

Part 01. Structural System

- Form Active -

Dr. Ho-Kyung Kim

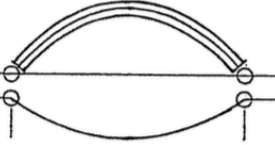
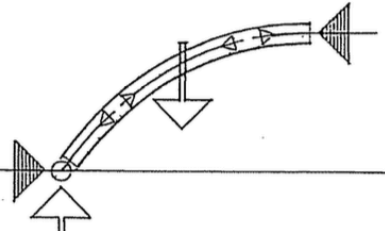
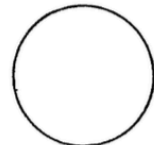
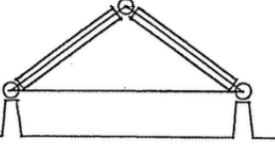
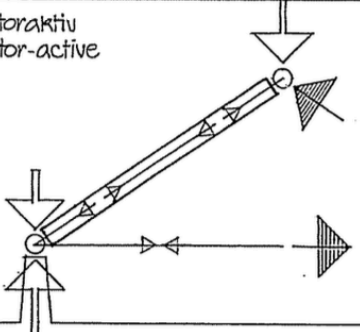
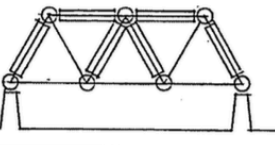
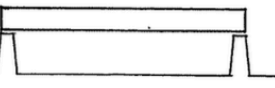
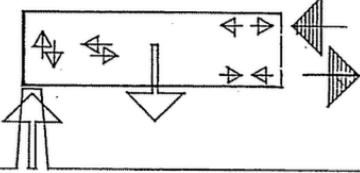
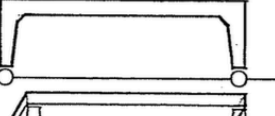
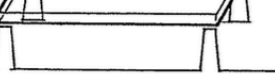
Structural Design Laboratory (SDL)

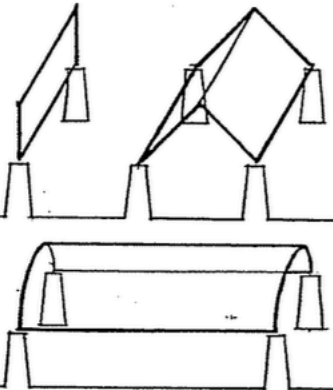
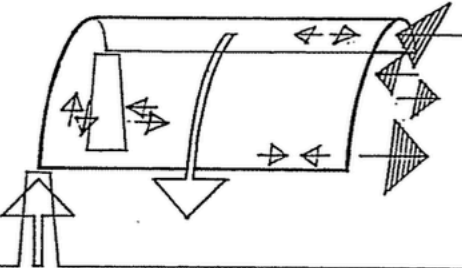
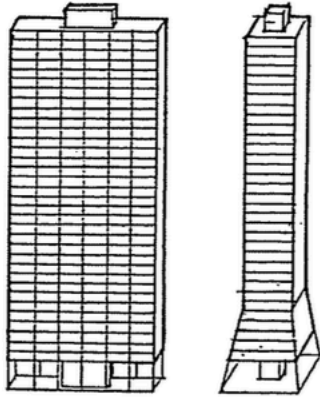
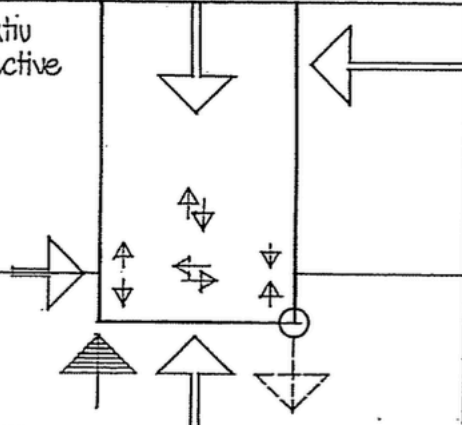
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Seoul National University



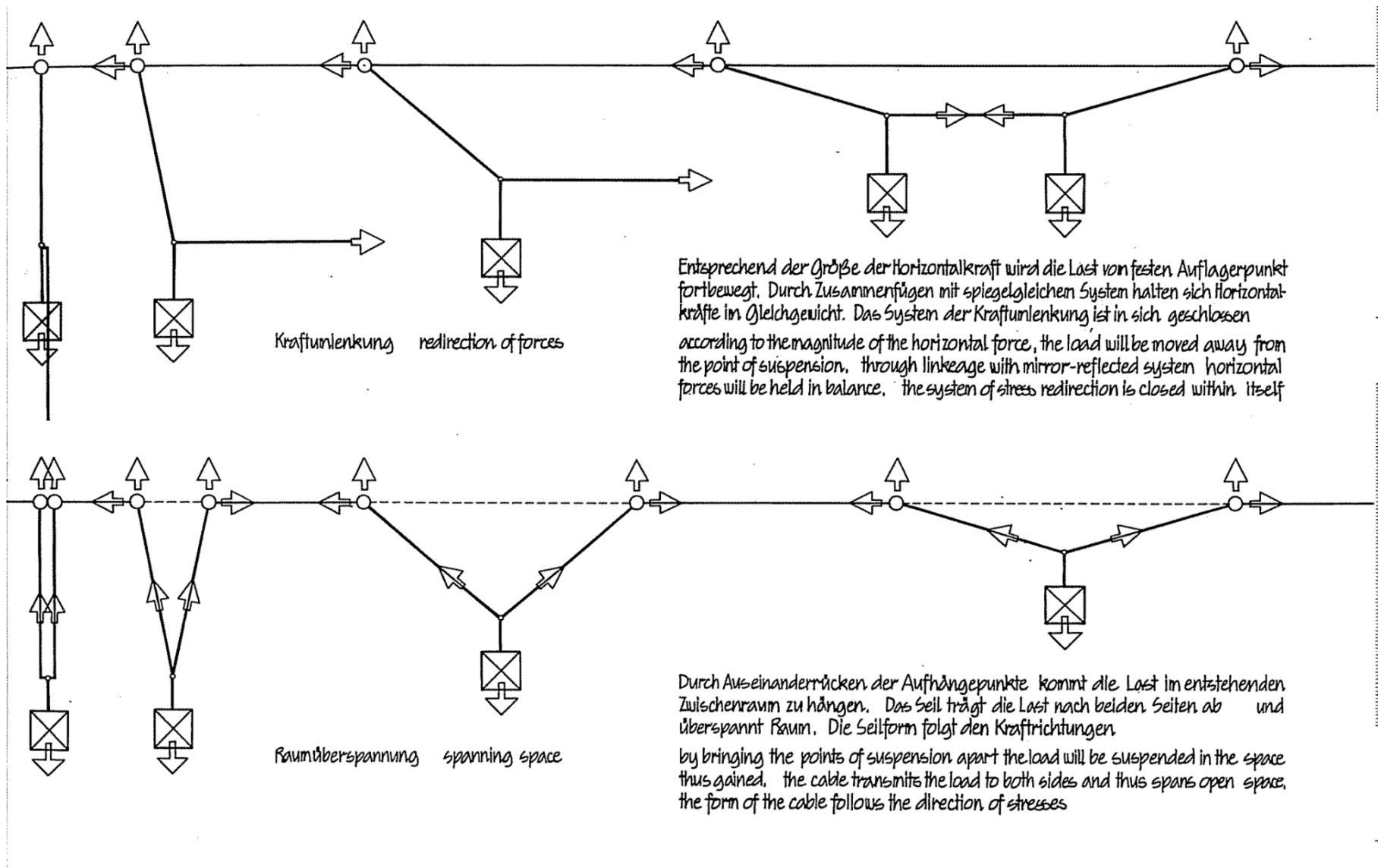
CLASSIFICATION OF STRUCTURE SYSTEMS IN INFRASTRUCTURES AND BUILDINGS (1/2)

Kriterium Criterion		Prototyp prototype	Kräfte forces	Merkmal feature	Mechanik der Kraftumlenkung mechanics of redirection of forces
1	FORM	 Stützbogen funicular arch Hängeseil suspension cable	Druck oder Zug compression or tension	Stützlinie thrust line	 formaktiv form-active
		 Kreisring circular ring Ballon balloon		Kettenlinie catenary Kreis circle	
2	VEKTOR VECTOR	 Dreiecksträger triangular truss	Druck und Zug compression and tension	Dreieck- verband	 vektoraktiv vector-active
		 Fachwerkträger trussed beam		triangu- lation	
3	QUER- SCHNITT CROSS SECTION	 Balken beam	Biegung Schnittkräfte bending section forces	Querschnitt- profil	 schnittaktiv section-active
		 Rahmen frame  Platte flat slab		sectional profile	

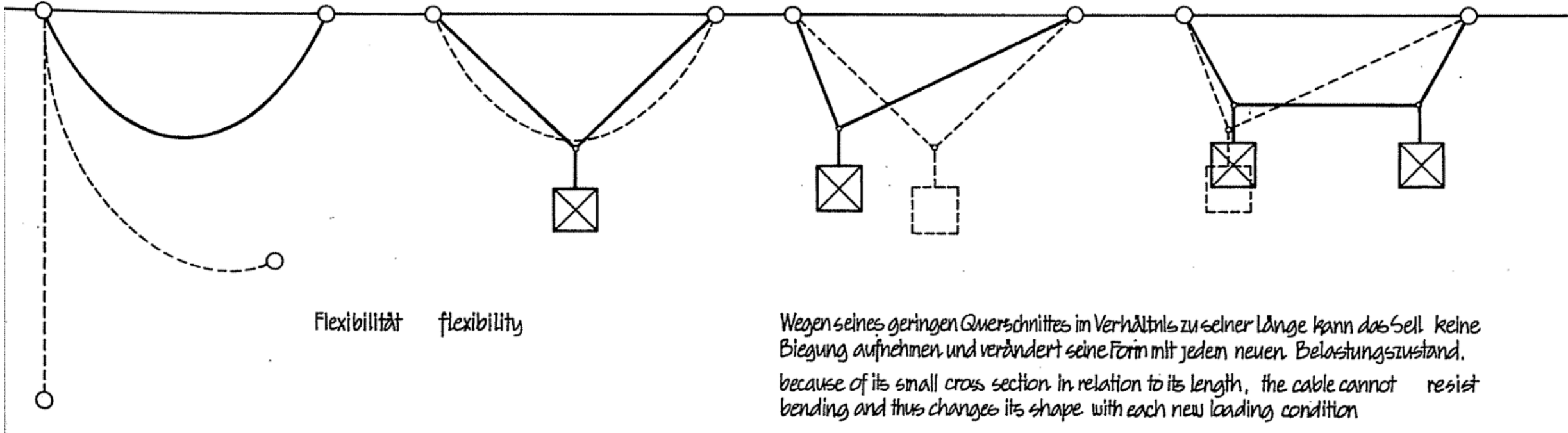
4	FLÄCHE SURFACE	 <p>Scheibe plate</p> <p>gefaltete Platte folded slab</p> <p>Zylinderschale cylindrical shell</p>	Membran- kräfte membrane stresses	Flächen form surface shape	flächenaktiv surface-active 
5	HÖHE HEIGHT	 <p>Scheibe slab</p> <p>Turn tower</p>	(Komplexe Be- dingungen) (complex conditions)	Lasten- Erdung Stabili- sierung load grounding stabilization	höhenaktiv height-active 

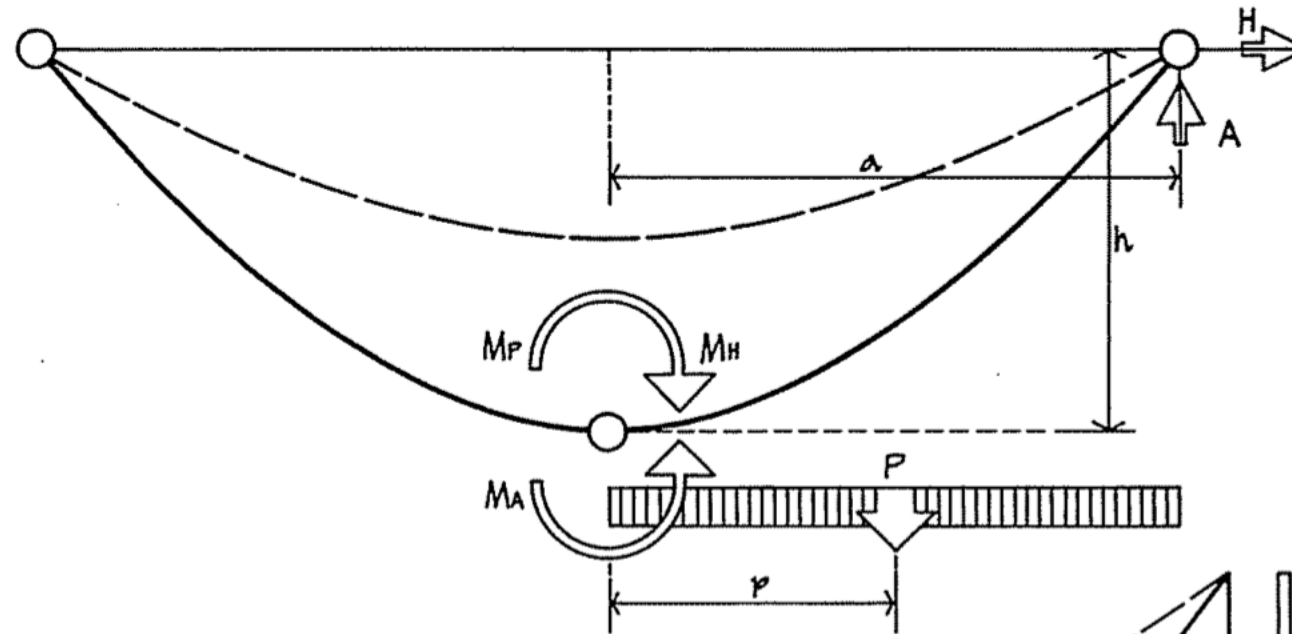
- ▶ Non-rigid, flexible matter, shaped in a certain way and secured by fixed ends, can support itself and span space: form-active structural system.
- ▶ Distinction of the form-active structure systems then is that they redirect external forces by simple normal stresses: the arch by compression, the suspension cable by tension.
- ▶ The structure form of form-active structure systems in the ideal case coincides precisely with the flow of stresses. Form-active structure systems therefore are the 'natural' path of forces expressed in matter.
- ▶ Any change of loading or support conditions changes the form of the funicular curve and causes a new structure form. While the load cable as a 'sagging' system under new loads assumes by itself a new tension line, the arch as a 'humping' system must compensate the changed pressure line with stiffness (bending mechanism).
- ▶ Because of their identity with the 'natural' flow of forces the form-active structure systems are the suitable mechanisms for achieving long spans and forming large spaces.

