Support and articulation – Annex

(Lagerung und Dilatation – Annex)

Support and articulation

Jointed bridges – Bearing layout examples (all)

Support and articulation – Bearing layout examples

Examples: Simply supported girder

In a simply supported girder, longitudinal fixity must be provided at an abutment.

The figure shows an «obvious» solution:

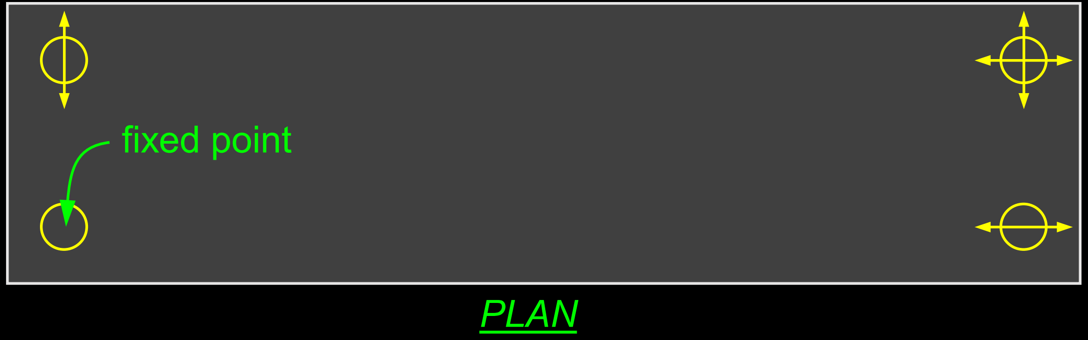
- longitudinal fixity provided by both bearings at left abutment
- transverse fixity provided by one bearing per abutment

  This bearing layout theoretically

- Avoids restraint due to expansion and contraction
- provides statically indeterminate horizontal support (clamped at left abutment)
- allows sharing longitudinal support reactions among two bearings

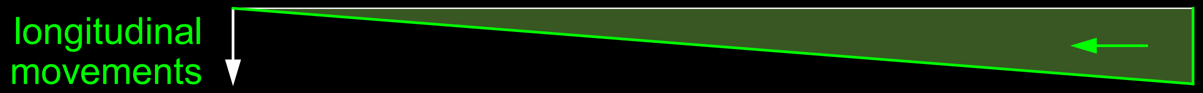
While this would be advantageous, this bearing layout should be avoided due to tolerances in uniaxial bearings, see next slide

Obvious solution – not recommended (yet often used …)

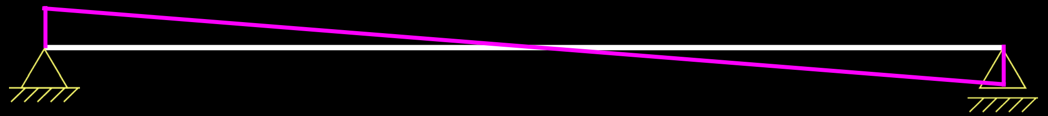


Vertical static system

Horizontal static system (clamped… but tolerances?)



Torsional support system (statically indeterminate)



Support and articulation – Bearing layout examples

Examples: Simply supported girder

The guides of uniaxial bearings usually have several millimetres of play due to tolerances

→ unclear if clamping at left abutment can be activated (girder stiff in transverse direction)

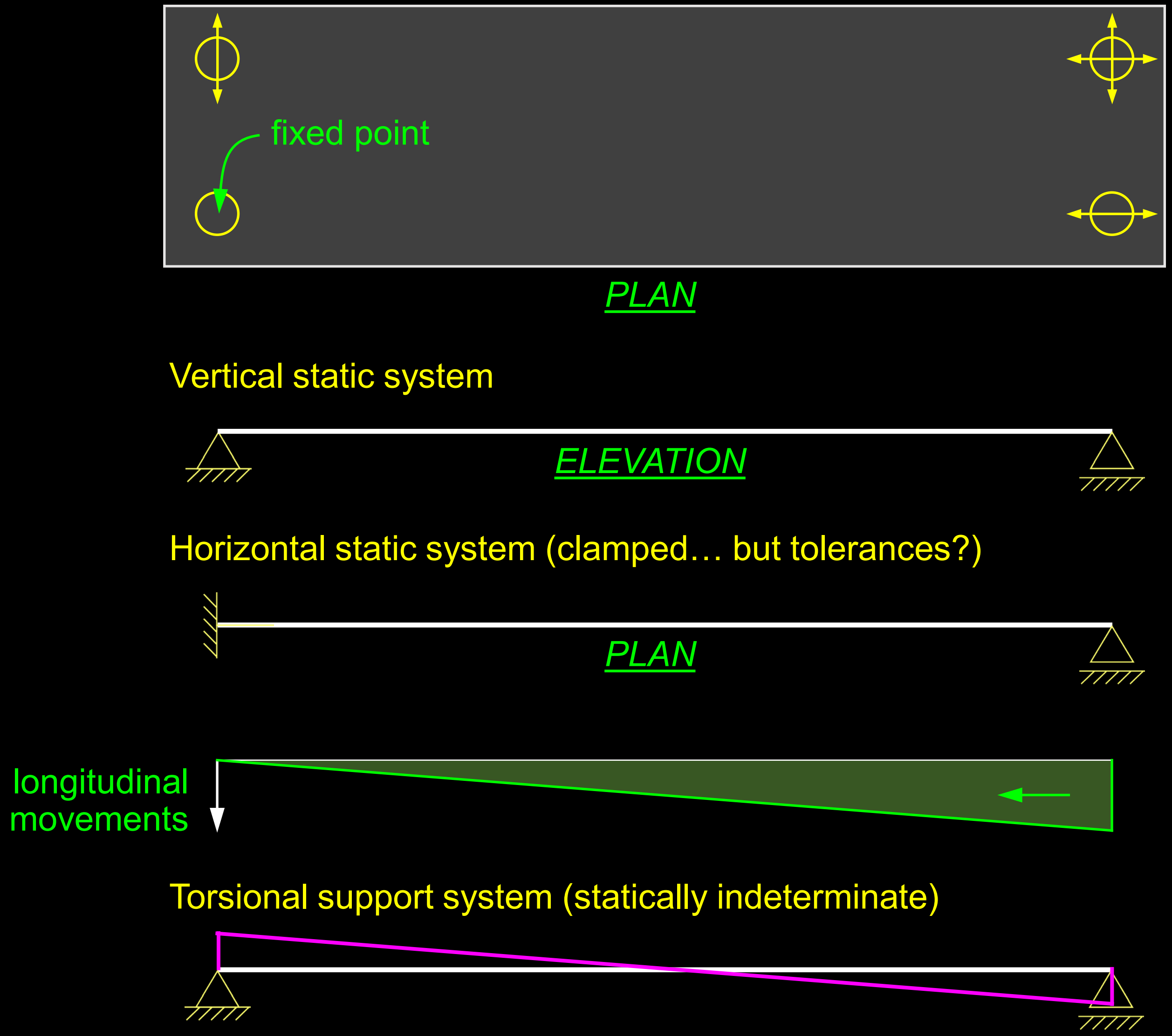
→ longitudinal forces will act on one bearing only, until it deforms considerably, but usual bearings do not provide sufficient ductility for relevant redistribution

→ layout to be avoided (though often used and shown in many textbooks)

Further remark: As in all usual solutions with four bearings (following slides), the support for vertical forces is statically indeterminate (3 vertical supports would be sufficient)

→ relevant for steel and prefabricated girders lifted in (precise levelling of supports required unless the torsional stiffness is small)

Obvious solution – not recommended (yet often used …)



