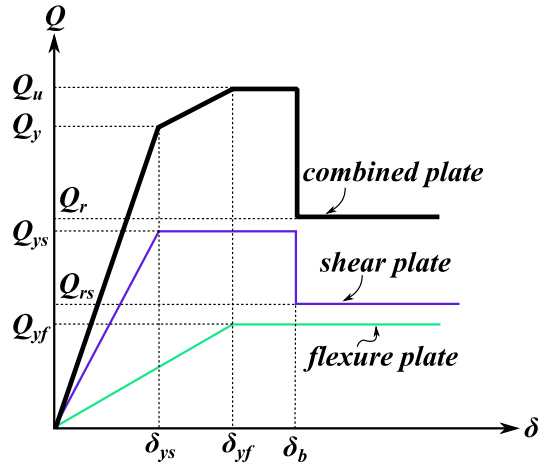
- **Short-core BRBs**

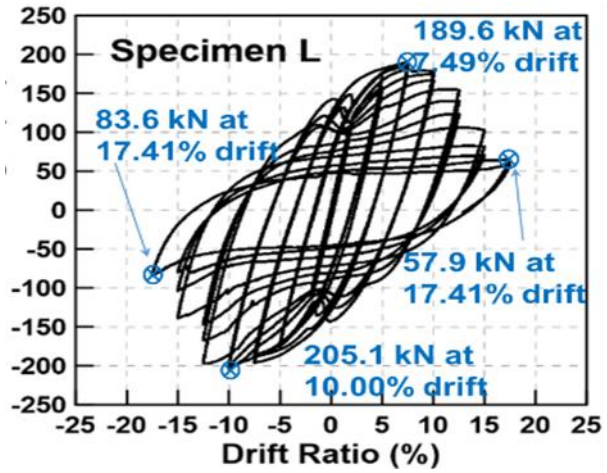




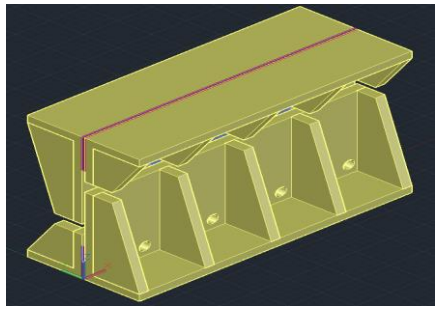


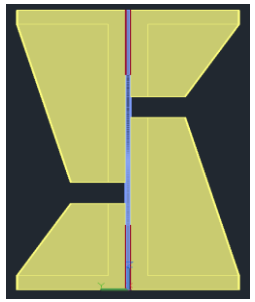
- **Shear-Flexure Yielding Device (SAFYD)**