RELATIONSHIP BETWEEN STRESS DIRECTION AND STRUCTURE FROM OF CABLE (1/2)

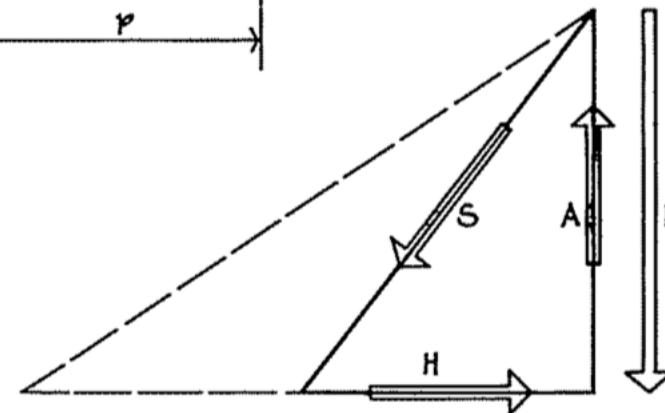


RELATIONSHIP BETWEEN STRESS DIRECTION AND STRUCTURE FROM OF CABLE (2/2)

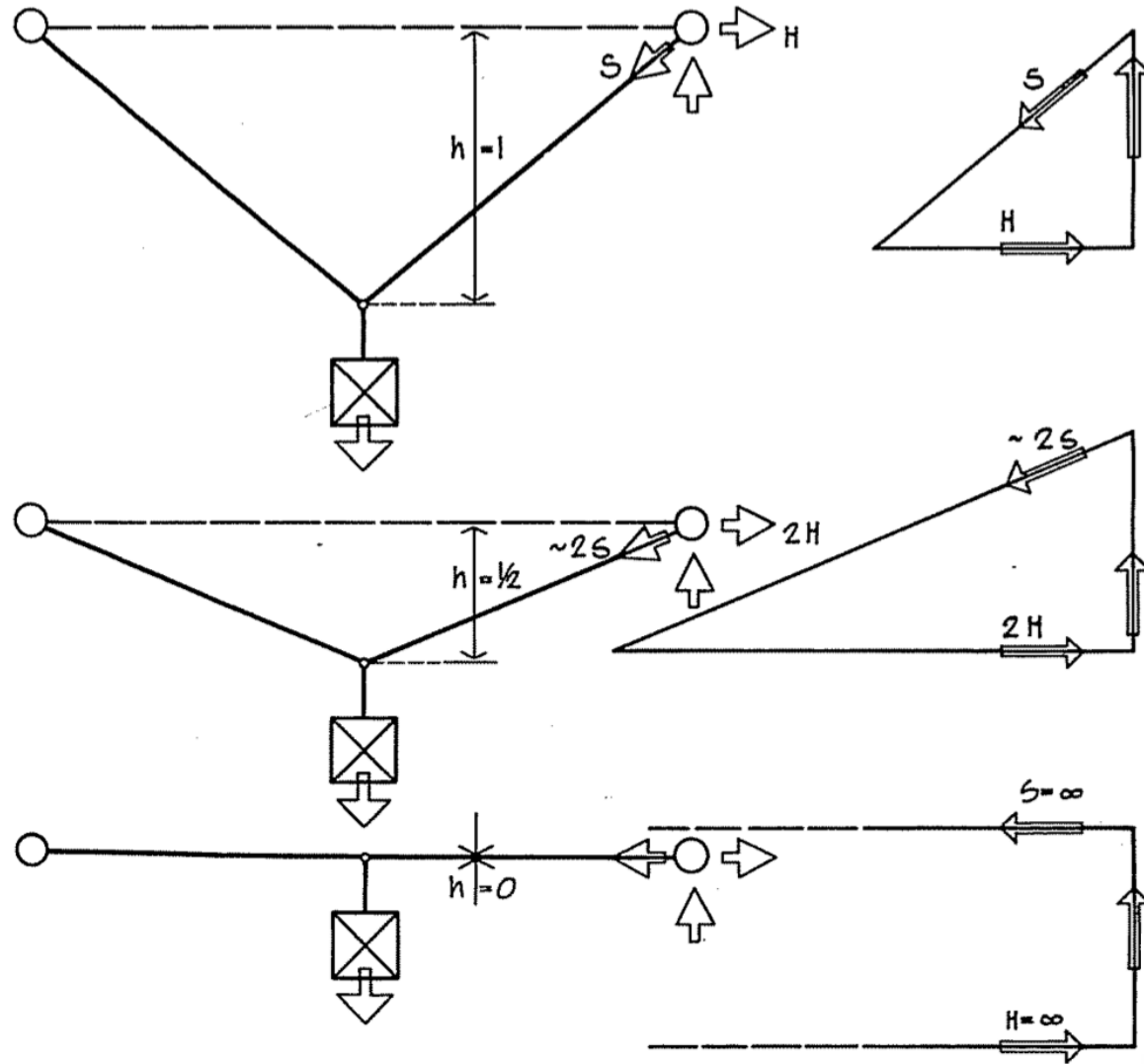




Durch das Moment der Horizontalreaktion M_H wird der Unterschied der Momente M_P und M_A ausgeglichen und Biegung ausgeschlossen
 due to the moment of horizontal reaction M_H the disparity of the moments M_P and M_A is compensated and bending is eliminated

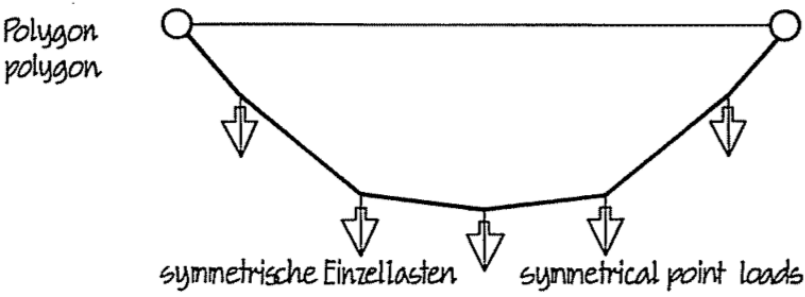
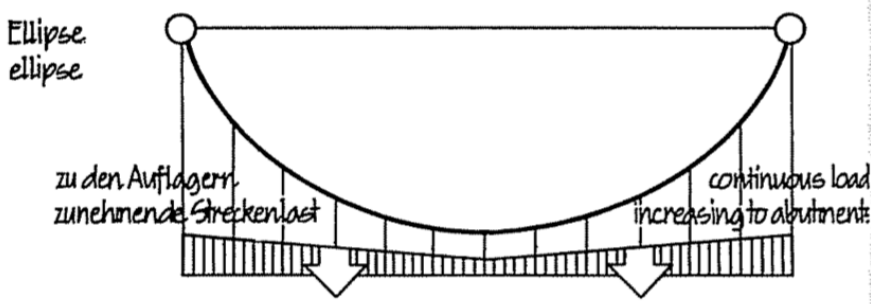
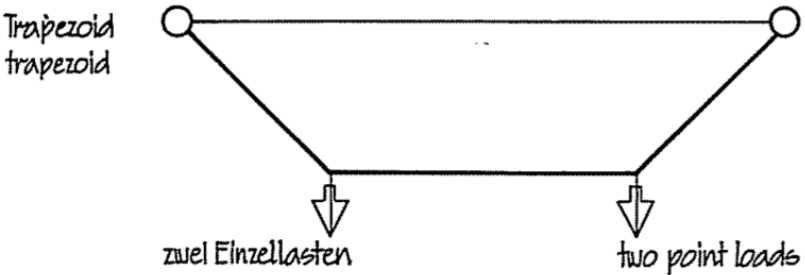
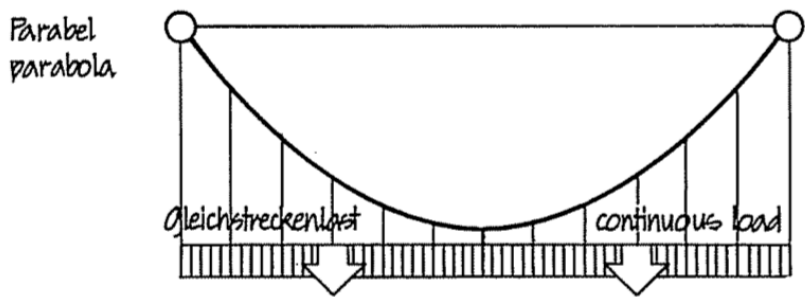
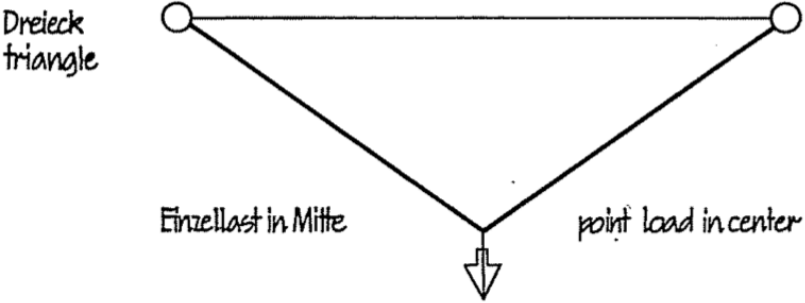
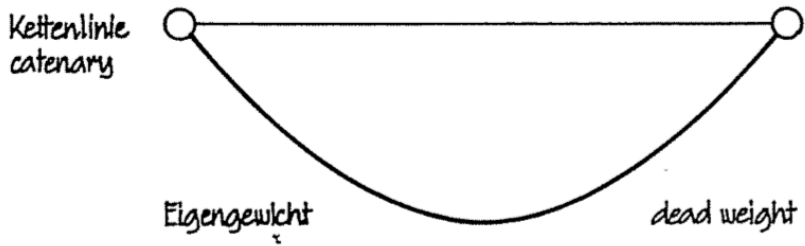


INFLUENCE OF SAG ON STRESS DISTRIBUTION

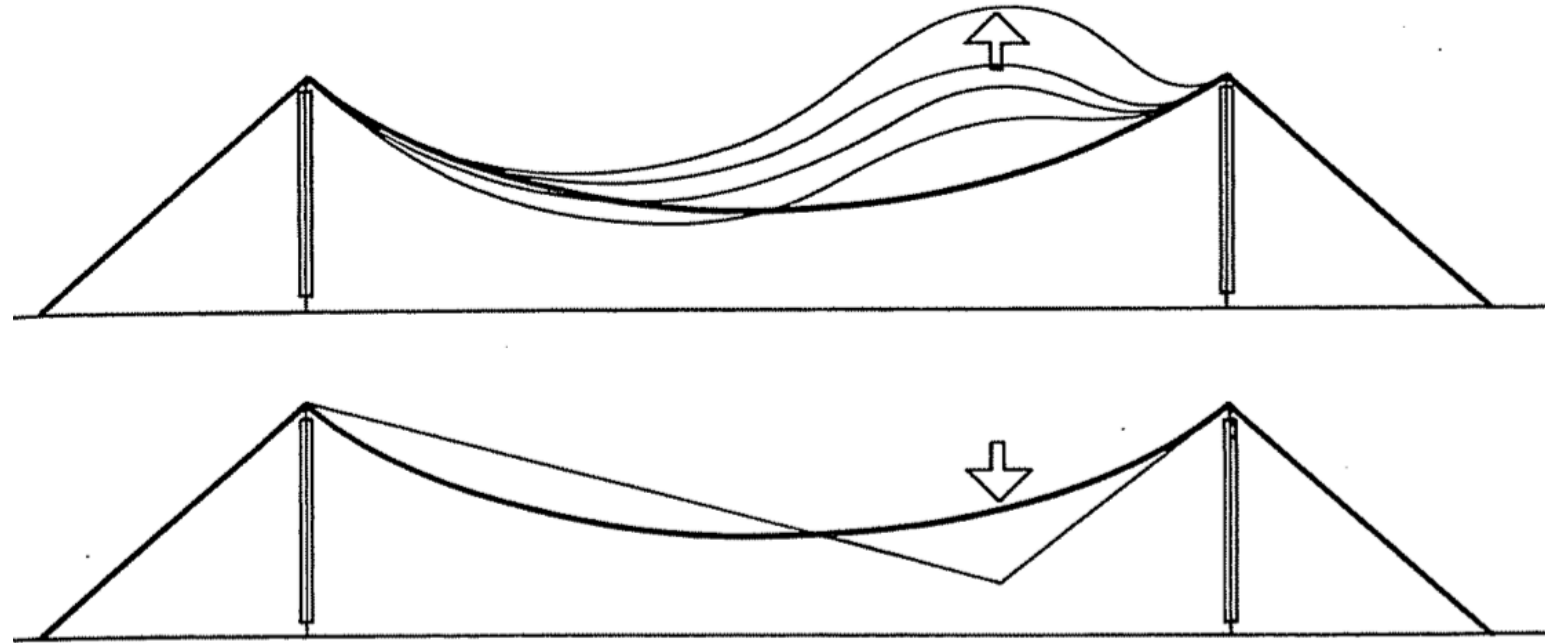


cable stress S and horizontal thrust H of a suspension cable are inversely proportional to its sag h . if the sag is zero, cable stress and horizontal thrust will become infinite, i.e. the suspension cable cannot resist to the load