Support and articulation – Bearing layout examples

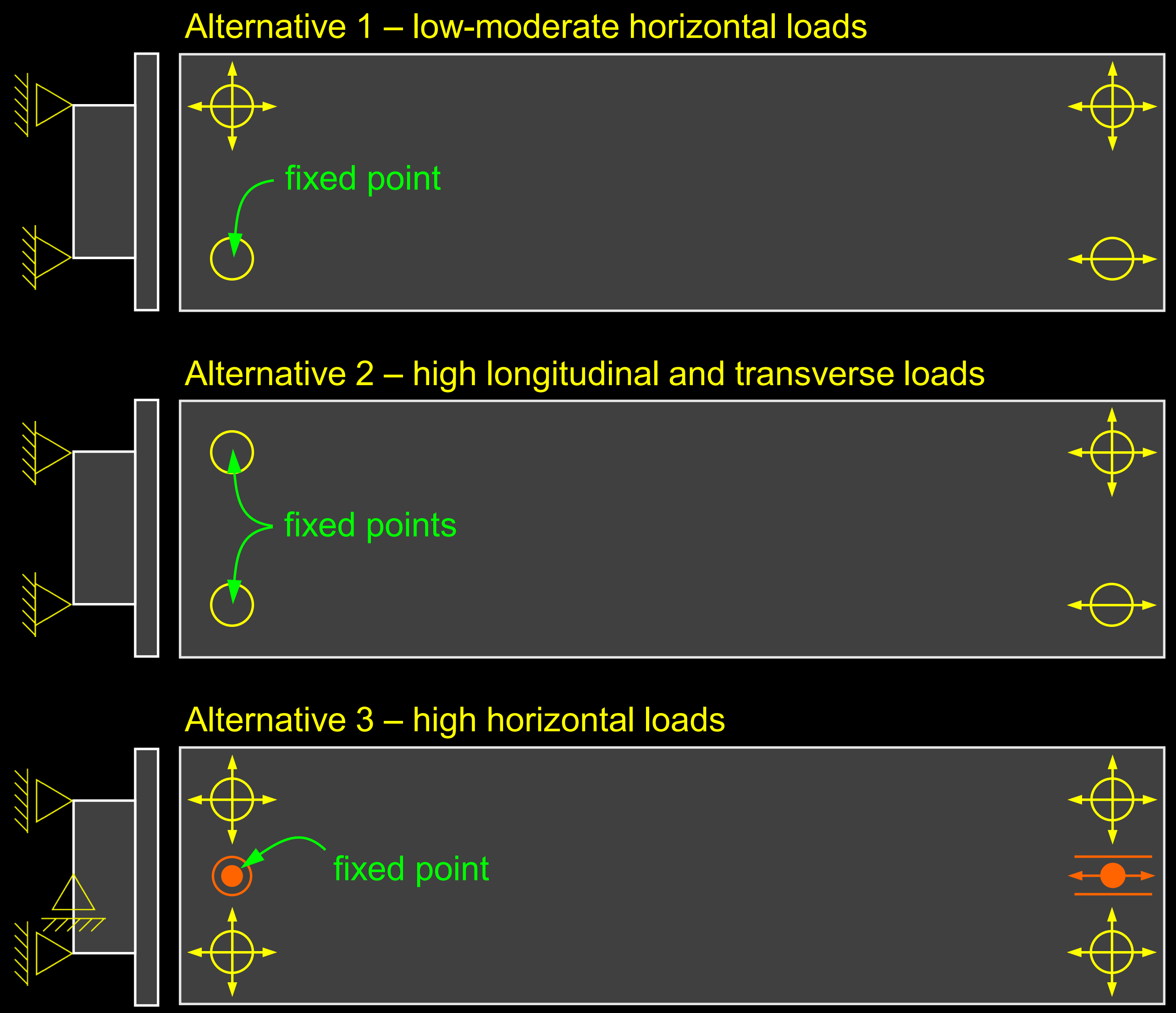
Examples: Simply supported girder

The figure shows three alternatives to the «obvious» solution on the previous slides:

(1) longitudinal fixity provided by one bearing at left abutment, transverse fixity by one bearing per abutment
→ statically determinate horizontal support
→ limited capacity for longitudinal forces

(2) Longitudinal and transverse fixity provided by two bearings on left abutment, transverse fixity by one bearing on right abutment
→ higher capacity for longitudinal forces
→ frame action in transverse direction to be considered at left abutment (higher transverse reactions)

(3) horizontal fixity provided entirely by separate guide bearings
→ suitable for high horizontal forces even for small vertical reactions (e.g. due to torsion)
→ more expensive



Support and articulation – Bearing layout examples

Examples: Continuous girder

Stiff twin piers or stems with movable bearings

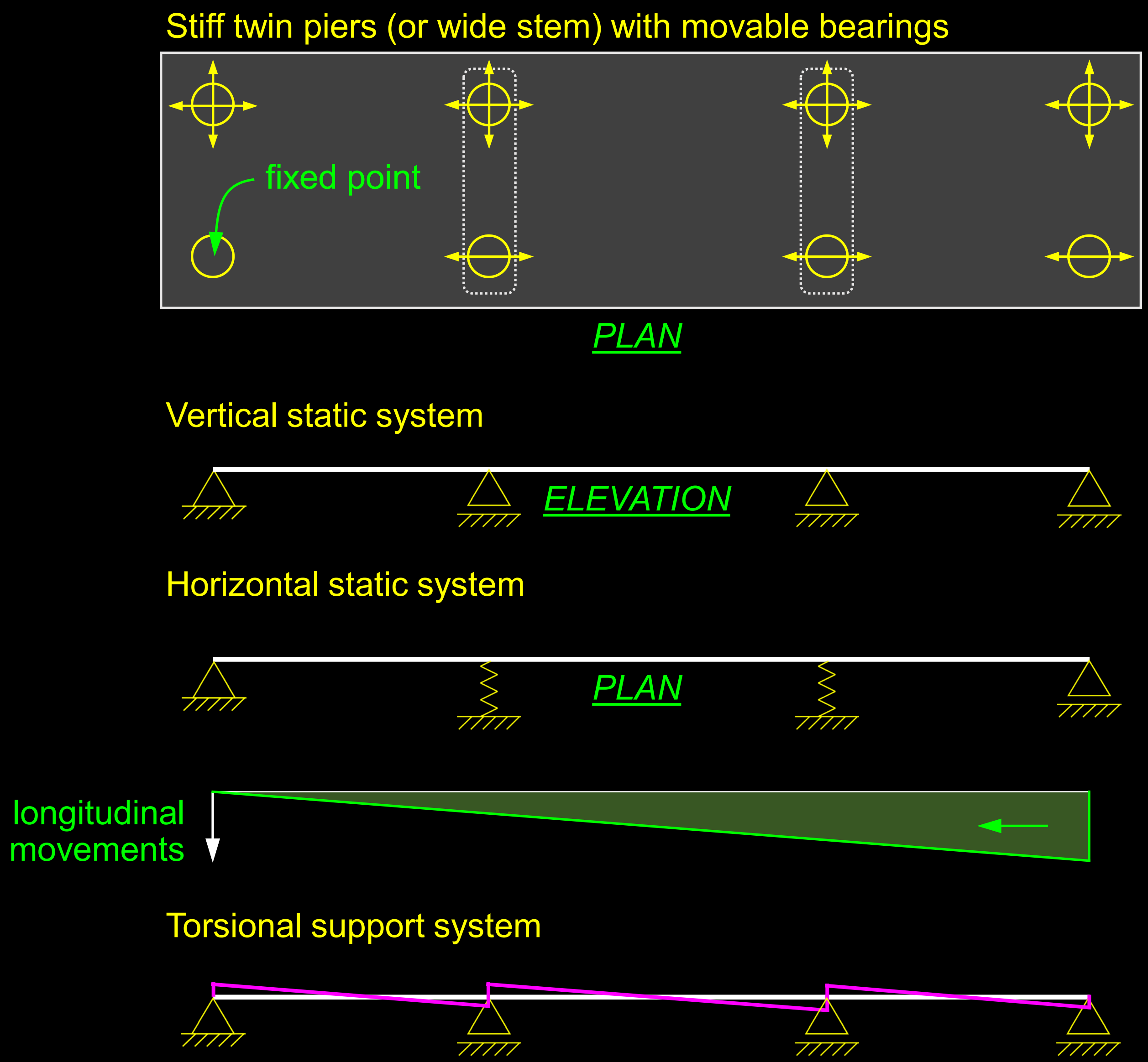
In continuous girders, longitudinal fixity may be provided by the piers or at an abutment.

The figure shows a solution for a girder supported on bearings positioned on top of stiff twin piers (or stems):

- longitudinal fixity provided at left abutment
- transverse fixity provided by one bearing per vertical support axis
- torsional support provided at abutments and piers

→ feasible solution, advantages / weak points:

… many bearings
… many stiff piers or massive stems
… large movements to be accommodated at right abutment
… short torsion span