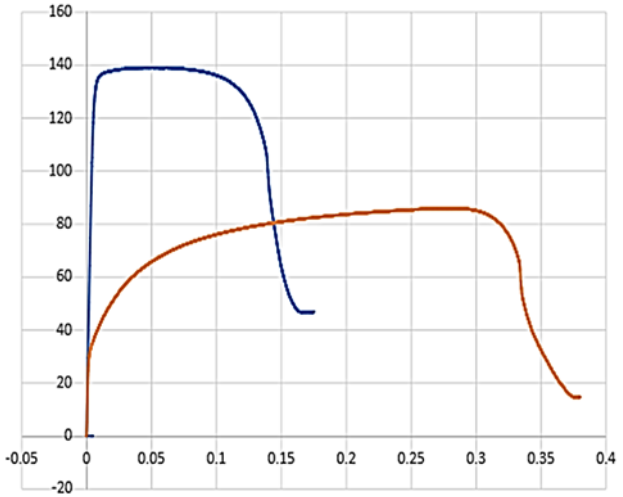


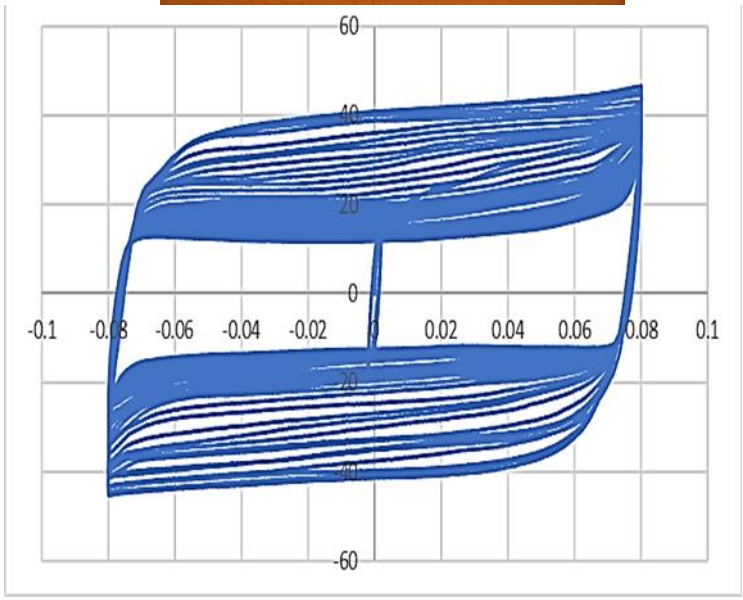


- **Buckling-inhibited shear yielding device**

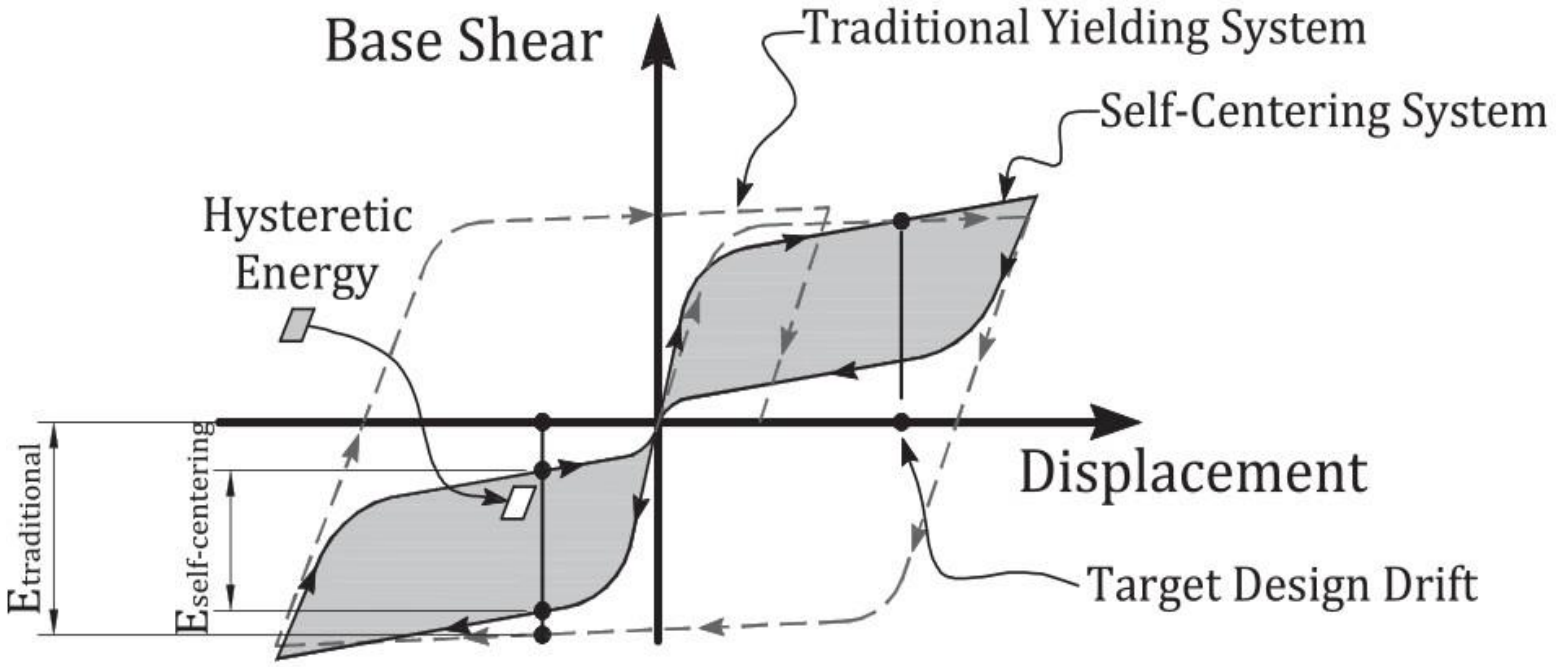