GEOMETRIC FUNICULAR FORMS

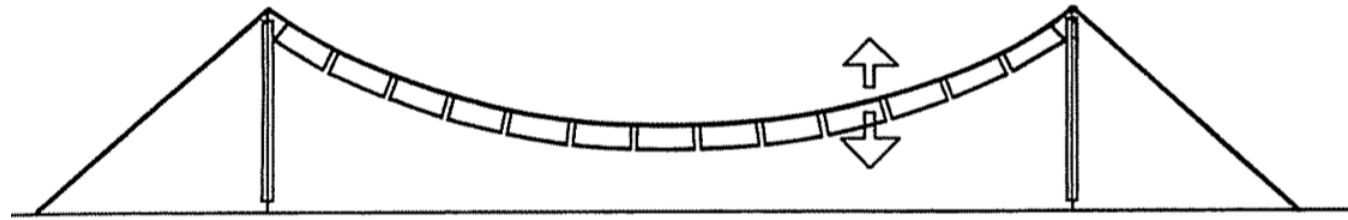


CRITICAL DEFLECTIONS OF THE SUSPENSION CABLE



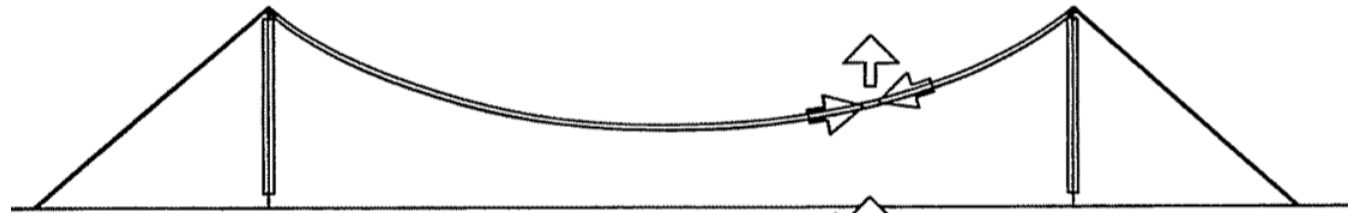
due to its small dead weight in relation to its span and because of its flexibility, the suspension cable is very susceptible to: wind uplift, vibrations, asymmetrical and moving loads

STABILIZATION OF SUSPENSION CABLE

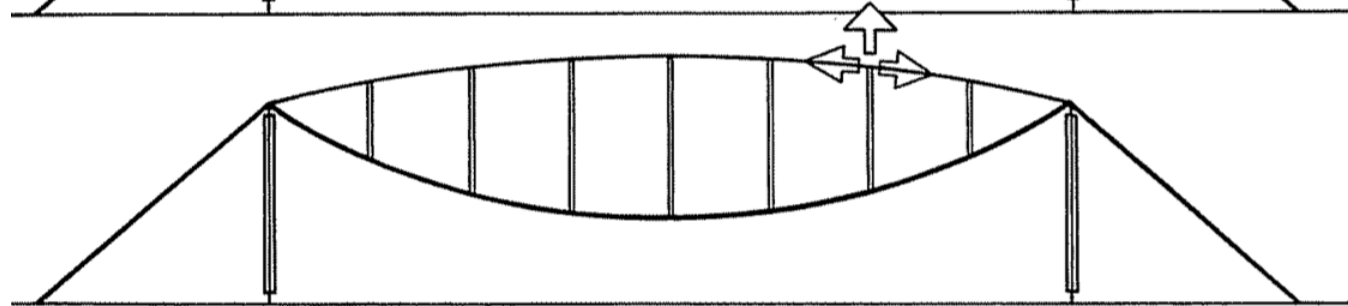


Stabilisierung des Tragsseiles
stabilization of suspension cable

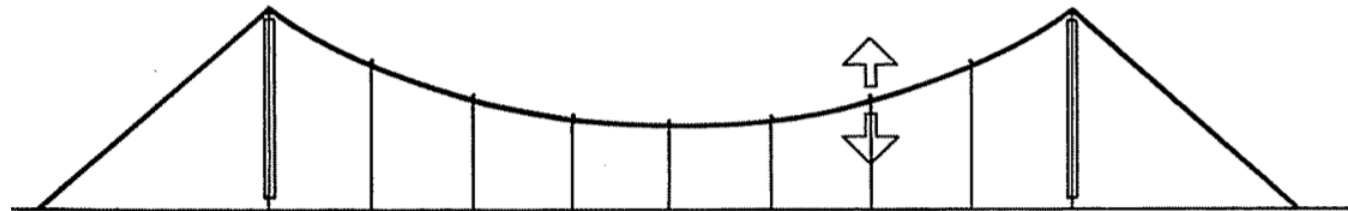
Erhöhung des Eigengewichtes increase of dead weight



stiffening through construction as inverted arch (or shell)
Versteifung durch Ausbildung als umgekehrter Bogen (oder Schale)

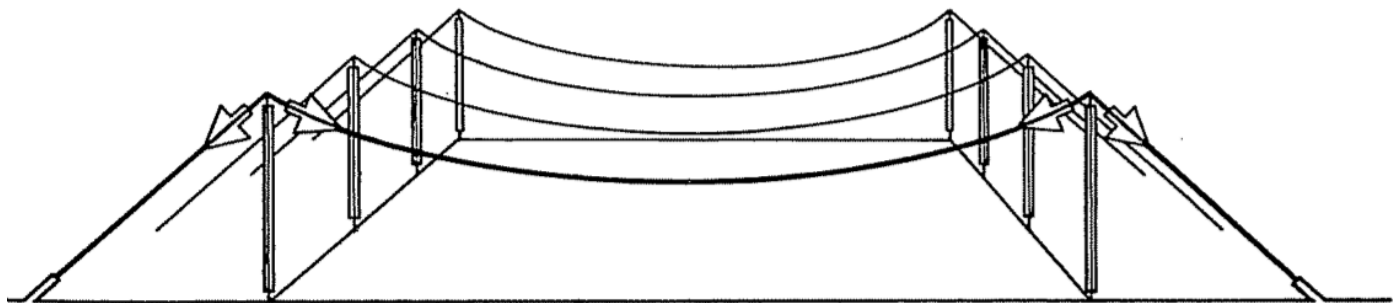


spreading against cable with opposite curvature
Verspannung mit gegensinnig gekrümmten Seil



fastening with transverse cables anchored to ground
Verspannung mit bodenverankerten Querseilen

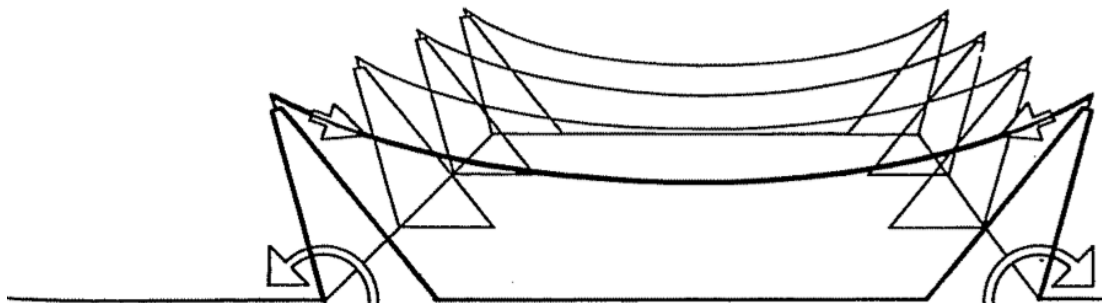
RESTRAINING SYSTEMS FOR PARALLEL SUSPENSION CABLES



Rückhaltesell

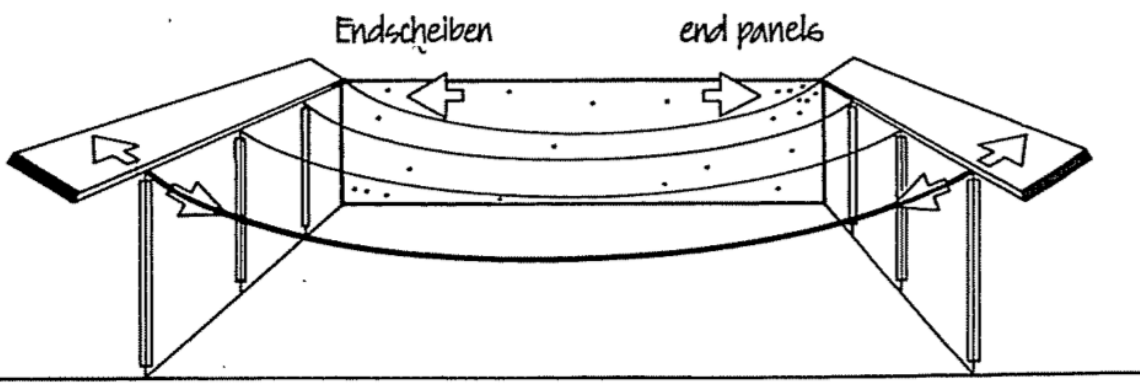
restraining cable

Rückhalte-Systeme für Parallel-Tragseile
Restraining systems for parallel suspension cables



biegesteife Schelbe

buttress



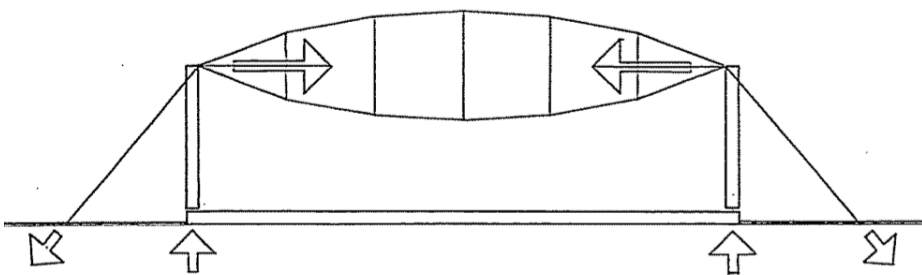
Endscheiben

end panels

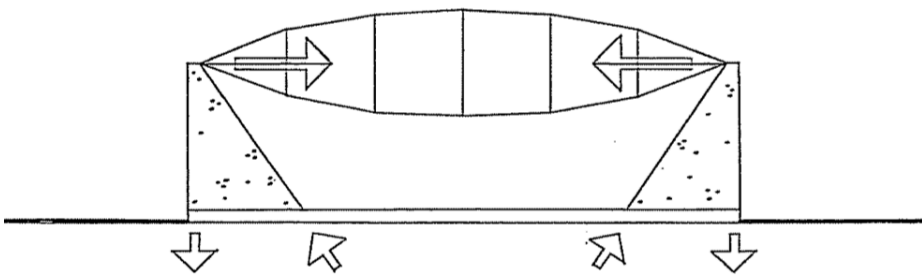
Horizontalträger

horizontal beam

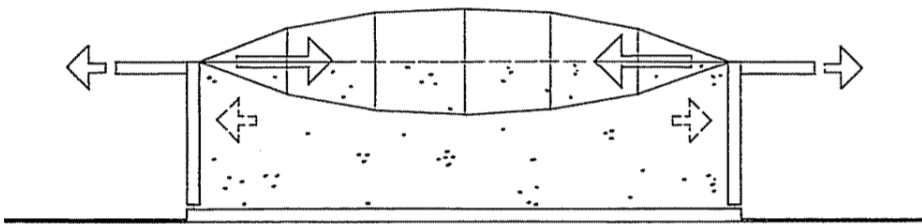
RESTRAINING SYSTEM FOR STABILIZATION OF SUSPENSION POINTS



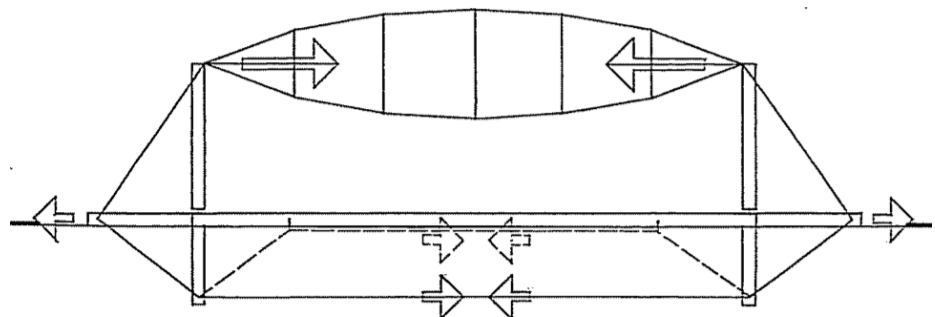
Seilabspannung der Aufhängepunkte mit Endverankerung der Seile
Cable restraining of suspension points with soil anchorage of cables



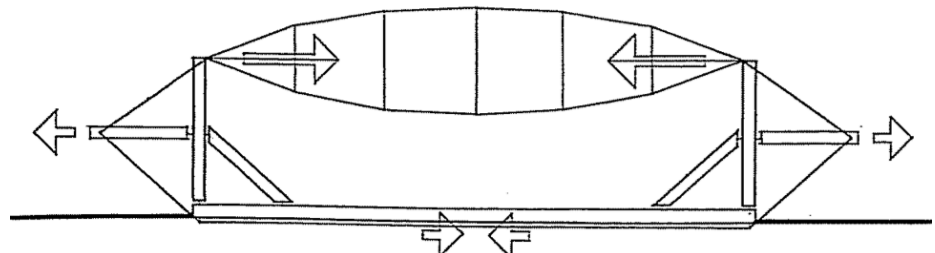
Kraftumlenkung in den Aufhängepunkten durch Pfeiler bzw. Streben
Redirection of forces in the suspension points through buttresses or bracings



Kraftübertragung durch Horizontalträger auf Querwände bzw. Druckbalken
Force transfer by horizontal girders to transverse walls or compression beams