Support and articulation – Bearing layout examples

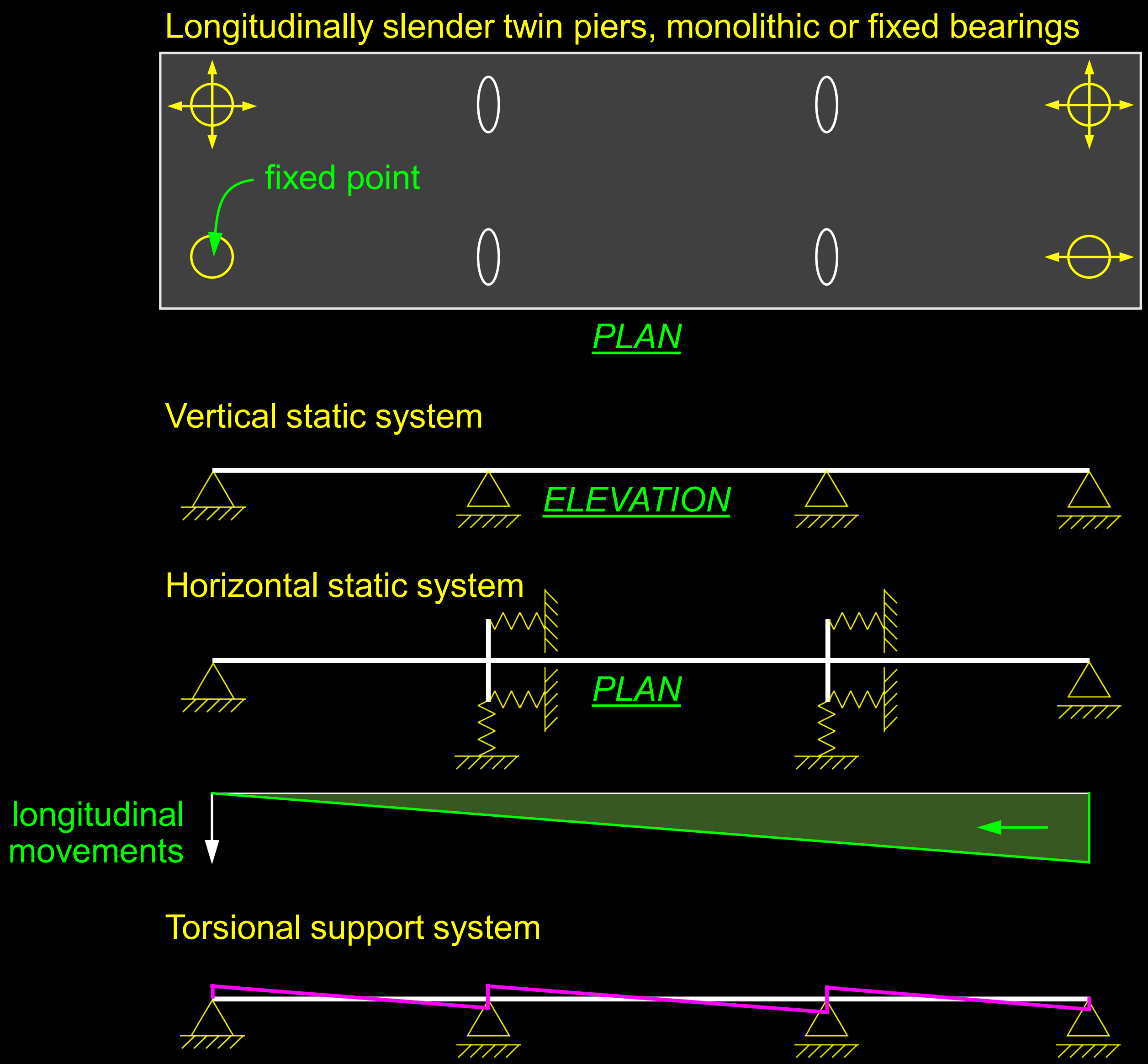
Examples: Continuous girder

Longitudinally slender twin piers, monolithic connection or fixed bearings

The figure shows a solution for a girder supported on slender twin piers, monolithically connected to the girder (or via fixed bearings / concrete hinges)

- longitudinal fixity provided at left abutment
- small longitudinal restraint (pier stiffness)
- transverse fixity provided by piers and one bearing per abutment
- torsional support provided at abutments and piers

→ feasible solution, advantages / weak points:
… bearings only at abutments
… many piers (but slender)
… large movements to be accommodated at right abutment
… short torsion span



Support and articulation – Bearing layout examples

Examples: Continuous girder

Twin piers longitudinally stabilising the girder

The figure shows a solution for a girder supported on twin piers, monolithically connected to the girder (or through fixed bearings / concrete hinges)

- longitudinal fixity provided by piers
- small longitudinal restraint (pier stiffness)
- transverse fixity provided by piers and one bearing per abutment
- torsional support provided at abutments and piers

→ feasible solution, advantages / weak points:

… bearings only at abutments

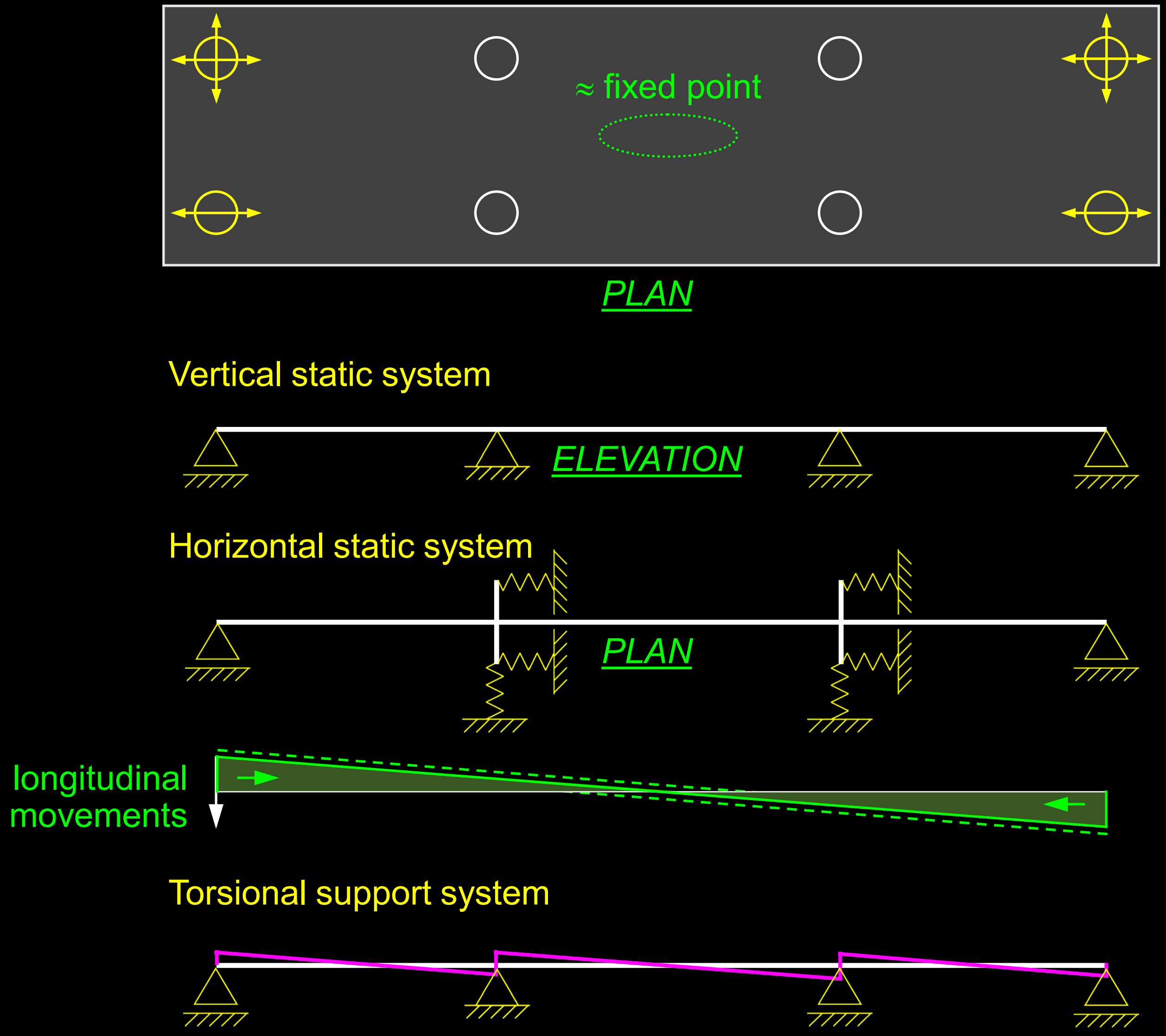
… many piers with higher demand on foundation