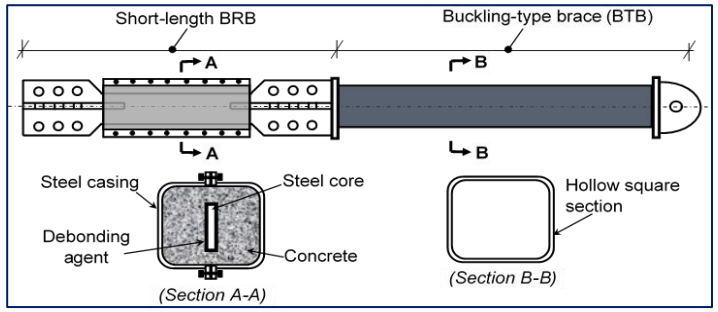


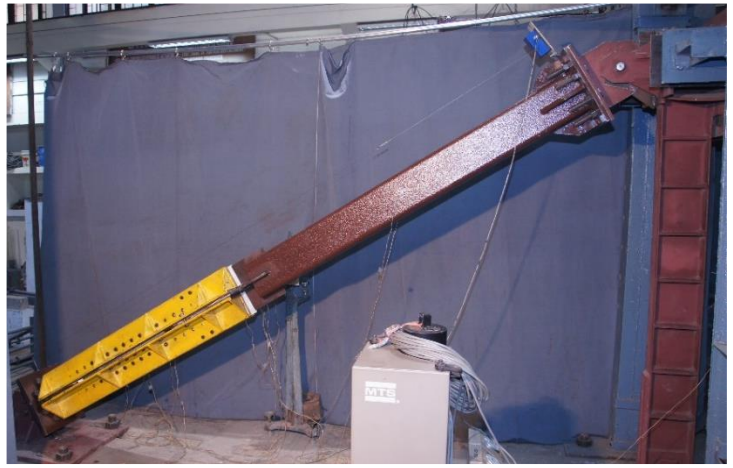


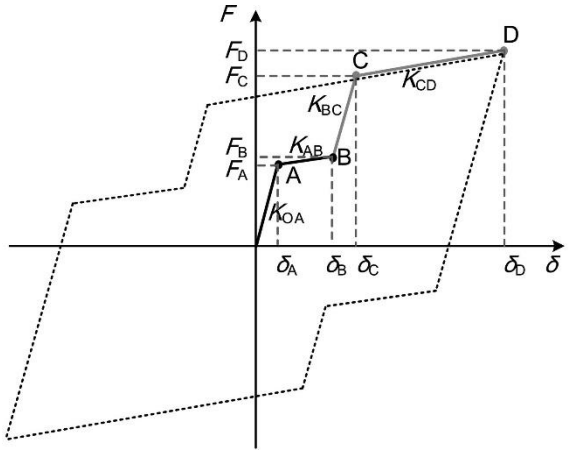
- **Resilient-based Design**
  - Recentering systems (Operation level of protection)