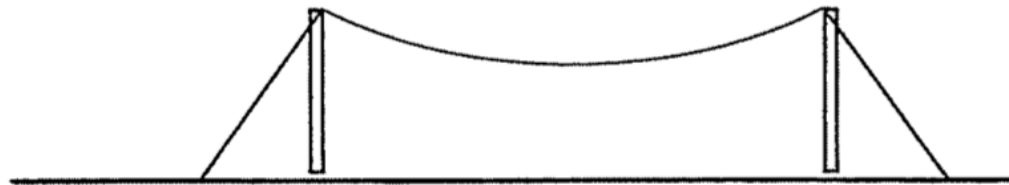
Seilabspannung mit Zuganker-Kraftschluß unterhalb Bodenplatte
Cable restraining with balancing tie member connection beneath floor slab



Abspannung und Abstrebung mit Zuganker-Kraftschluß unter/in Bodenplatte
Restraining and bracing with tie member connection beneath/within floor slab

STRUCTURES FOR SUSPENSION POINTS

formaktiv / form-active

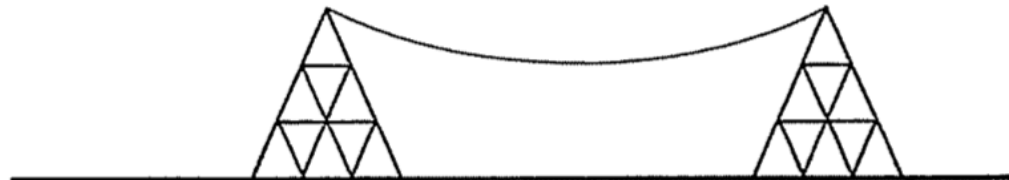


Stütze mit Schrägseil column with oblique cable



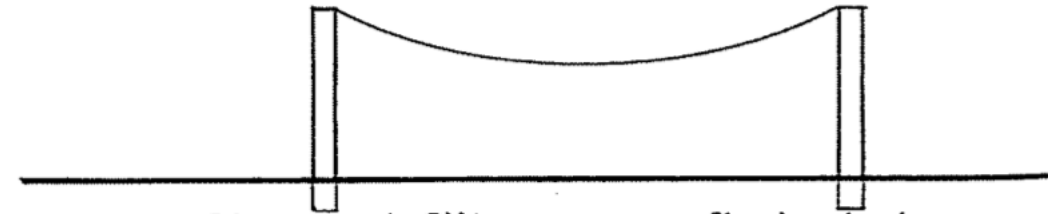
Schrägstütze mit Seil oblique column with cable

vektoraktiv / vector-active

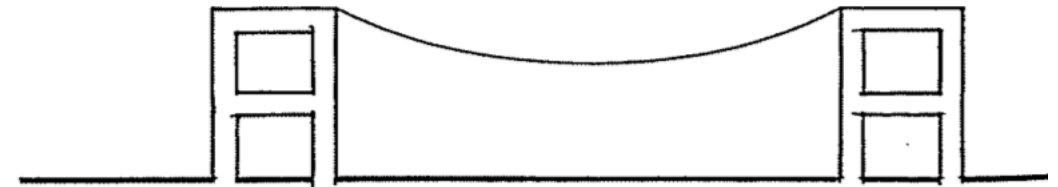


Fachwerk-Pylon trussed pylon

schnittaktiv / section-active

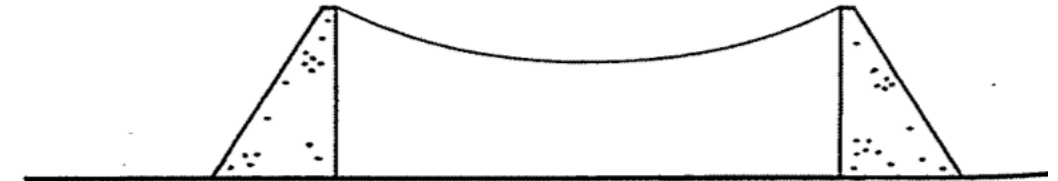


Eingespannte Stütze fixed-end column

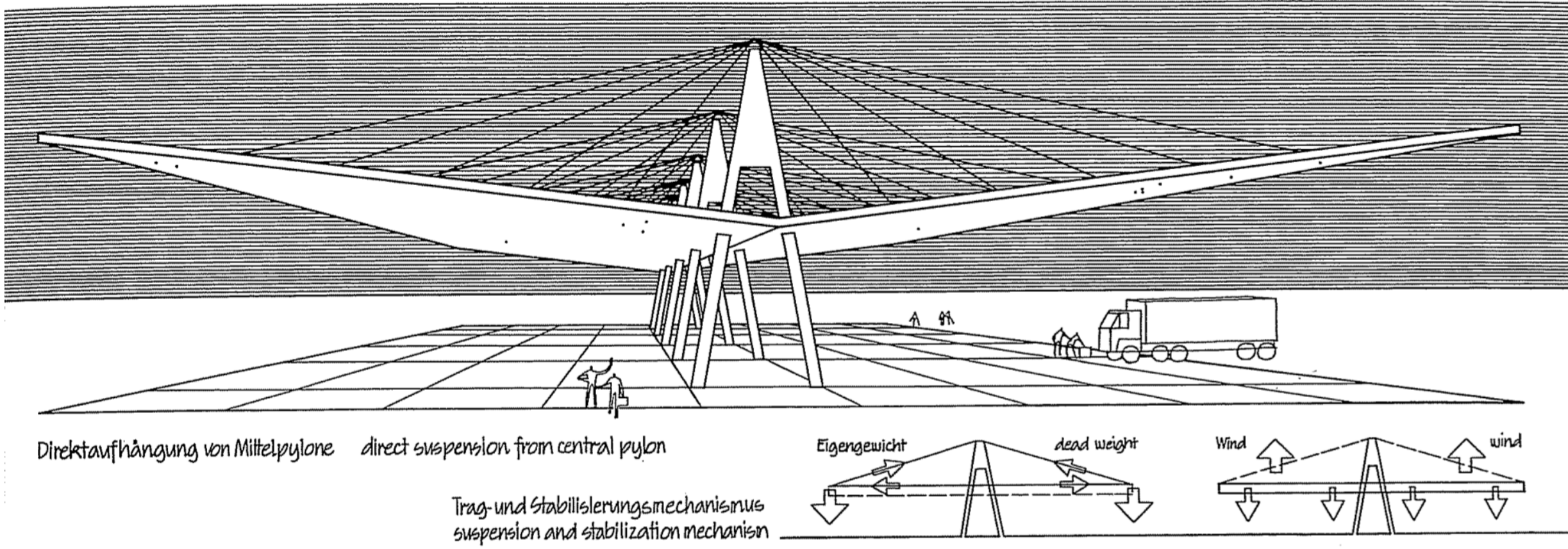


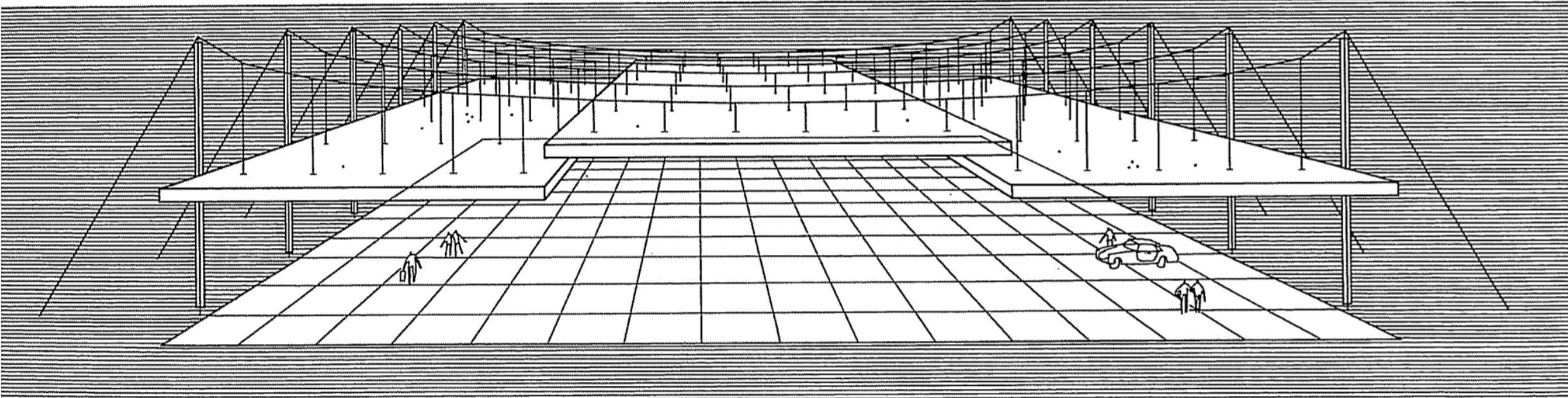
Biegesteifer Rahmen rigid frame

flächenaktiv / surface-active



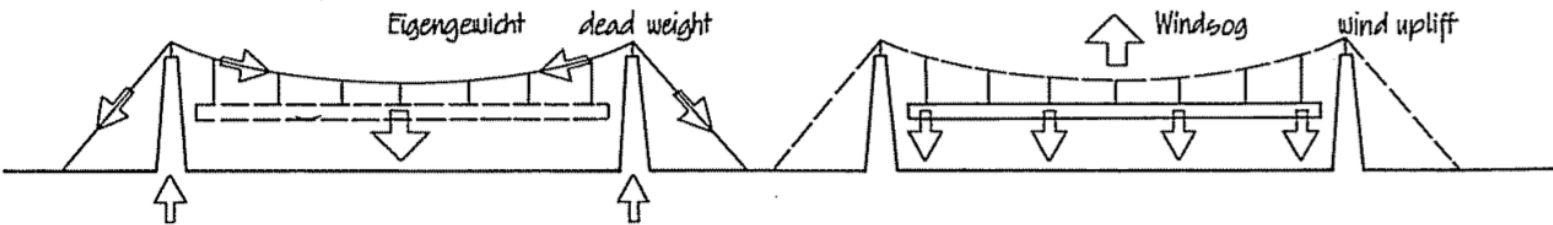
Scheiben-Pfeiler shear wall buttress

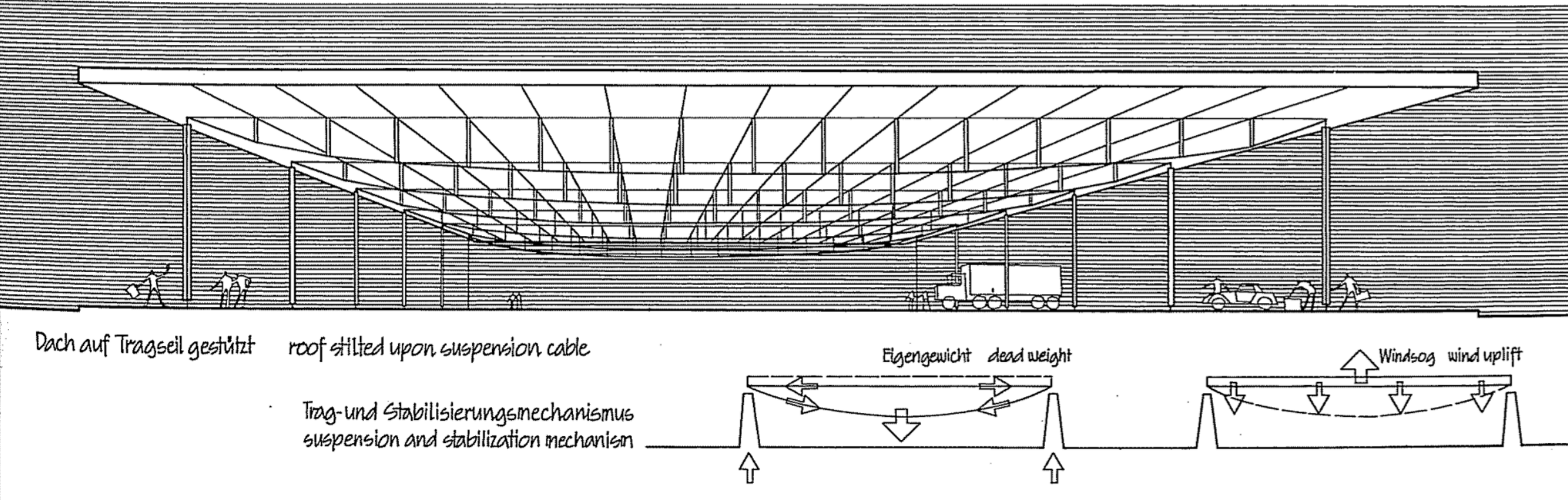




Dach von Tragseil abgehängt roof suspended from cable

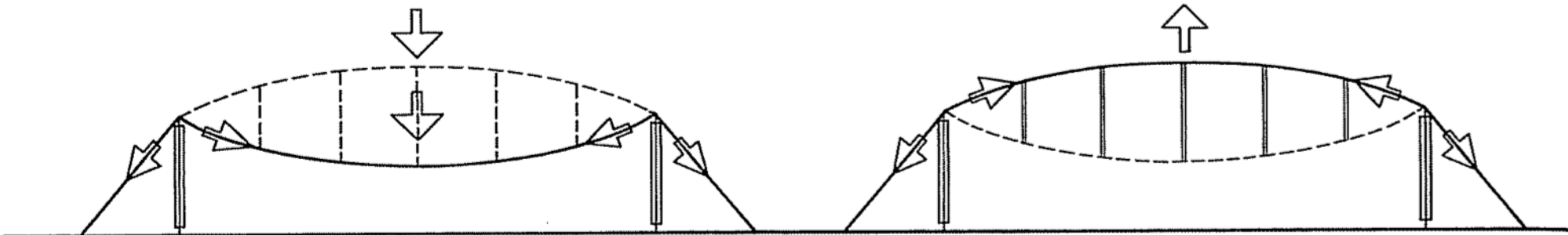
Trag- und Stabilisierungsmechanismus
suspension and stabilization mechanism