… movements split among abutments

… short torsion span

… uncertainty in position of fixed points

Twin piers, monolithic (or fixed bearings) – *flexible system*



Support and articulation – Bearing layout examples

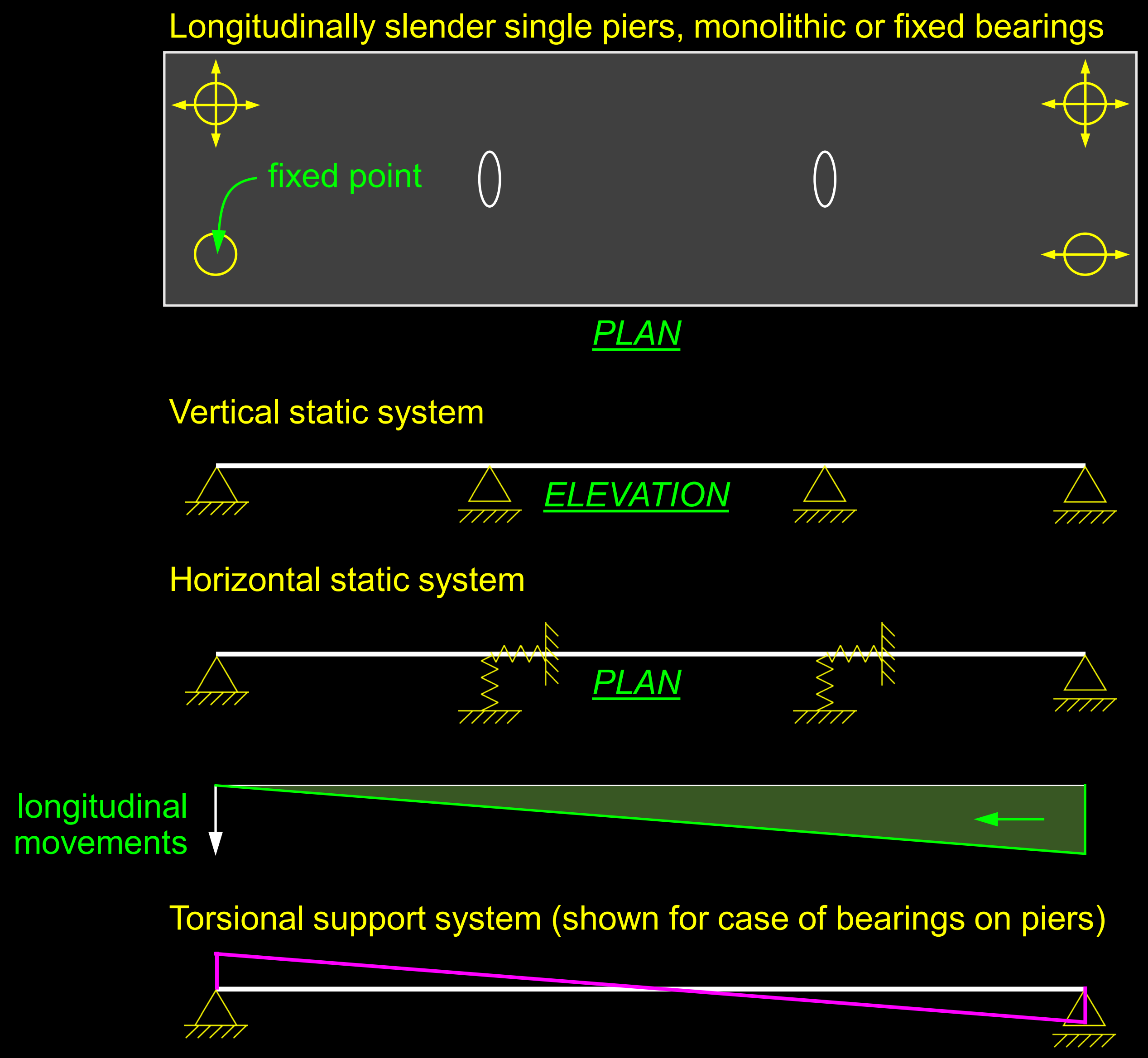
Examples: Continuous girder

Longitudinally slender single piers, monolithic connection or fixed bearings

The figure shows a solution for a girder supported on longitudinally slender single piers, monolithically connected to the girder (or via fixed bearings / concrete hinges)

- longitudinal fixity provided at left abutment
- small longitudinal restraint (pier stiffness)
- transverse fixity provided by piers and one bearing per abutment
- torsional support provided at abutments, plus transverse frame action (see notes)

→ feasible solution, advantages / weak points:
… bearings only at abutments
… few piers, elegant solution
… large movements at right abutment
… long torsion span → risk of uplift at abutments (see next slides)



Support and articulation – Bearing layout examples

Examples: Continuous girder

Single piers longitudinally stabilising the girder

The figure shows a solution for a girder supported on single piers, monolithically connected to the girder (or via fixed bearings / concrete hinges)

- longitudinal fixity provided by piers
- small longitudinal restraint (pier stiffness)
- transverse fixity provided by piers and one bearing per abutment
- torsional support provided at abutments only (plus transverse frame action, see notes)

→ feasible solution, advantages / weak points:

… bearings only at abutments

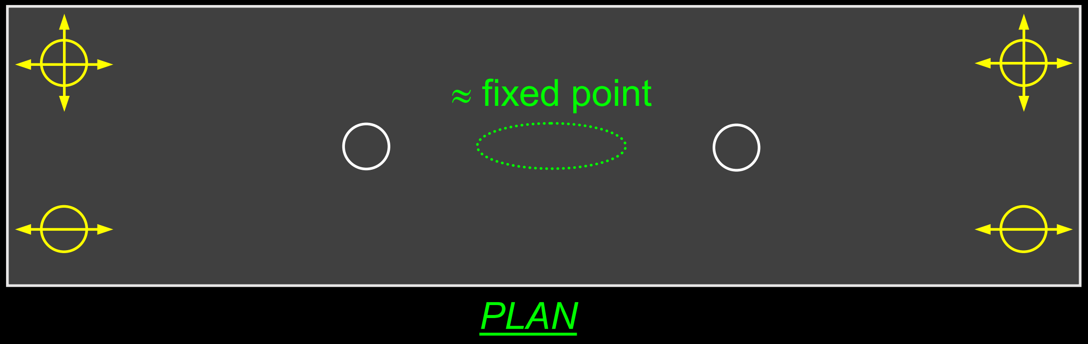
… few piers, elegant solution but
higher demand on pier foundations

… movements split among abutments

… uncertainty in position of fixed points

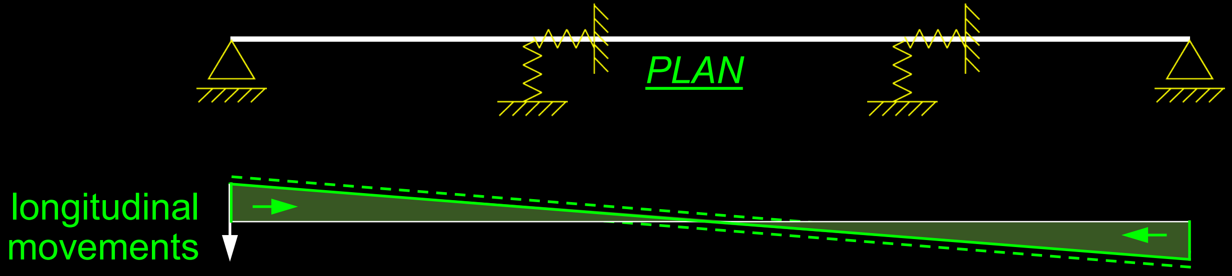
… long torsion span → risk of uplift at
abutments (see next slides)

Single piers, monolithic or fixed bearings

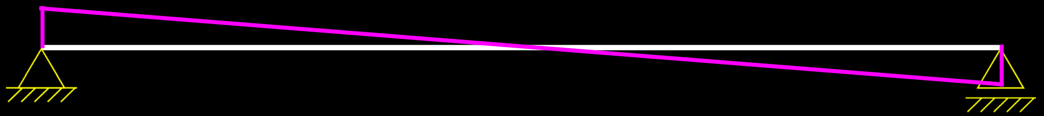


Vertical static system

Horizontal static system



Torsional support system (shown for case of bearings on piers)



Support and articulation – Bearing layout examples

Support and articulation – Bearing layout examples

Examples: Continuous girder

If single piers are used, torsional moments at the abutments are higher and hence uplift may occur

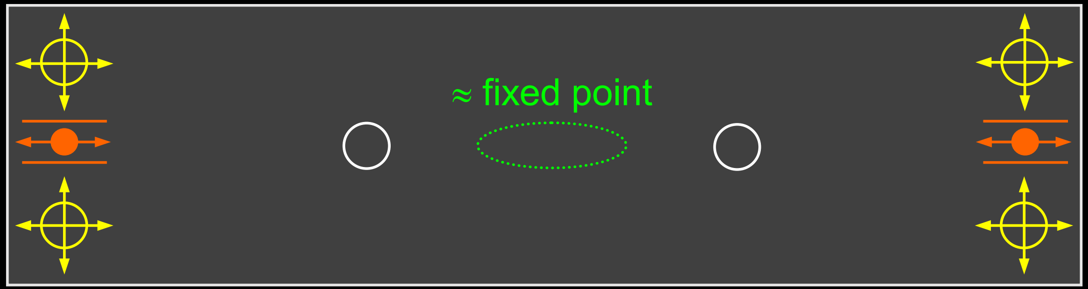
→ avoid if possible by changing the bearing layout, see «basic principles for choice of bearing layout» for options)

- even without uplift, the vertical support reactions may not be sufficient to transfer horizontal loads with conventional bearings

→ guide bearings may be required, as illustrated in the figures on the slide

Longitudinally slender single piers, monolithic or fixed bearings

Single piers, monolithic or fixed bearings



Horizontal static system (same as without guide bearings)