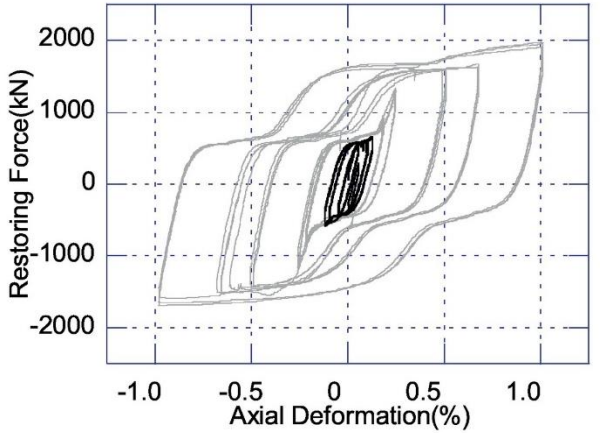


- **Fe-based Super-elastic Brace**



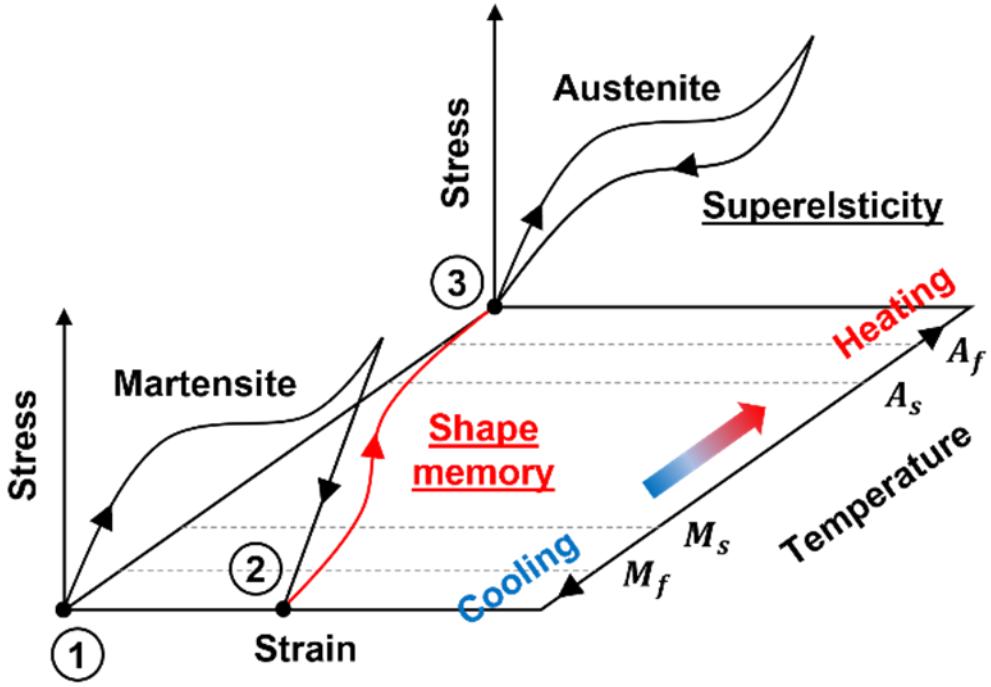




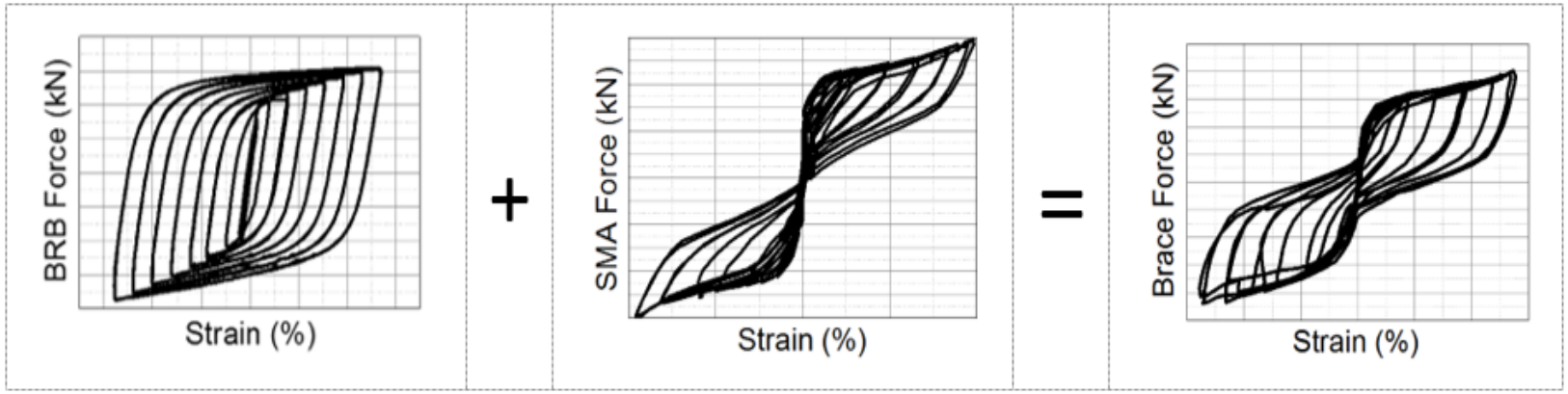


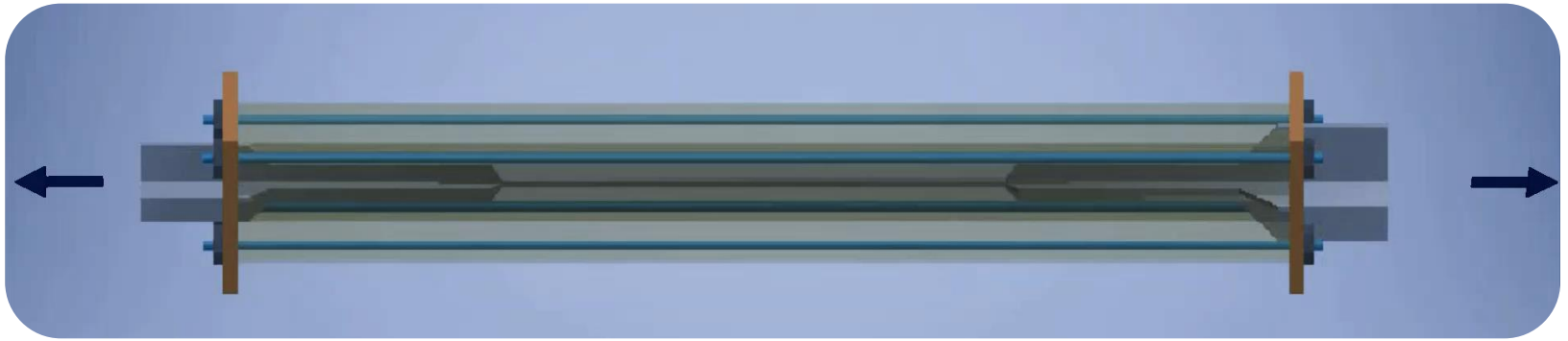