BEARING AND STABILIZING MECHANISM OF PRESTRESSED SYSTEMS

Tragseil unter Stabilisierungsseil
suspension cable below
stabilization cable



Tragseil über Stabilisierungsseil
suspension cable above
stabilization cable



Tragseil teils über teils unter
Stabilisierungsseil
suspension cable partly above
partly below stabilization cable

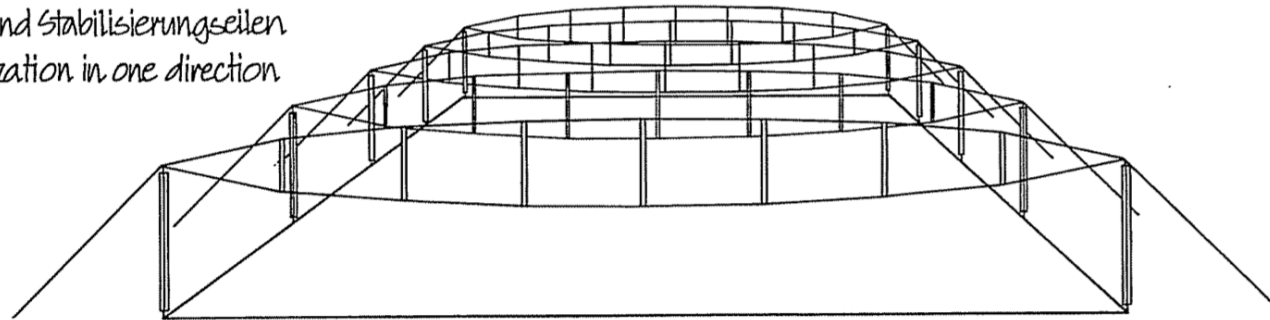


Tragmechanismus / bearing mechanism

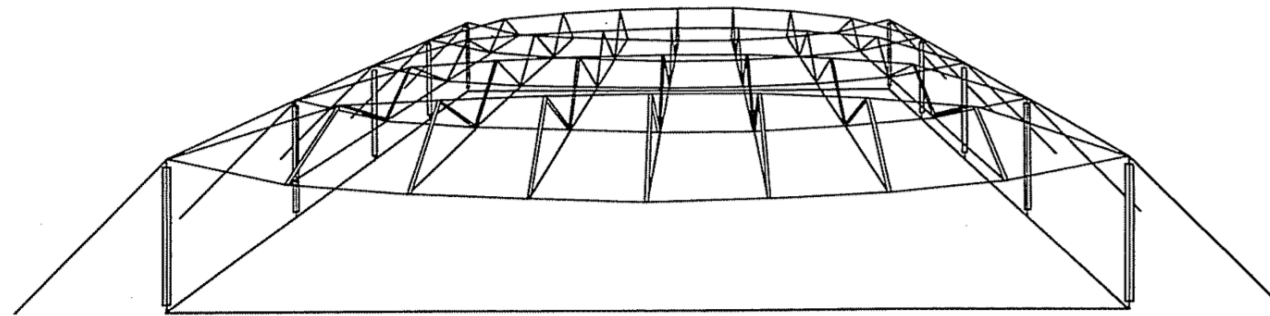
Stabilisierungsmechanismus / stabilizing mechanism

SYSTEMS WITH SUSPENSION AND STABILIZATION IN ONE DIRECTION

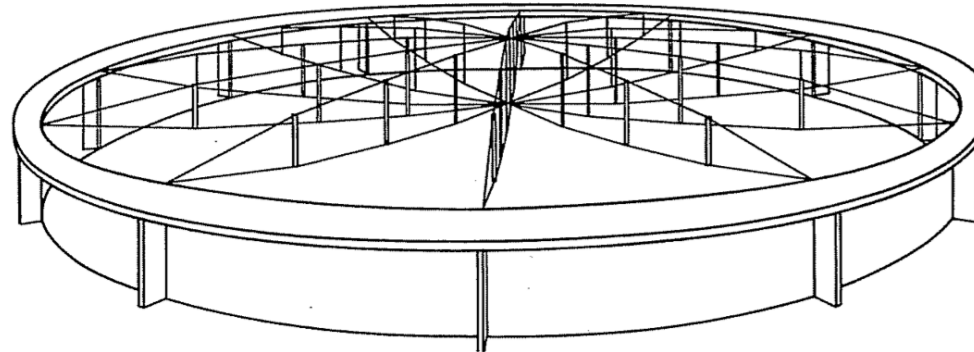
Systeme mit gleichgerichteten Trag- und Stabilisierungseilen
systems with suspension and stabilization in one direction



ebenes Parallelsystem
flat parallel system

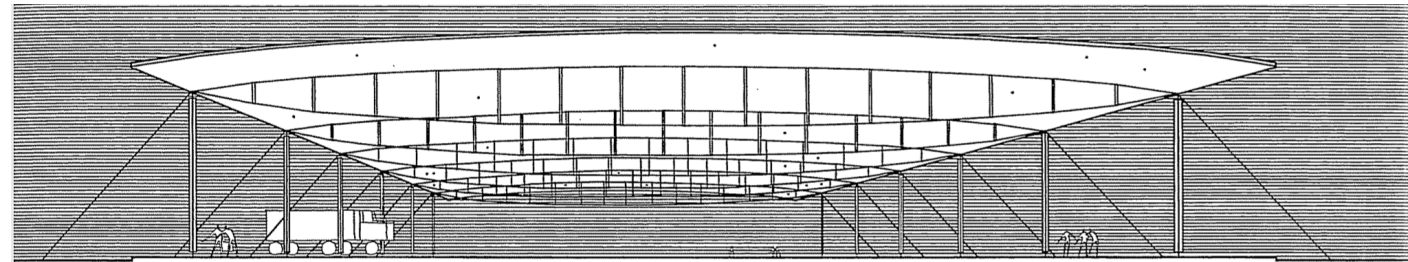


versetztes Parallelsystem
spatial parallel system



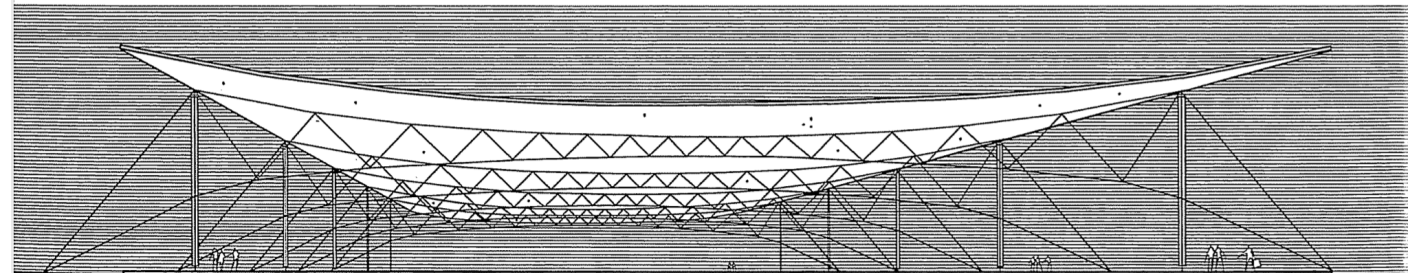
ebenes Rotationssystem
flat rotational system

FLAT PARALLEL SYSTEMS WITH STABILIZATION THROUGH COUNTER CABLES (1/5)



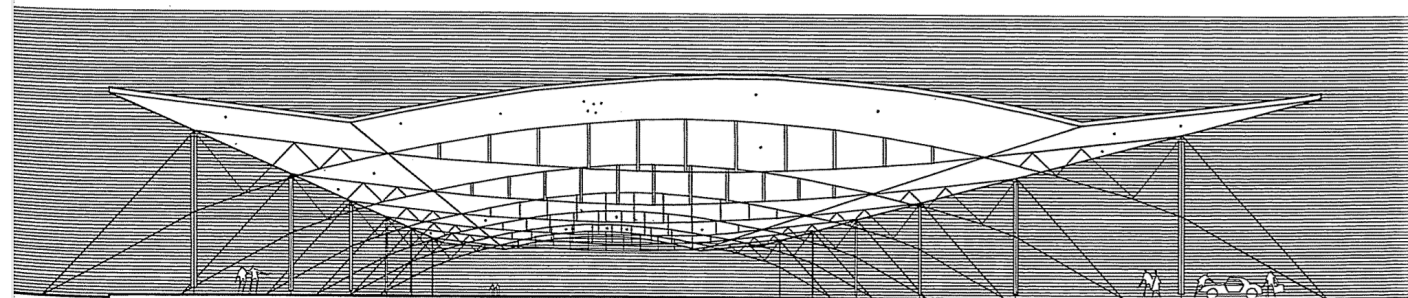
Stabilisierungseil über Tragsseil

stabilization cable above suspension cable



Stabilisierungseil unter Tragsseil

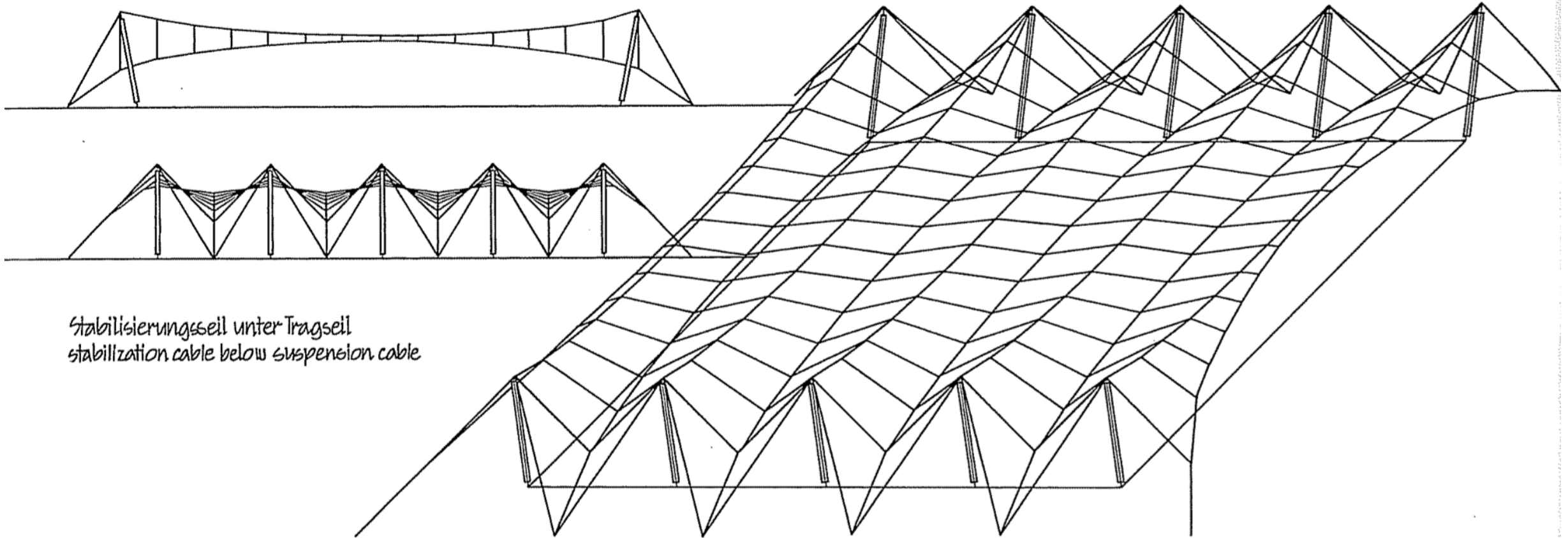
stabilization cable under suspension cable



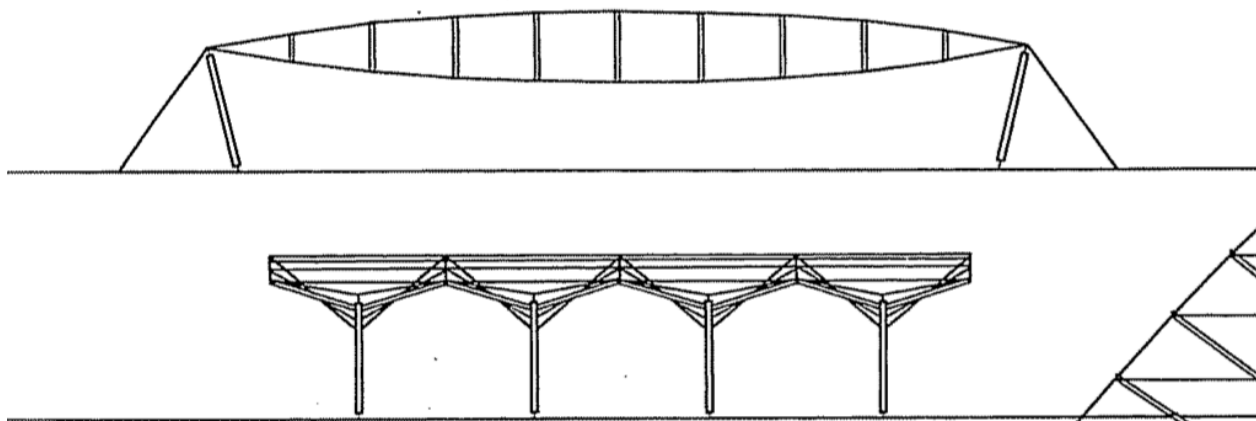
Stabilisierungseil teils über teils unter Tragsseil