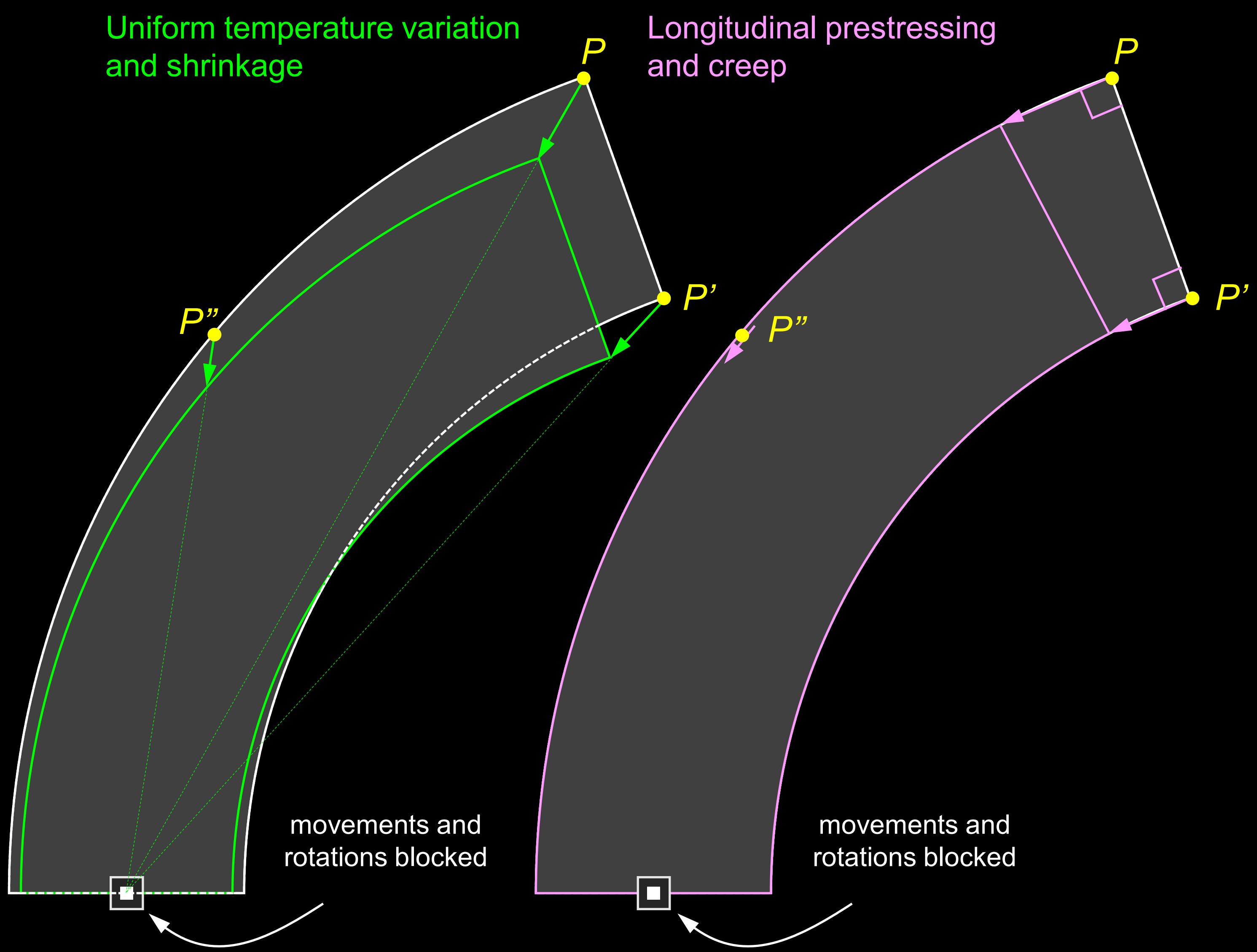
Support and articulation – Curved bridge kinematics

Examples: Curved bridges (kinematics)

Two types of girder deformations occur:

- longitudinal prestressing and creep
  → axial deformation
  → girder shortens along ist axis
  → radius of curvature remains unchanged
  → tangential movements at opposite bridge end
- uniform temperature variation and shrinkage
  → uniform (3D) deformation
  → girder is «scaled»
  → radius of curvature changes
  → “radial” movements in direction of fixed point

In straight bridges, the direction of these movements (nearly) coincide. In strongly curved bridges, the differences are significant.



Support and articulation – Curved bridge kinematics

Examples: Curved bridges (kinematics)

By allowing a rotation around the fixed point (usually at one abutment), it is possible to obtain the same direction of movement, due to

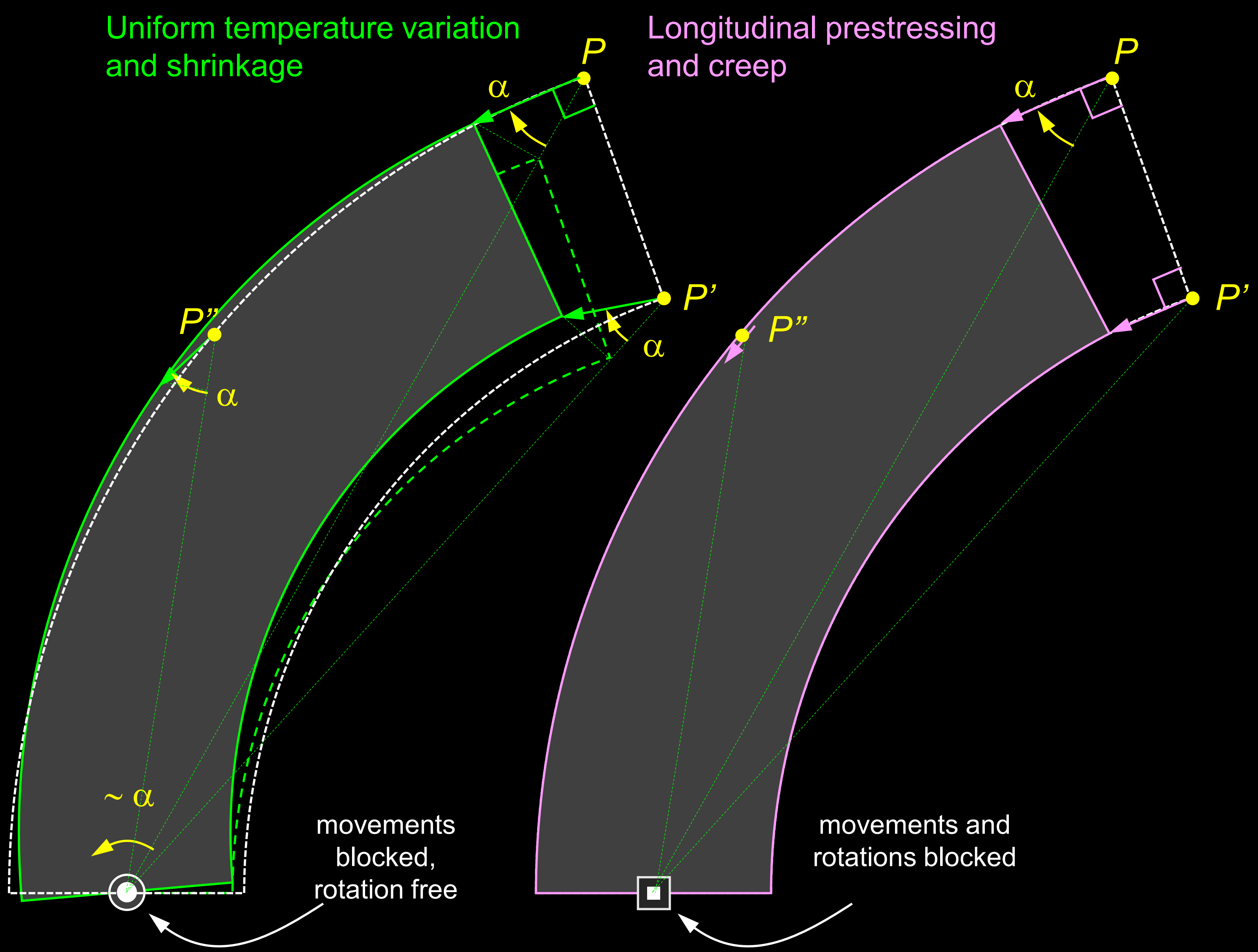
- temperature and shrinkage and
- longitudinal prestressing and creep

for one specific point *P* of a curved girder. Typically, the point P is chosen at a uniaxial sliding bearing at the opposite abutment, moving tangentially to the girder axis (standard expansion joint width can be used), see figure on the right.

All other points (e.g. P', P'') still move in different directions due to temperature and shrinkage and longitudinal prestressing and creep, respectively.