Self-centering BRBs

- **Shape Memory Alloy**



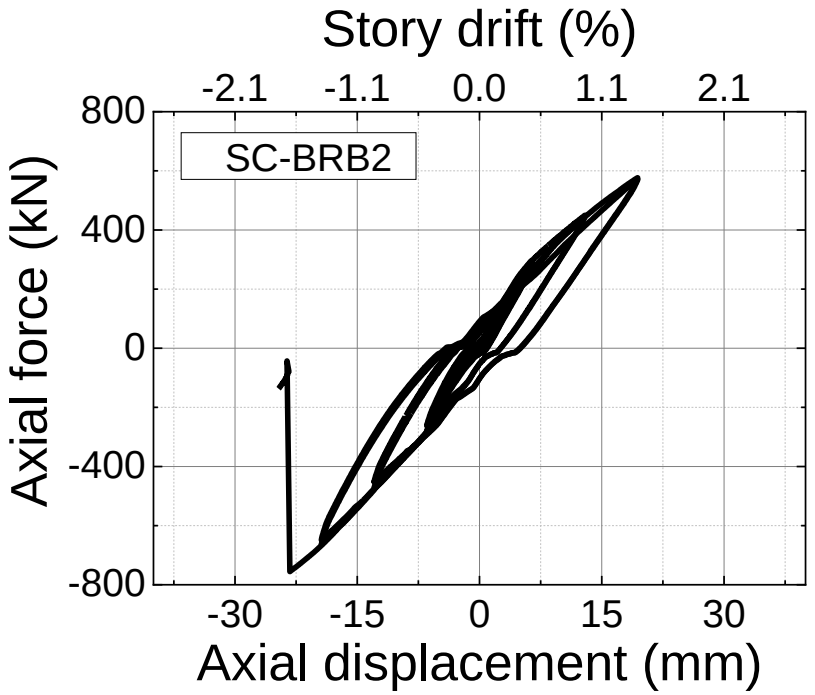
- **SMA-BRB**


BRB Force (kN)
Strain (%)
+
SMA Force (kN)
Strain (%)
=
Brace Force (kN)
Strain (%)