stabilization cable partly above partly below suspension cable

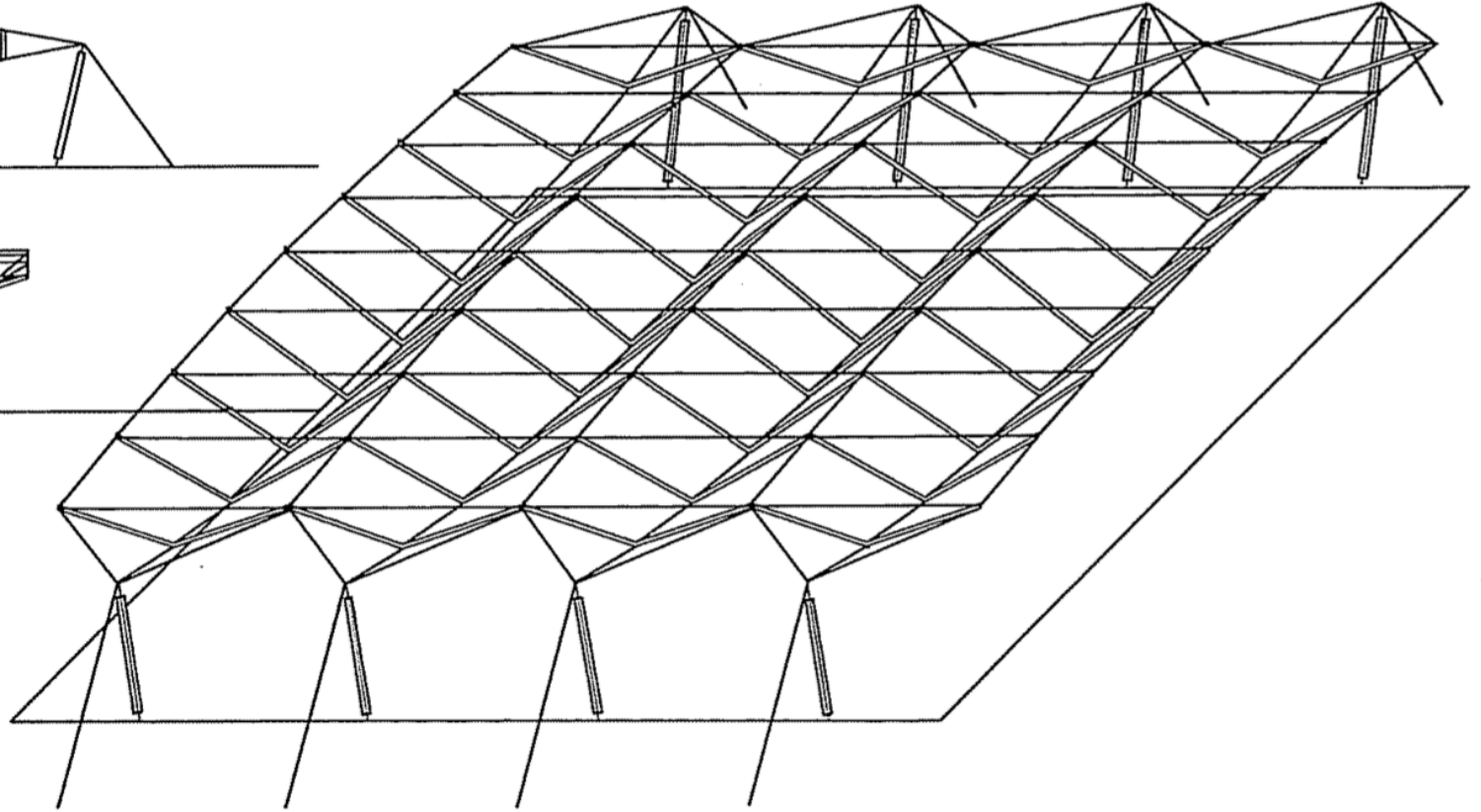
Suspension cable and
stabilization cable in one plane

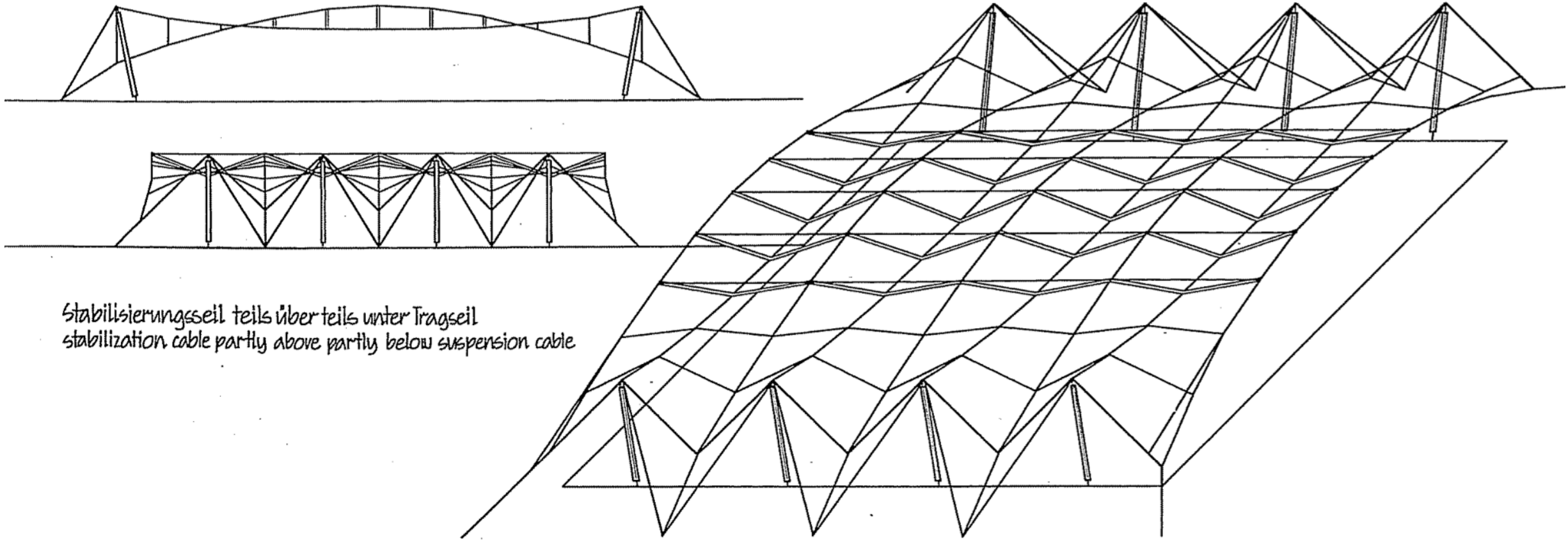


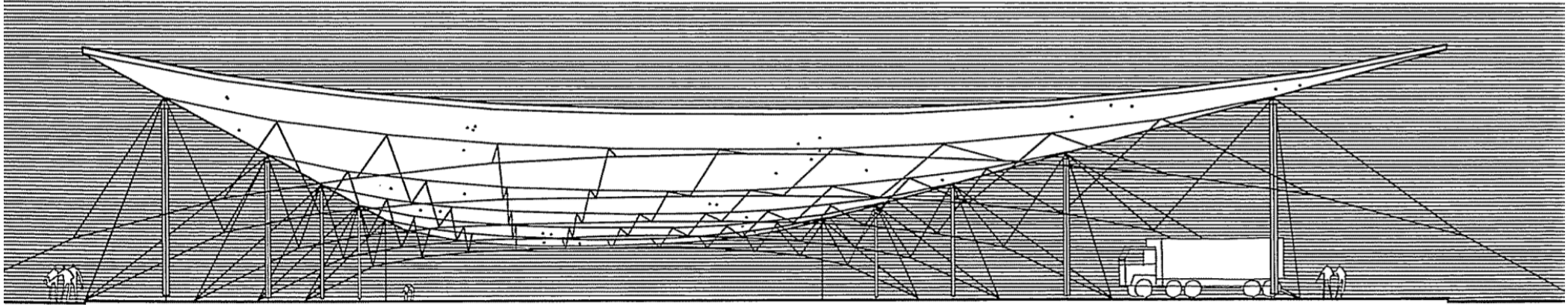
Stabilisierungsseil unter Tragseil
stabilization cable below suspension cable