→ only one uniaxially movable bearing (other than the fixed point) possible for horizontally restraint-free support of curved bridges

→ corresponds to isostatic support in plan



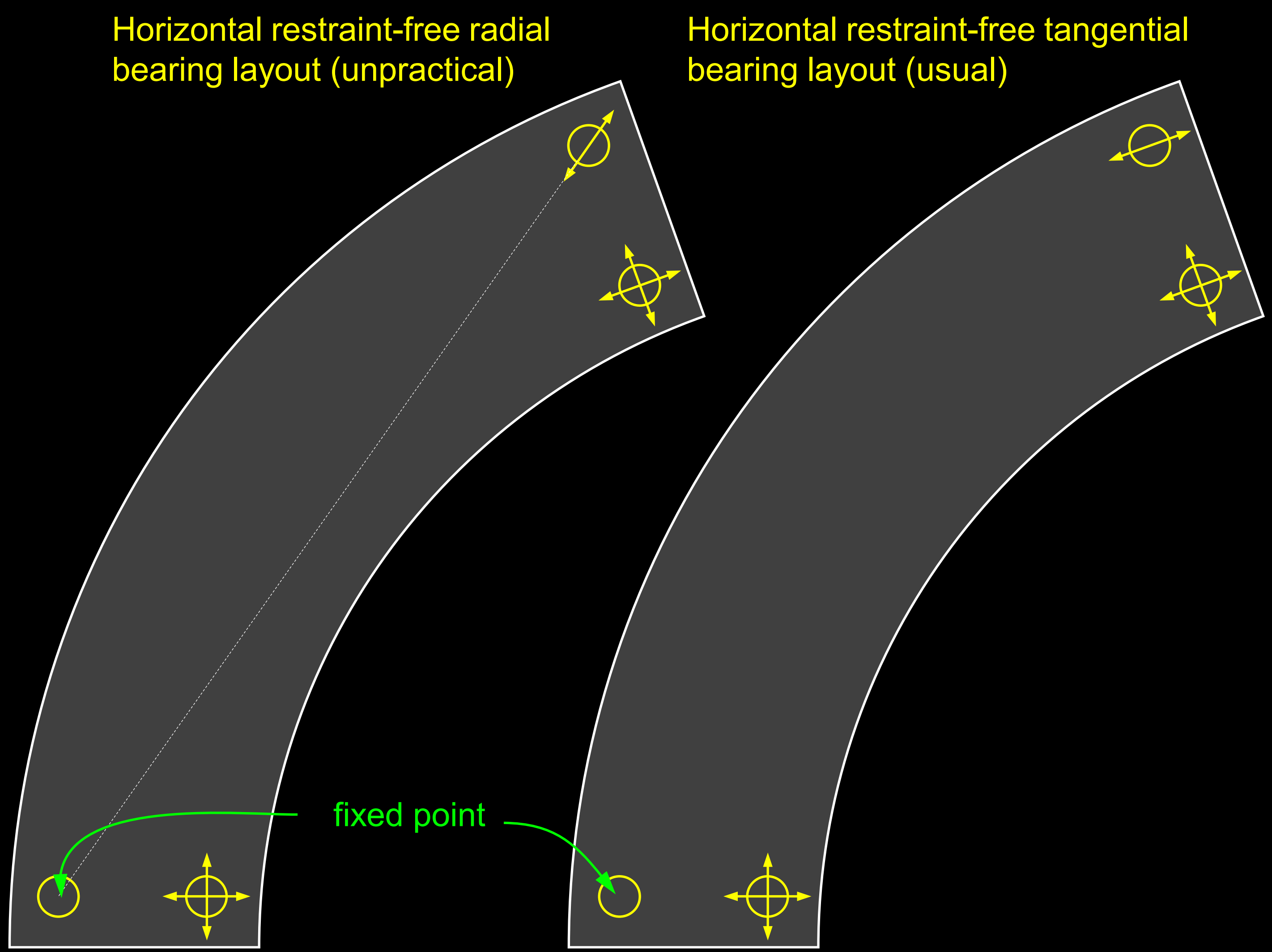
Support and articulation – Bearing layout examples

Examples: Curved simply supported girder

In simply supported curved bridges, horizontal fixity must be provided at an abutment:

- at the other abutment, a tangential bearing layout is preferable (standard expansion joint)
- horizontally fixed bearings are preferably positioned at the outside (larger support reaction)

Regarding longitudinal and transverse fixity see straight simply supported bridges (slide with possible alternatives 1-3).



Support and articulation – Bearing layout examples

Examples: Curved simply supported girder

Strongly curved bridges accommodate girder deformations by radial movements (see integral bridges)

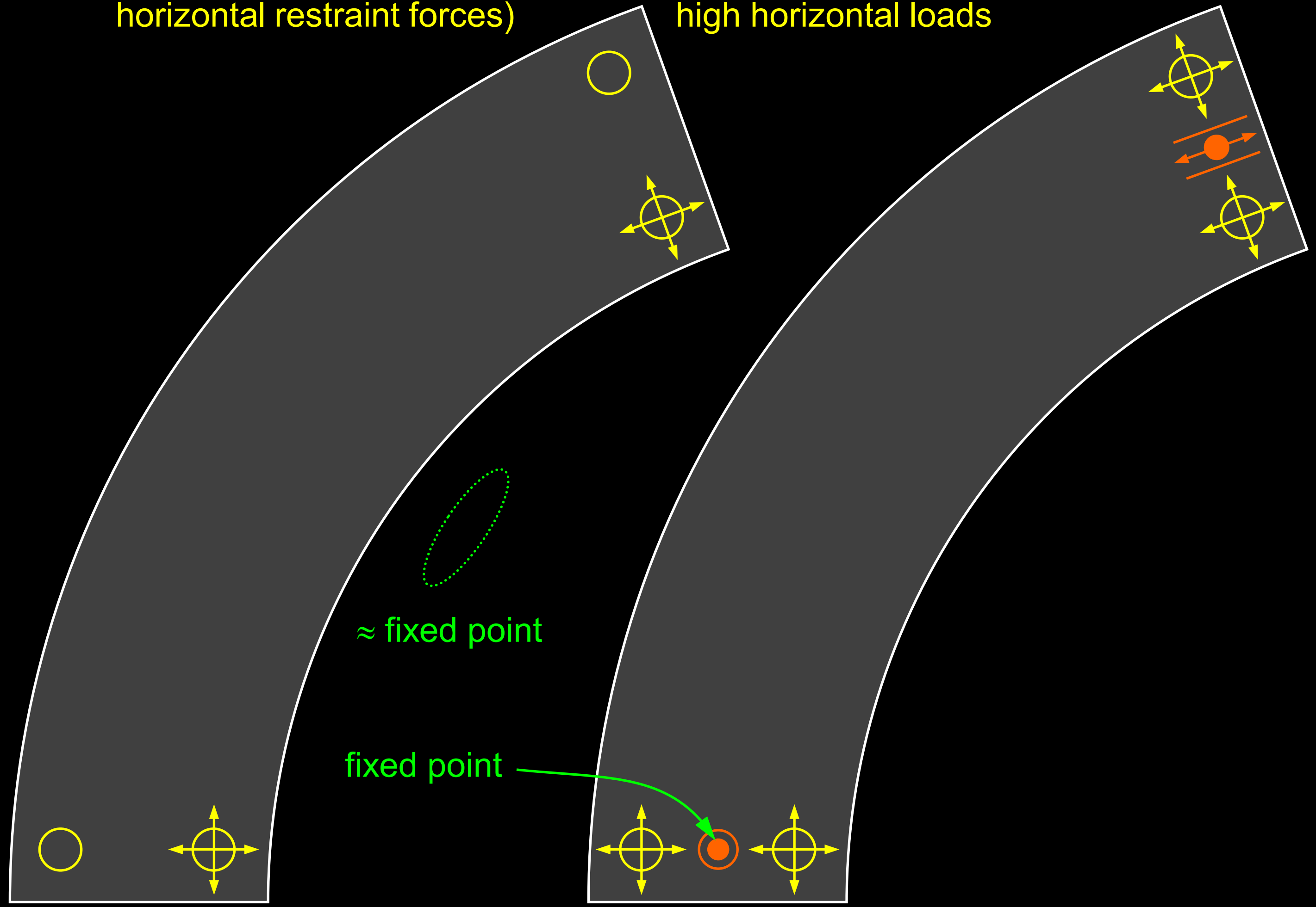
→ longitudinally fixed bearings at both abutments is often possible, with only small restraint forces

→ but preferably use integral abutments (see integral bridges) if this applies

If the vertical reactions are small, and/or the horizontal forces are large, guide bearings may be required, see also straight simply supported bridges

Bearing layout for strongly curved bridges (causing small horizontal restraint forces)

Horizontal restraint-free bearing layout for small vertical reactions / high horizontal loads