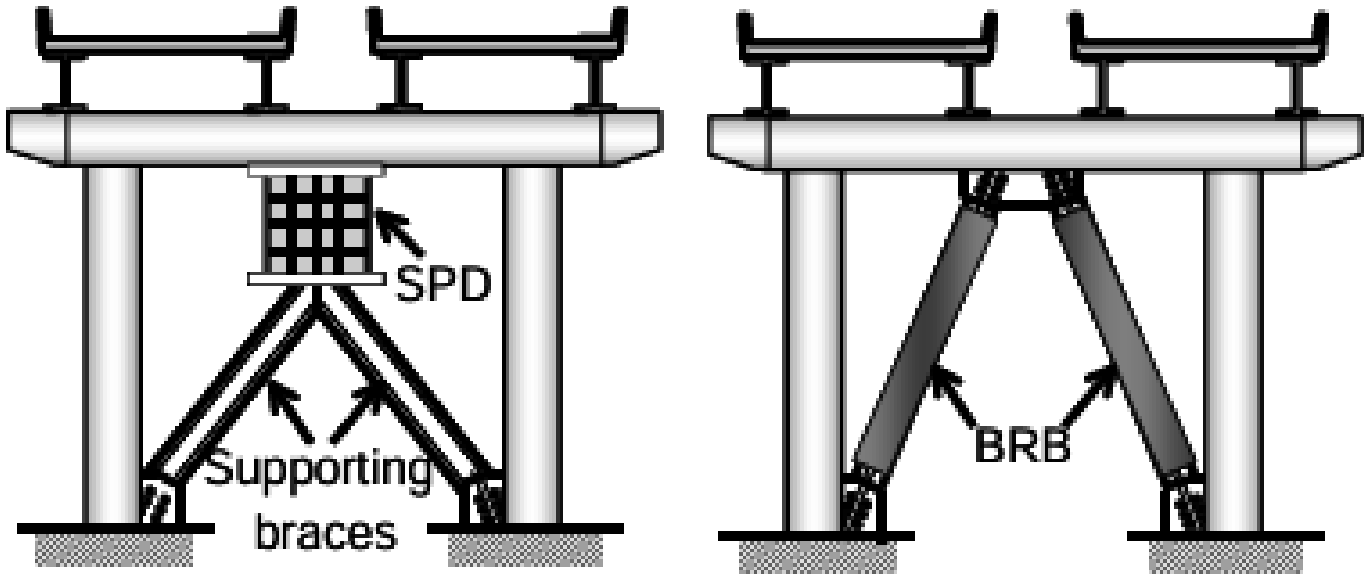


Self-centering BRBs

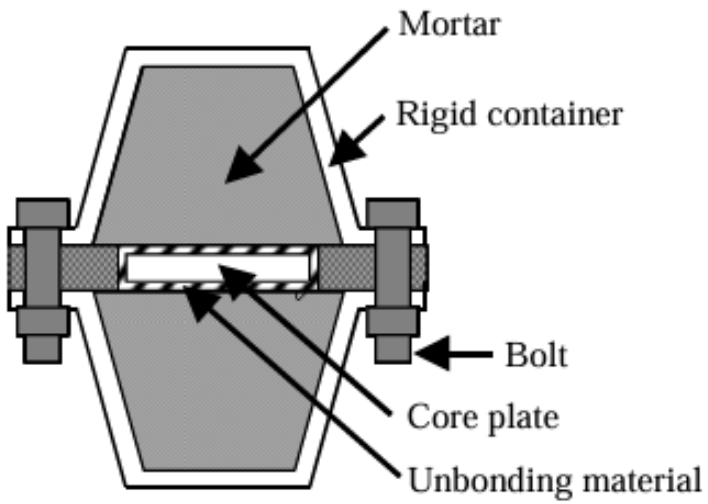
- **SMA-BRB**

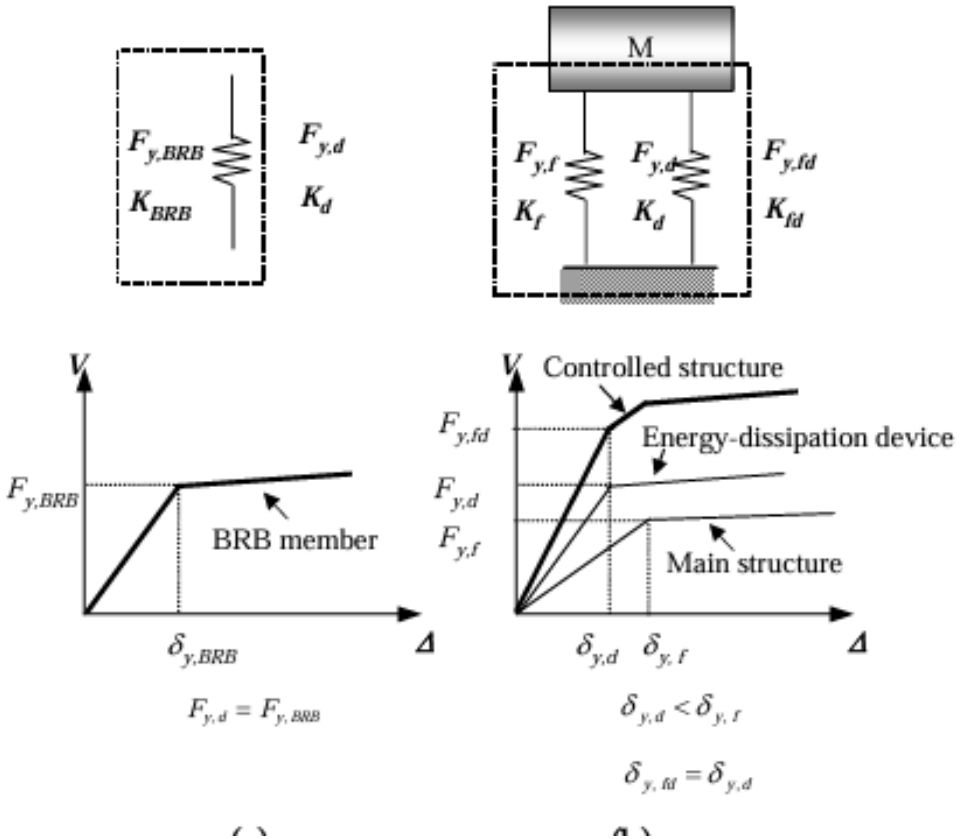


- **New bridges**

