What is Structural Innovation?

Worksheet

Structural innovation is the design and analysis of new structural systems — such as diagrids, tensile membranes and seismic base isolation — that carry loads more efficiently than traditional column-and-beam framing.

Questions

1. In the beam deflection formula $\delta = 5wL^4/(384EI)$, doubling the span L (all else constant) increases deflection by a factor of:

A) 2
B) 4
C) 8
D) 16

2. What is the main structural advantage of a diagrid system?

A) It requires more interior columns
B) It carries lateral and gravity loads through the exterior, freeing interior space
C) It only works on low-rise buildings
D) It eliminates the need for foundations

3. What does base isolation primarily protect against?

A) Wind loads
B) Seismic (earthquake) forces
C) Thermal expansion
D) Water infiltration

4. A tensile membrane structure resists loads mainly through:

A) Compression in thick columns
B) Bending in rigid beams
C) Pure tension in curved fabric or cables
D) Shear in concrete walls

5. A simply supported steel beam spans 6 m and carries a uniform load of 10 N/mm. E = 200,000 N/mm² and I = 80,000,000 mm⁴. Find the maximum deflection.

6. A 50-story tower needs a lateral (wind/seismic) bracing system that also frees up the façade for uninterrupted views.

7. A stadium roof must span 200 m column-free with minimal material and rapid erection.

8. Define: What is a diagrid structural system?

9. Define: What does the beam deflection formula $\delta = 5wL^4/(384EI)$ tell you?

10. Define: What is base isolation?

Answer Key

1. D) 16 — Deflection scales with L^4, so doubling L multiplies deflection by $2^4 = 16$.

2. B) It carries lateral and gravity loads through the exterior, freeing interior space — Diagrids triangulate the exterior to resist loads, reducing or removing interior structure.

3. B) Seismic (earthquake) forces — Base isolators absorb and decouple ground motion during earthquakes, protecting the structure above.

4. C) Pure tension in curved fabric or cables — Tensile membranes are shaped (form-found) so they stay entirely in tension under load.

5. $\delta = 5wL^4 / (384EI)$ $L^4 = 6000^4 = 1.296\times10^{15}$ mm⁴ Numerator = $5 \times 10 \times 1.296\times10^{15} = 6.48\times10^{16}$ Denominator = $384 \times 200{,}000 \times 80{,}000{,}000 = 6.144\times10^{15}$ $\delta = 6.48\times10^{16} / 6.144\times10^{15} \approx 10.55$ mm

6. Traditional option: internal shear core plus perimeter columns, but this adds interior structure and blocks views Innovative option: a diagrid exoskeleton — diagonal triangulated steel members on the exterior carry both gravity and lateral loads Diagrid removes the need for most interior columns, opening floor plates and façade views Decision: specify a diagrid perimeter structure, reducing steel tonnage by resisting lateral loads through triangulation

7. Evaluate options: heavy steel trusses vs a tensile membrane structure Tensile membranes carry loads purely in tension through doubly-curved fabric, needing far less material than trusses Structural analysis (form-finding) shapes the membrane's curvature so it stays in pure tension under wind and snow loads Decision: specify a cable-supported tensile membrane roof, verified with nonlinear form-finding analysis

8. An exterior triangulated grid of diagonal members that carries both gravity and lateral loads, often eliminating interior columns and core-only bracing.

9. It gives the maximum sag of a simply supported beam under uniform load — deflection grows with the fourth power of span length.

10. A seismic protection strategy that decouples a building from ground motion using flexible bearings, reducing the forces transmitted to the structure.