Stabilisierungsseil über Tragseil
stabilization cable above suspension cable

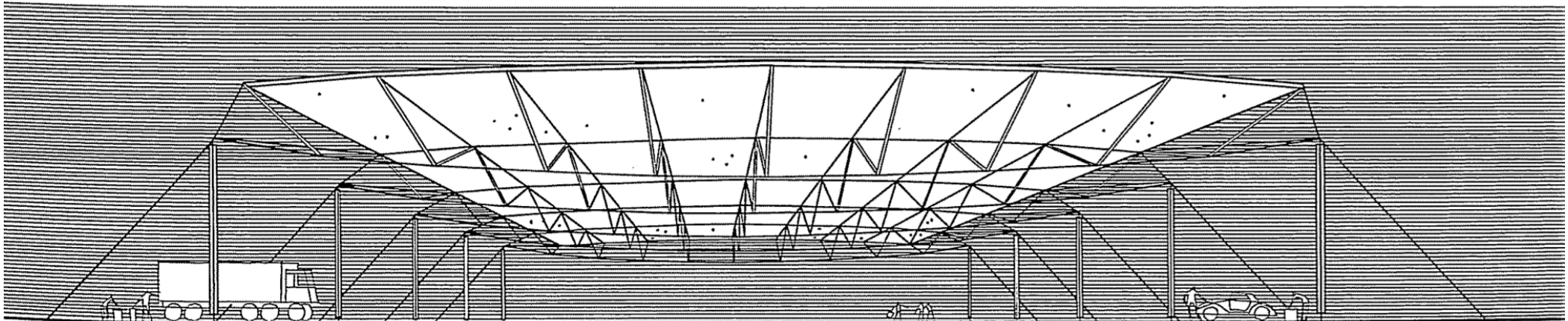






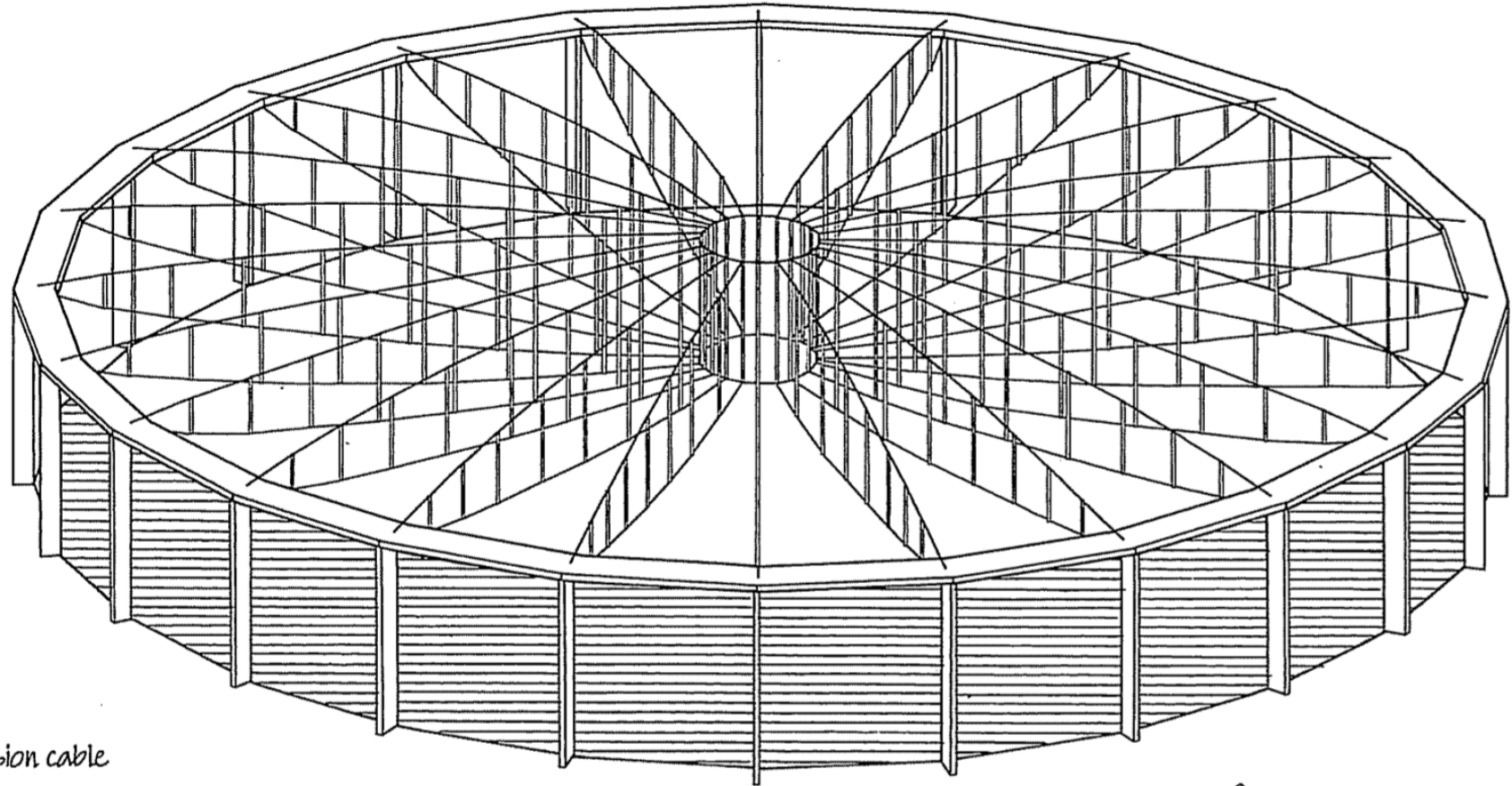
Stabilisierungssell unter Tragseil

stabilization cable below suspension cable



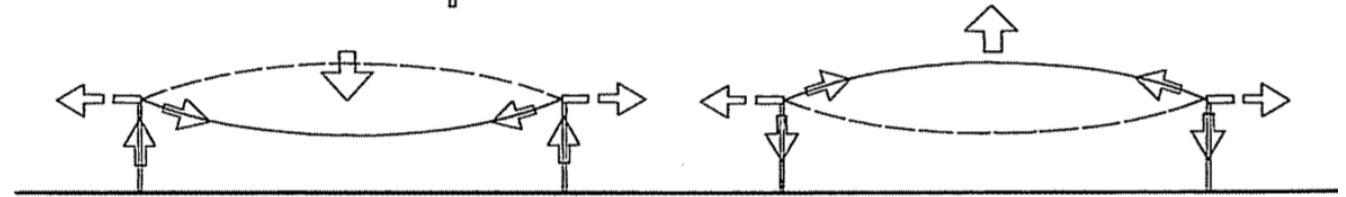
Stabilisierungssell über Tragseil

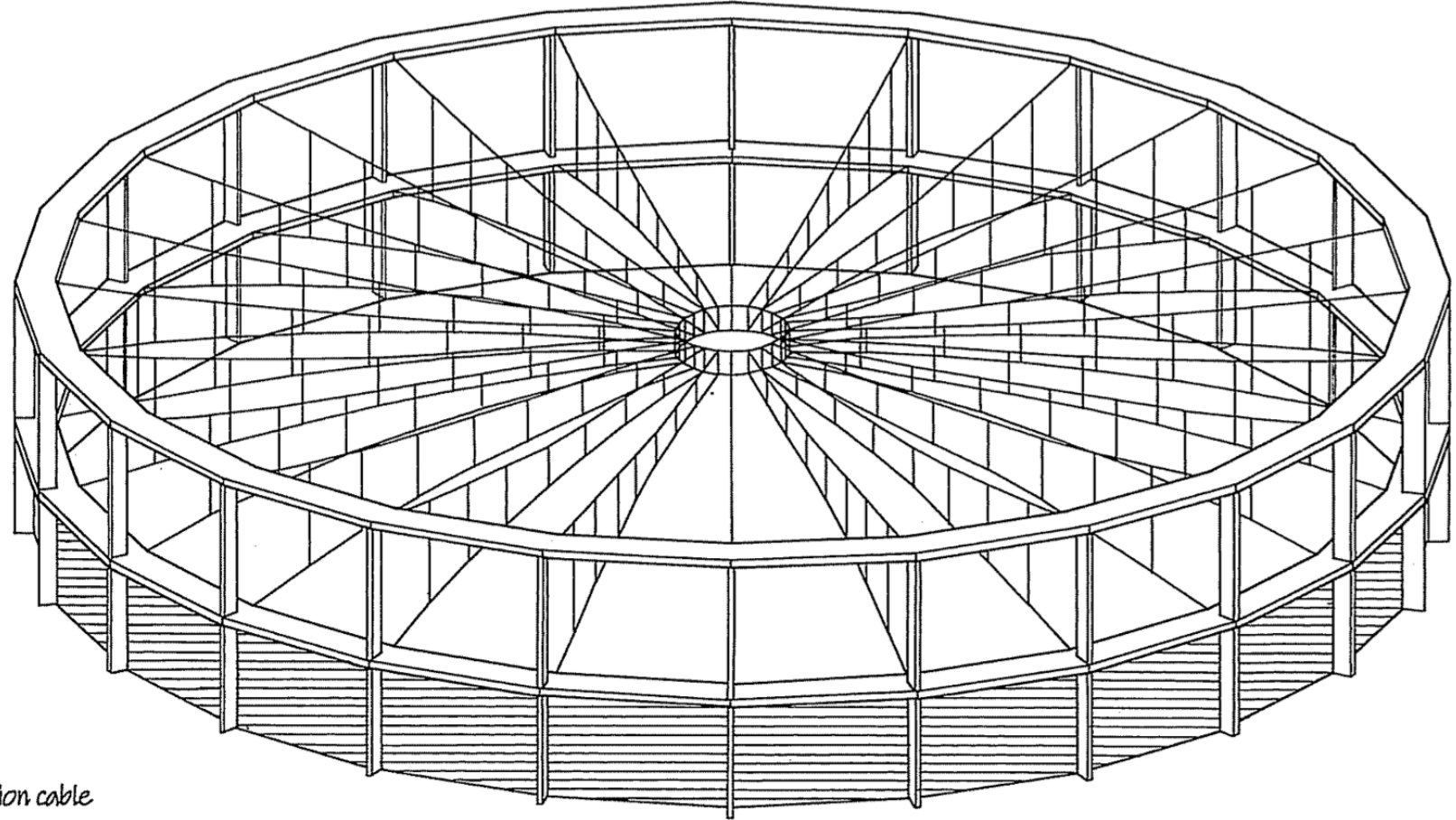
stabilization cable above suspension cable



Stabilisierungsseil über Tragseil
stabilization cable above suspension cable

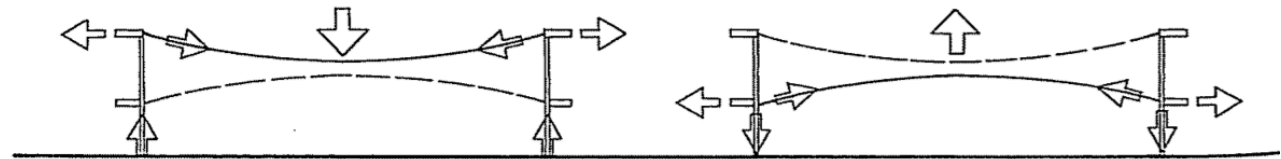
Trag- und Stabilisierungsmechanismus
suspension and stabilization mechanism



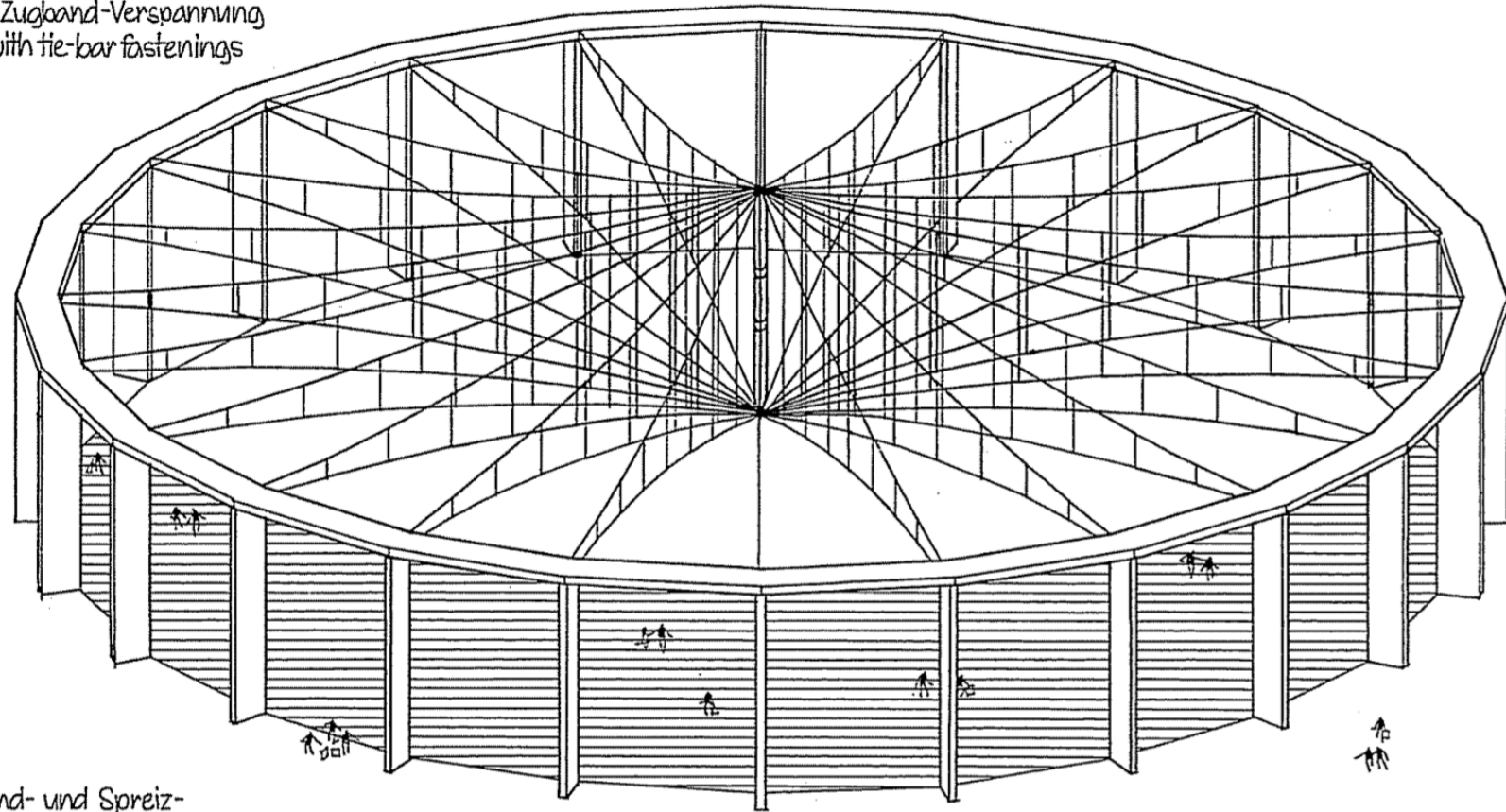
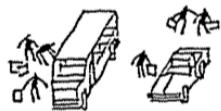


Stabilisierungssell unter Tragsell
stabilization cable below suspension cable

Trag- und Stabilisierungsmechanismus
suspension and stabilization mechanism

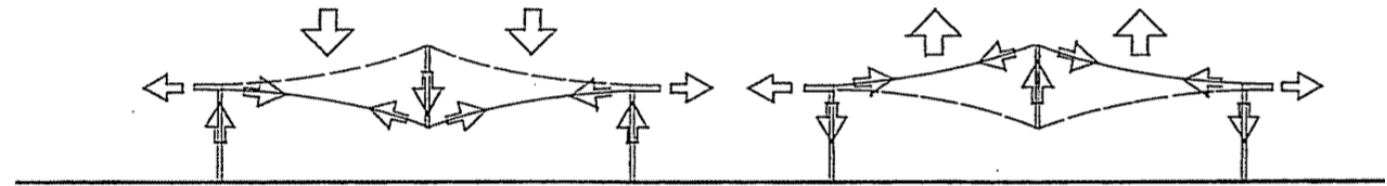


Zentrale Spreiz-Stabilisierung mit Zugband-Verspannung
Central spreader stabilization with tie-bar fastenings



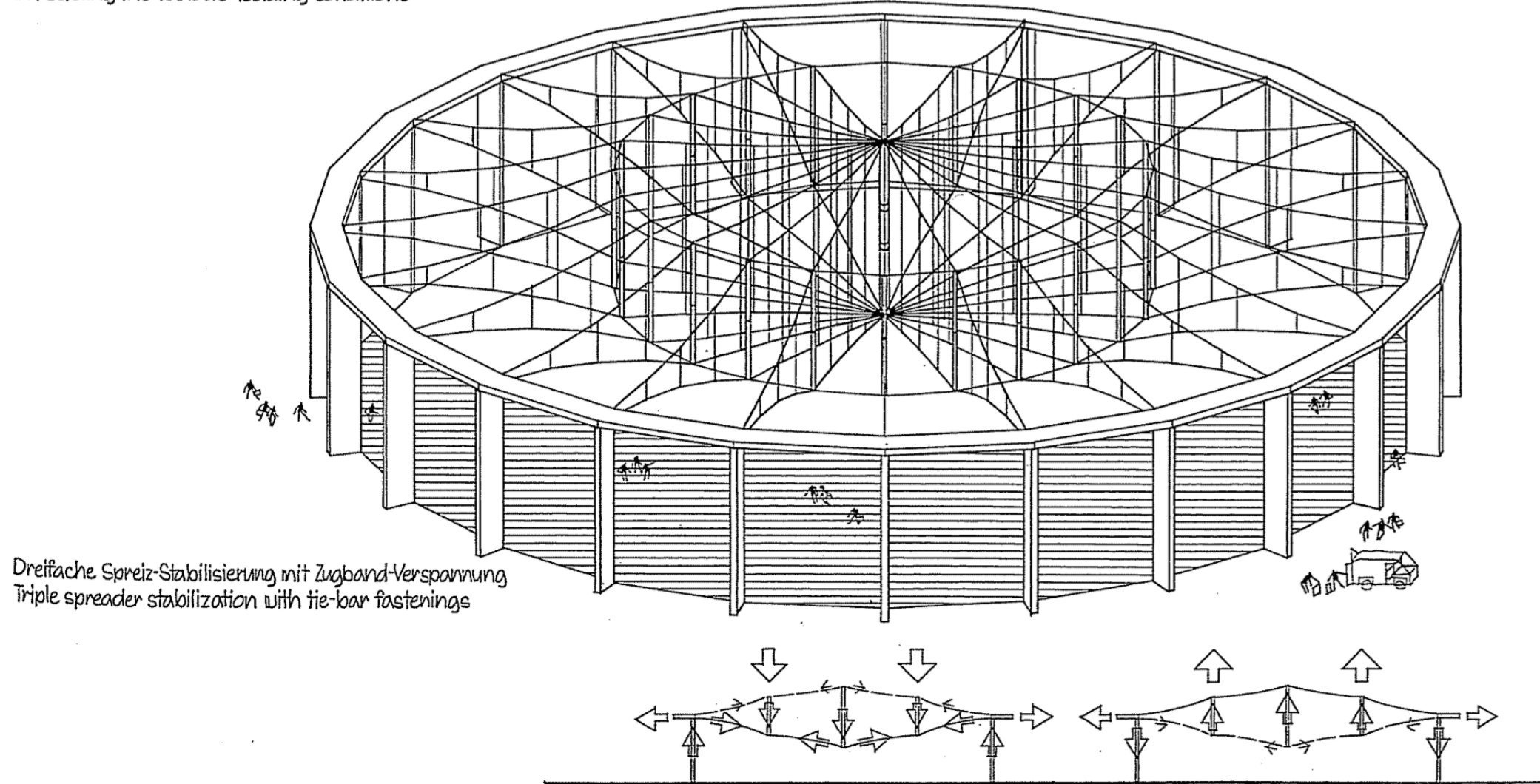
Durch Kombination von Zugband- und Spreiz-Verspannung der beiden Funktionsseile wird die eindeutige Zuordnung als Tragseil bzw. als Stabilisierungsseil aufgelöst. Beide Funktionsseile werden an jedem Belastungsfall beteiligt