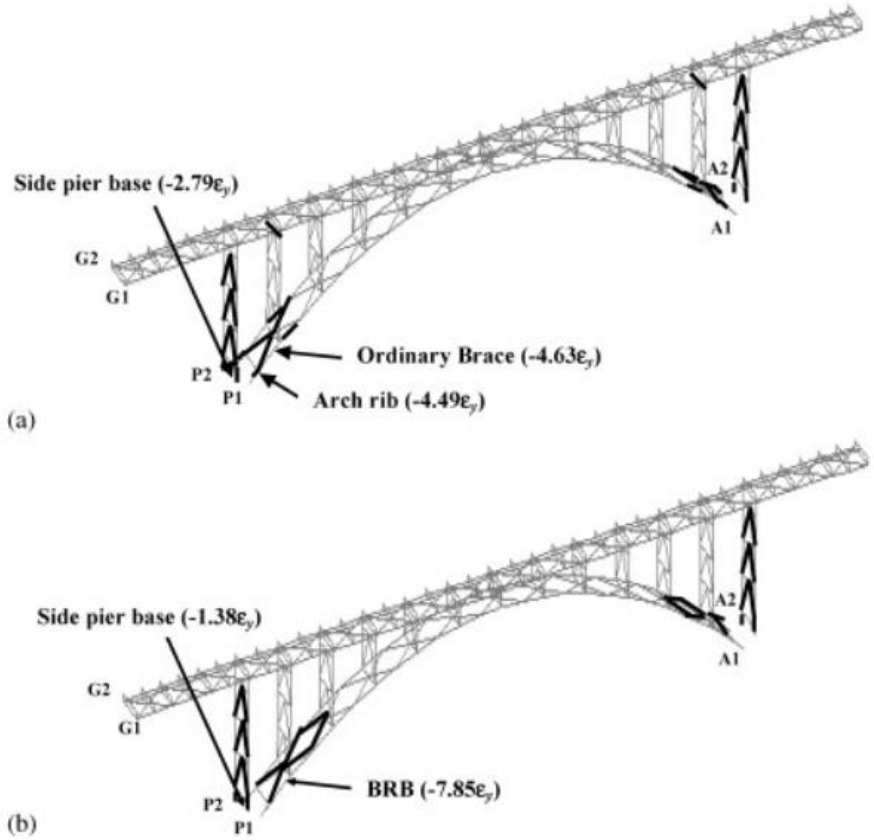


- **New bridges with BRBs**





- **Upgradation of existing bridges**



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