Support and articulation – Bearing layout examples

Examples: Curved continuous girder

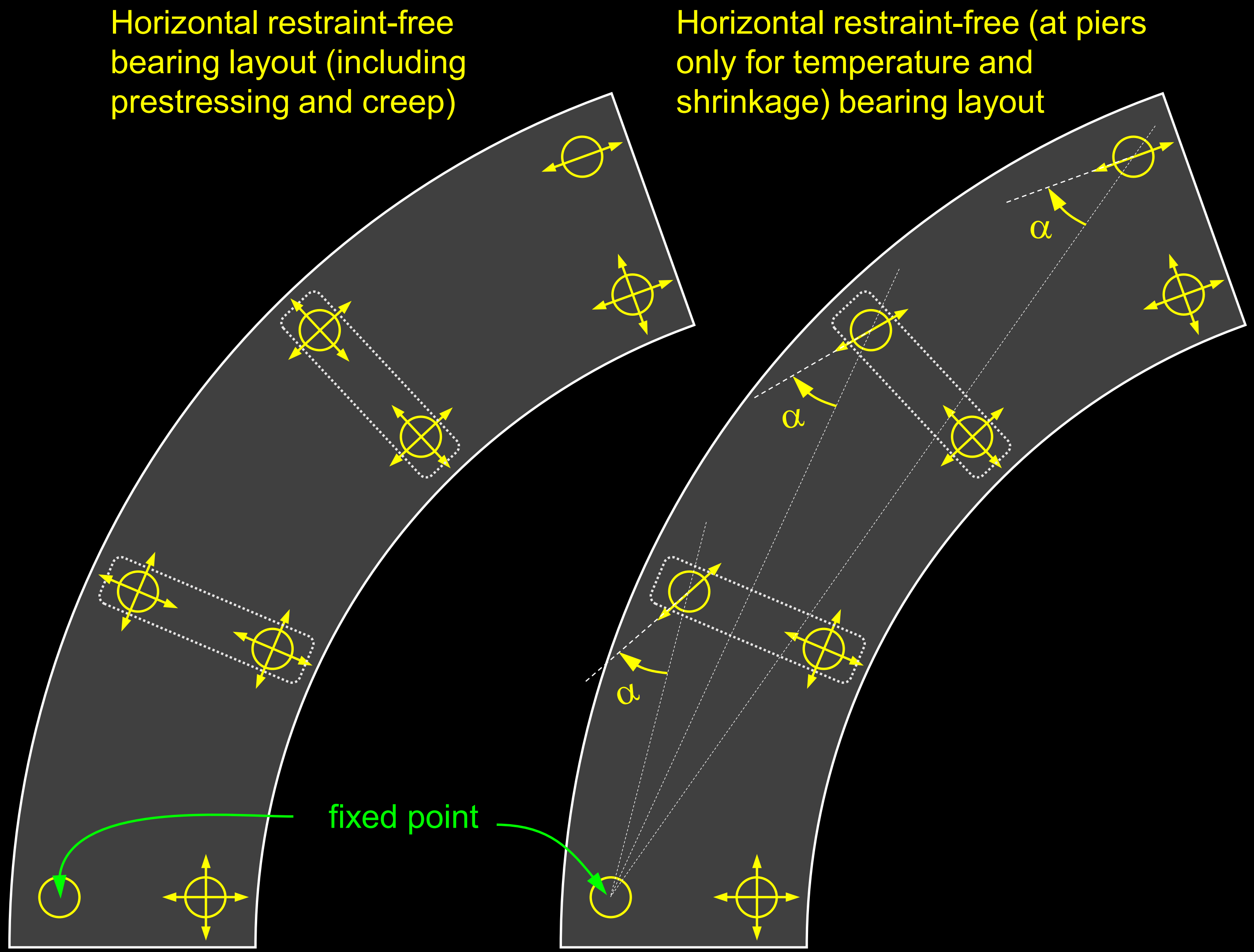
Stiff twin piers or stems with movable bearings

Basically, the bearing layouts outlined on the previous slides for straight continuous girders may also be used in curved girders.

Here, only the particularities of curved girders are highlighted.

The bearing layouts shown in the figure on this slide are horizontally restraint-free for

- general girder deformations (left)
  (all transverse horizontal loads need to be resisted at abutments, large reactions → guide bearings may be required)
- temperature and shrinkage only (right)
  (suitable for steel and composite bridges, restraint caused by prestressing and creep, pier stiffness in direction transverse to movement direction)



Support and articulation – Bearing layout examples

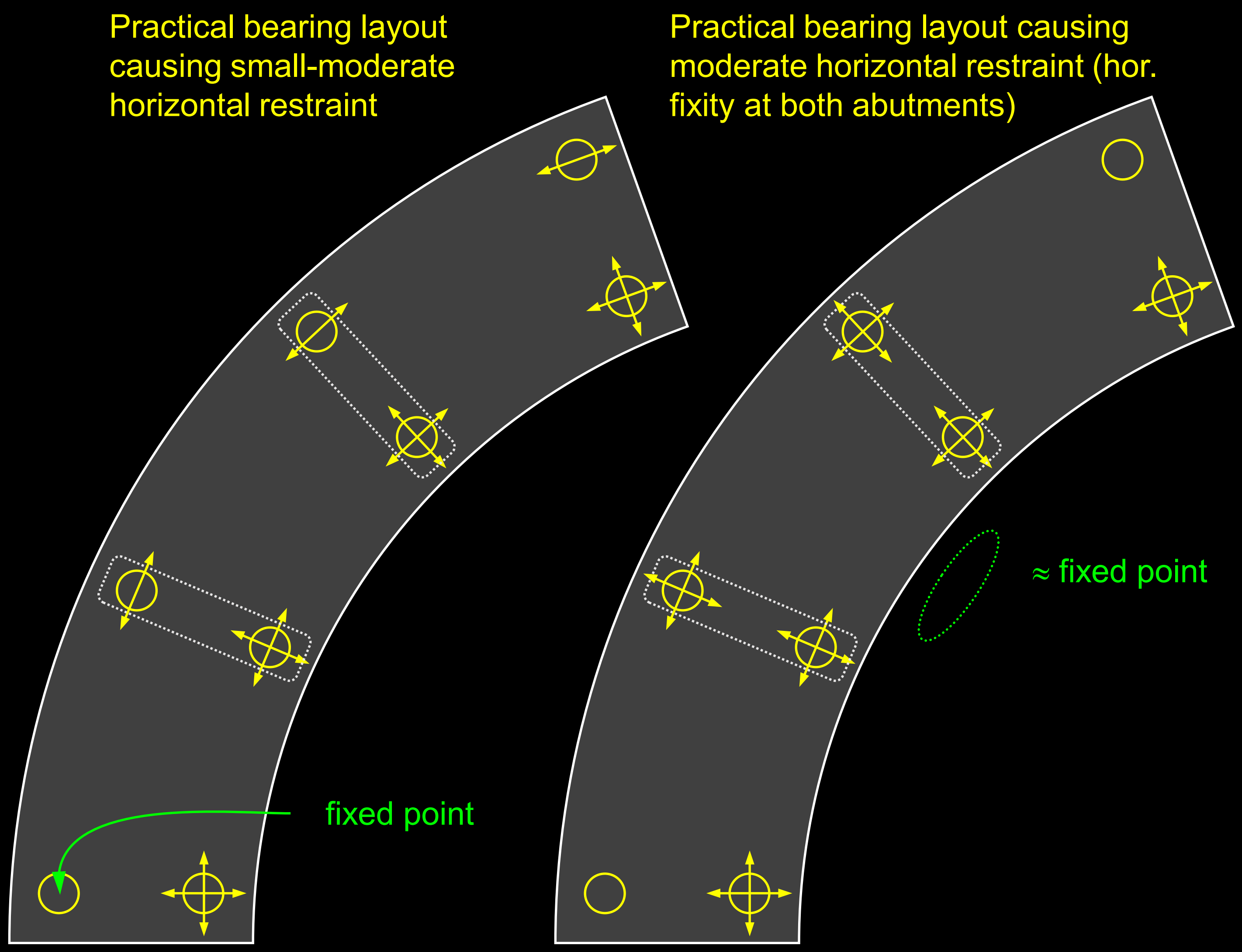
Examples: Curved continuous girder

Stiff twin piers or stems with movable bearings

Often, it is more practical to accept moderate restraint forces and align the bearings to the girder axis (left figure, restraint caused by temperature and shrinkage, transverse pier stiffness).

As for simply supported curved girders, longitudinal fixity at both abutments is often possible without causing excessive restraint, see integral bridges (right figure; note that if stiff stems are used, sliding bearings are required to enable radial movement of the girder).

As a reminder, bearings resisting horizontal loads are positioned on the outside where vertical reactions are higher.