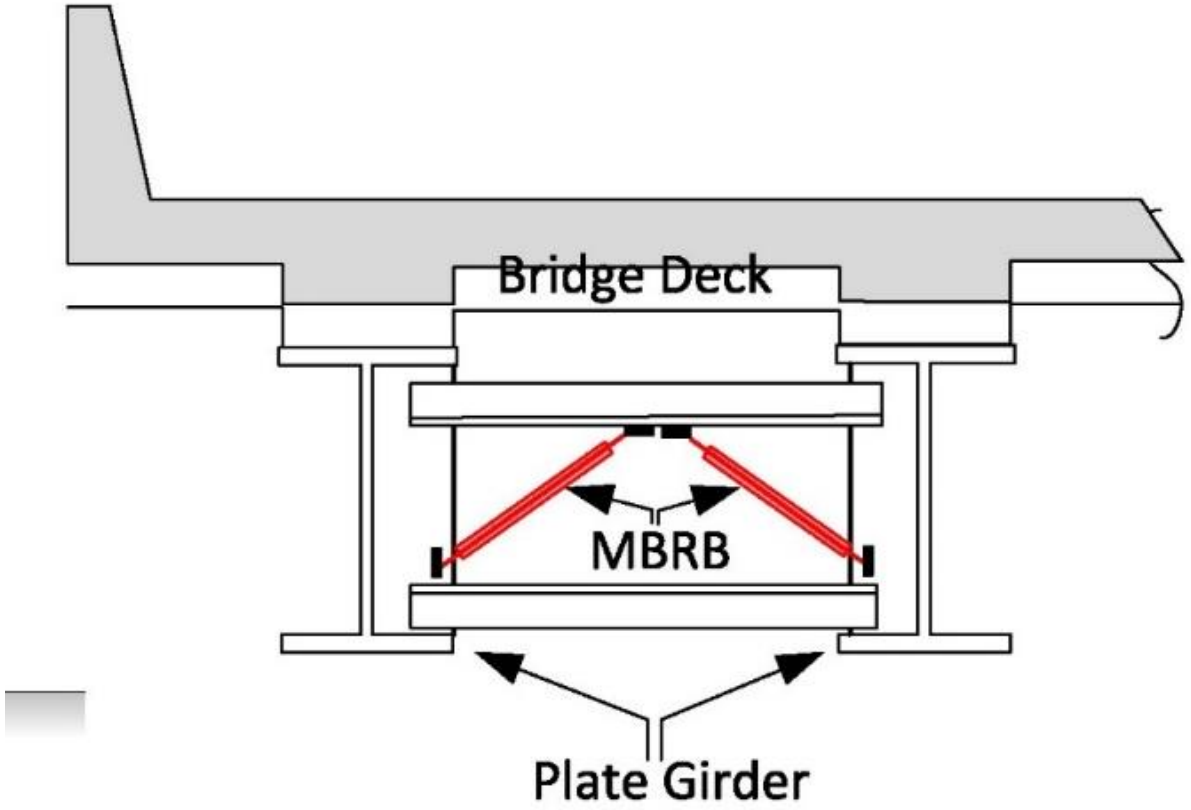
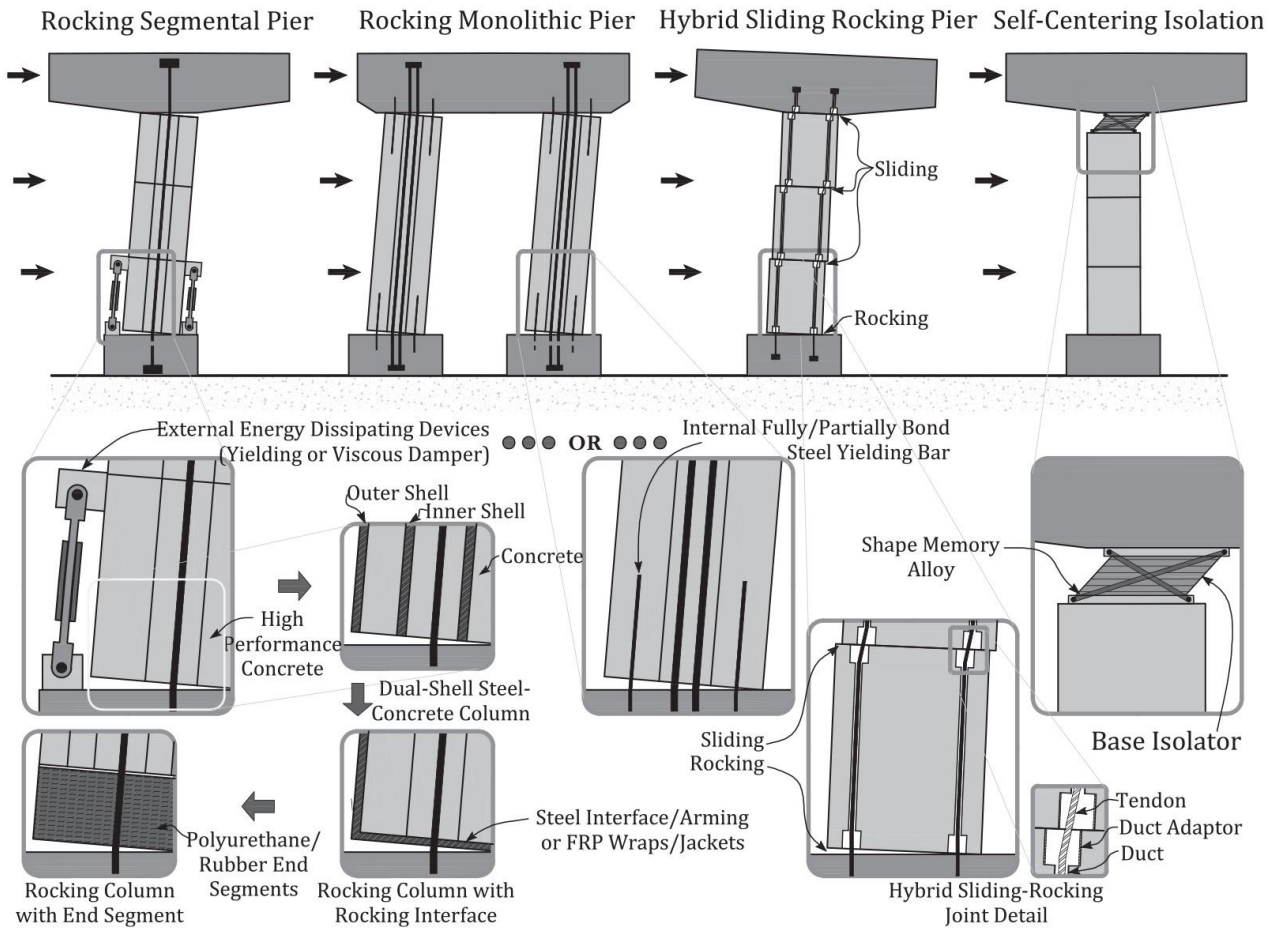
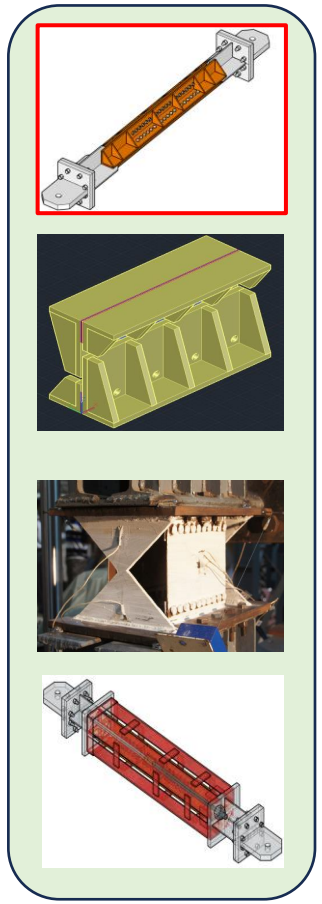


- **Rocking Bridge systems**





Thank you