Support and articulation – Bearing layout examples

Examples: Curved continuous girder

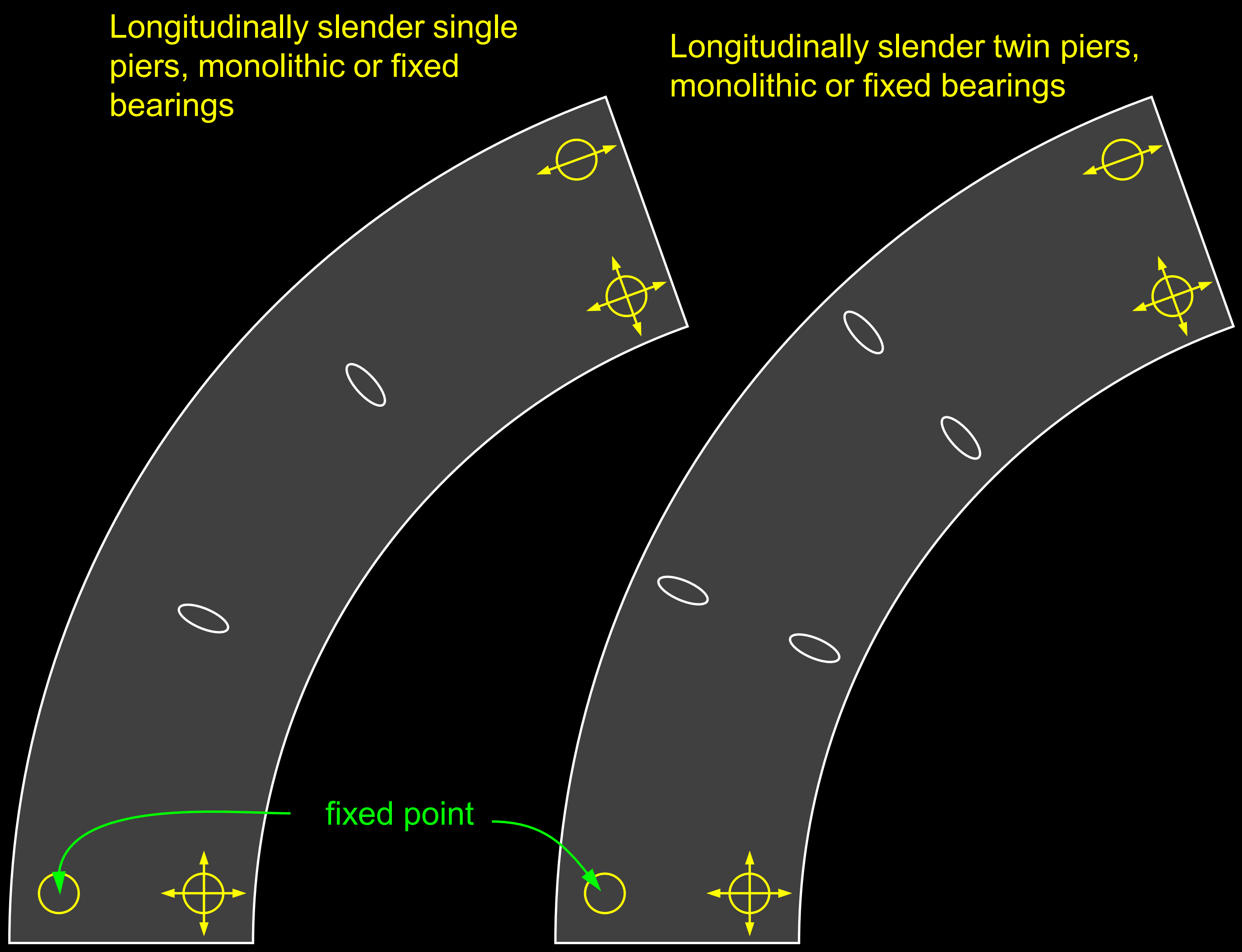
Monolithically connected slender piers, fixed point at abutment

As for straight continuous girders, small restraint forces caused by monolithically (or via fixed bearings or concrete hinges) connected piers can often be accepted.

On this slide, solutions with a fixed bearing at an abutment are shown. Providing longitudinal fixity (see previous slide) at both abutments would also be possible here.

Compared to straight bridges, uplift is more likely due to the curvature in plan, particularly in the single piers solution ($\rightarrow$ guide bearings)

Further advantages and drawbacks see straight girders.



Support and articulation – Bearing layout examples

Examples: Curved continuous girder

Monolithically connected piers longitudinally stabilising the girder

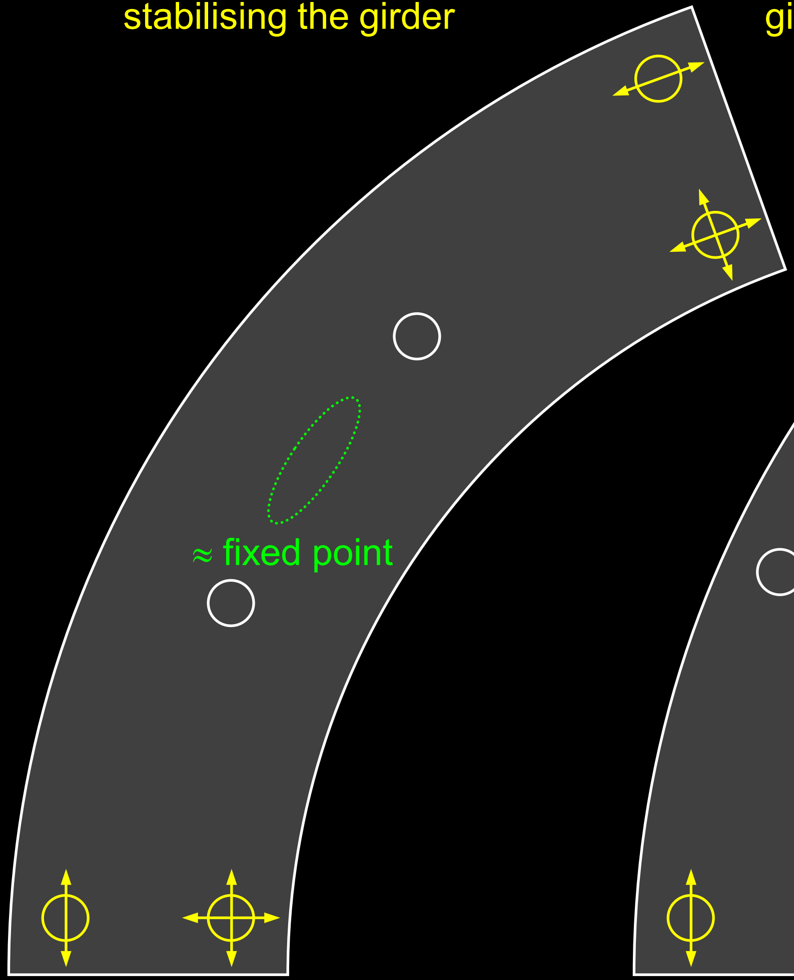
As for straight continuous girders, small restraint forces caused by monolithically (or via fixed bearings or concrete hinges) connected piers can often be accepted.

On this slide, solutions where the piers provide longitudinal fixity are shown.

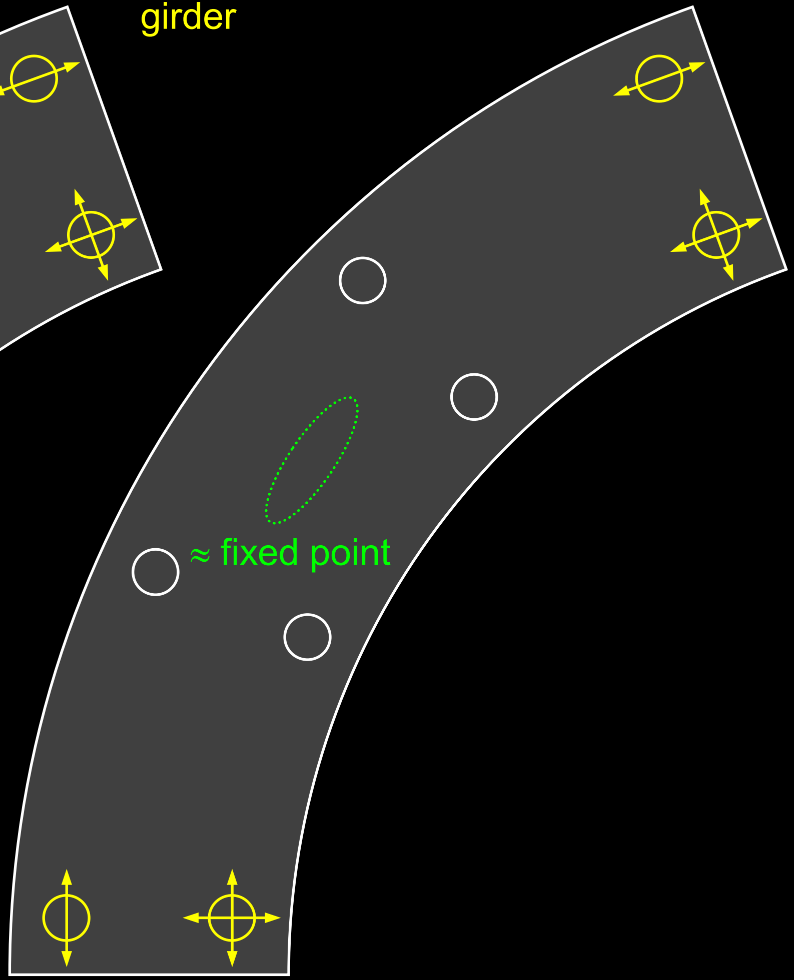
Compared to straight bridges, uplift is more likely due to the curvature in plan, particularly in the single piers solution ($\rightarrow$ guide bearings)

Further advantages and drawbacks see straight girders.

Single monolithically connected piers longitudinally stabilising the girder



Twin monolithically connected piers longitudinally stabilising the girder



Support and articulation – Bearing layout examples

Examples: Curved continuous girder

Designers sometimes hesitate to use single piers in curved bridges since they anticipate that

- due to the longer torsional span (compared to twin pier support layouts)
- the torques M_y/r caused by curvature
- will result in ~~disproportional torsional moments~~

However, in a continuous girder, the positive and negative torques (caused by positive and negative bending moments) largely compensate, such that only little torsion is resisted by piers providing torsional support anyway. Solutions with single piers are therefore perfectly feasible in long curved bridges.

Further details see curved bridges.