By combination of tie-bar and spreader-bar fastenings the clear-cut distinction in either suspension cable or stabilization cable will be

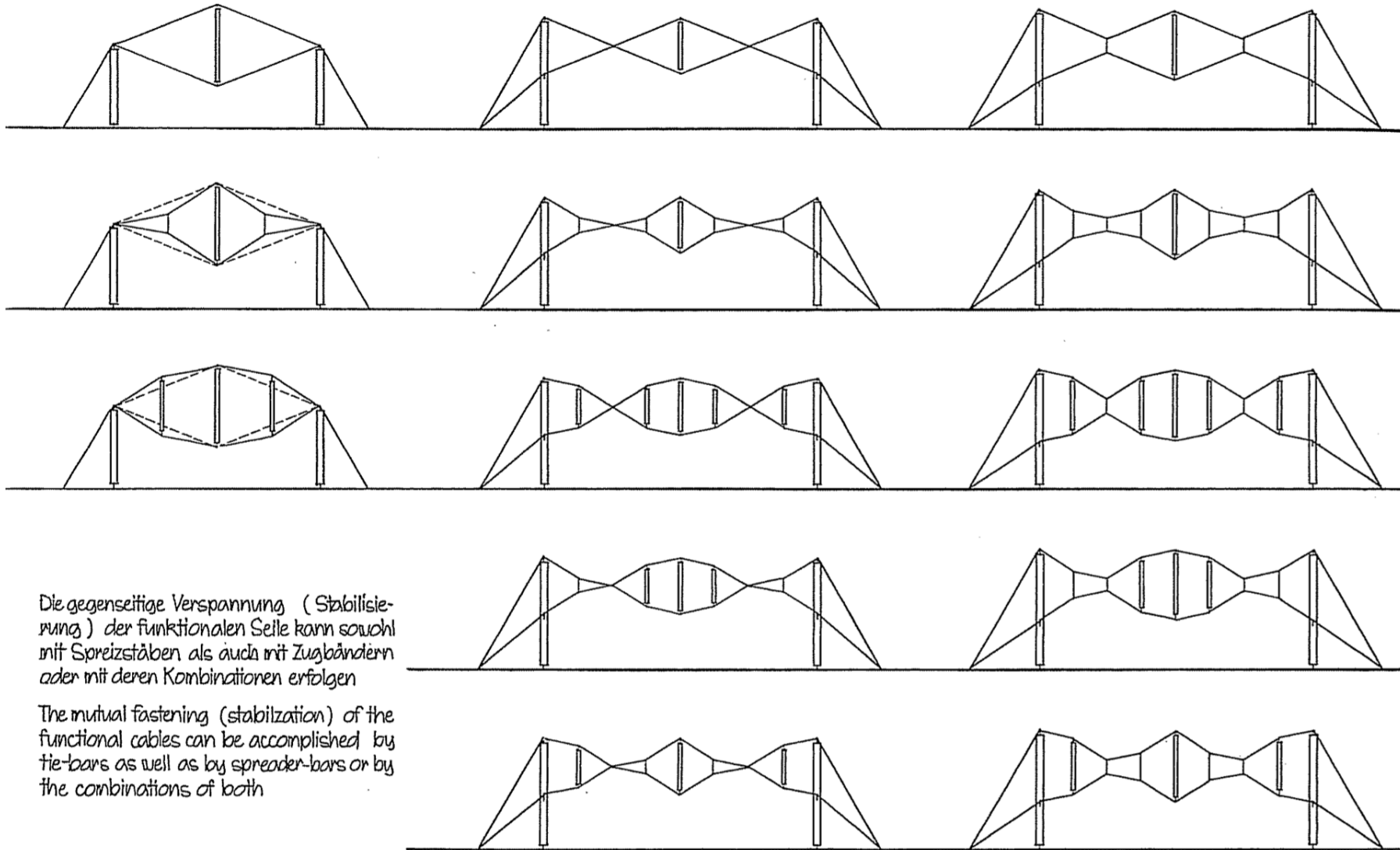


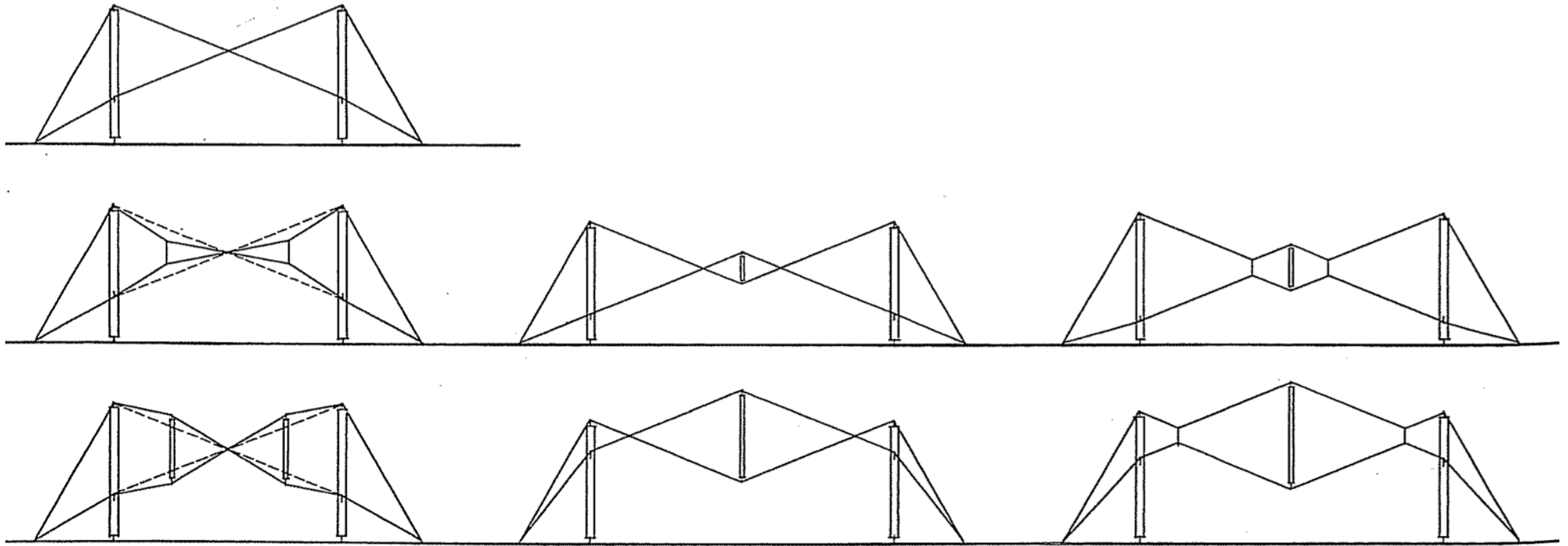
ROTATIONAL SYSTEMS WITH ALTERNATING TECHNIQUES OF STABILIZATION (2/2)

discovered, both functional cables will be active
in resisting the various loading conditions



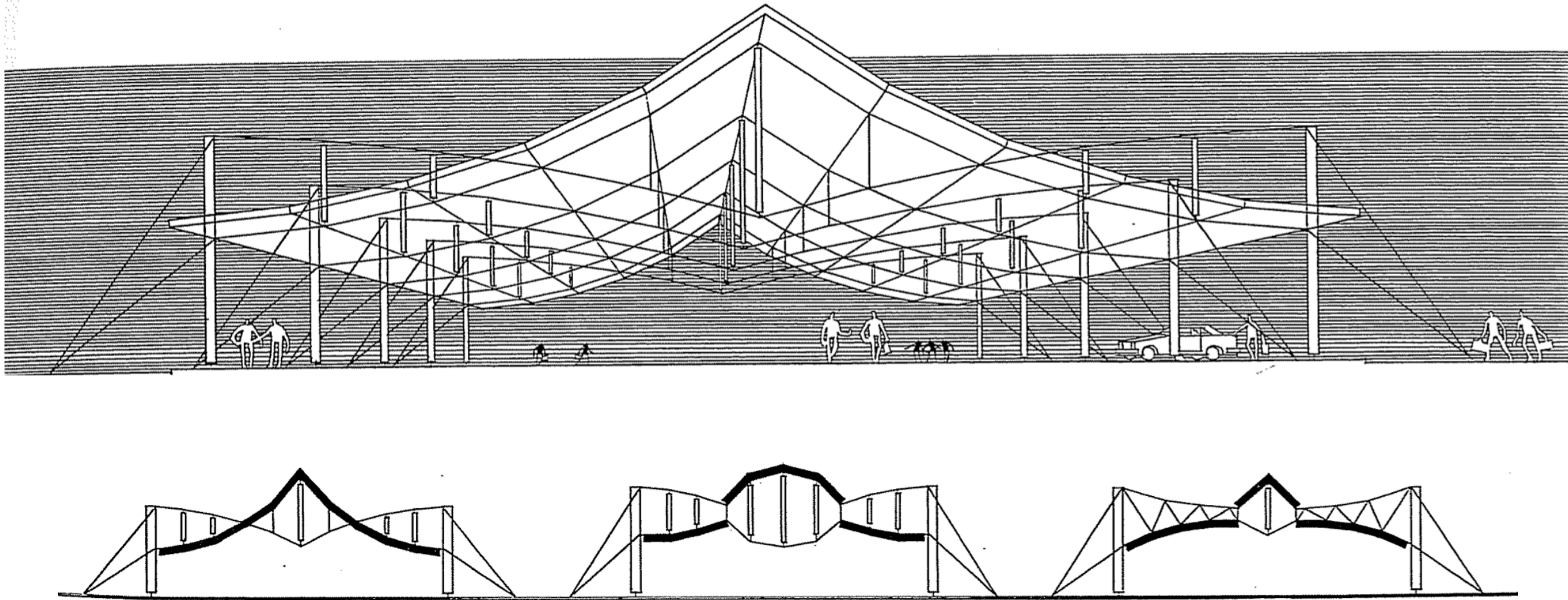
FASTENING SYSTEMS FOR STABILIZATION WITH TIE-BAR AND SPREAD-BAR (1/2)

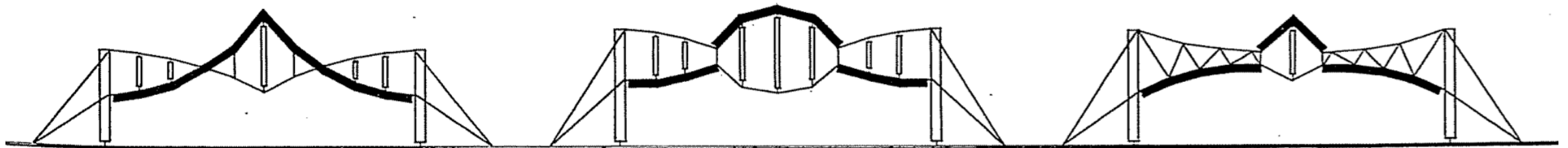
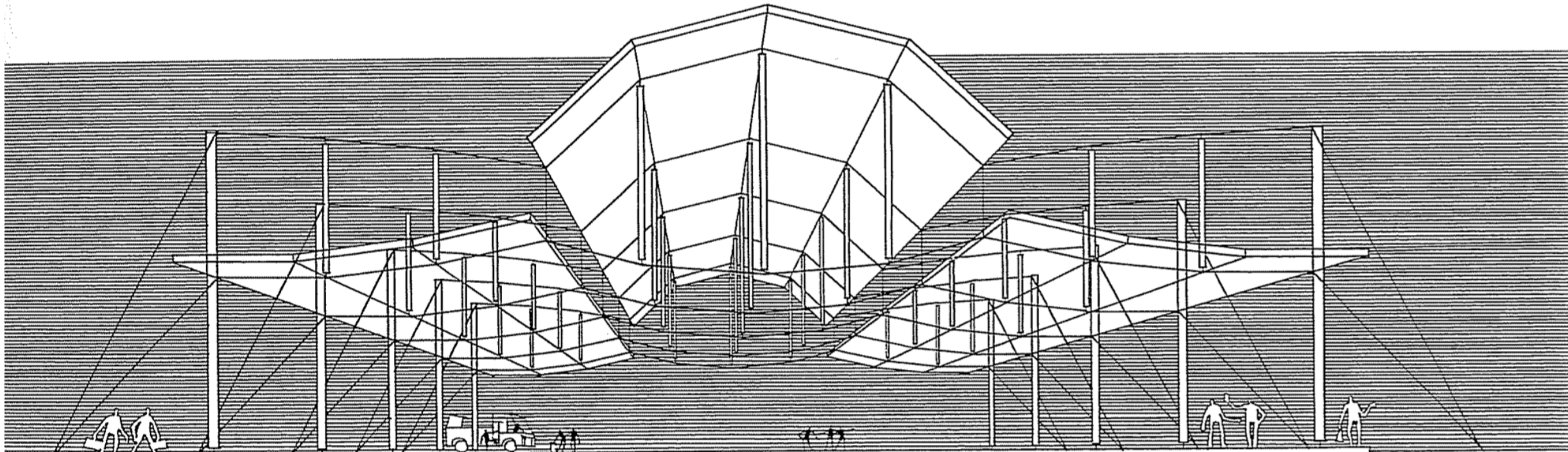


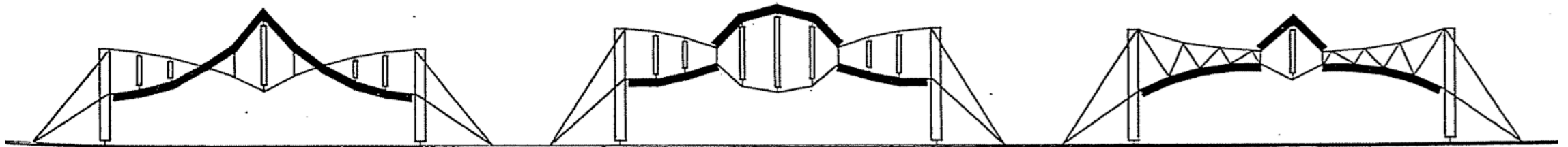
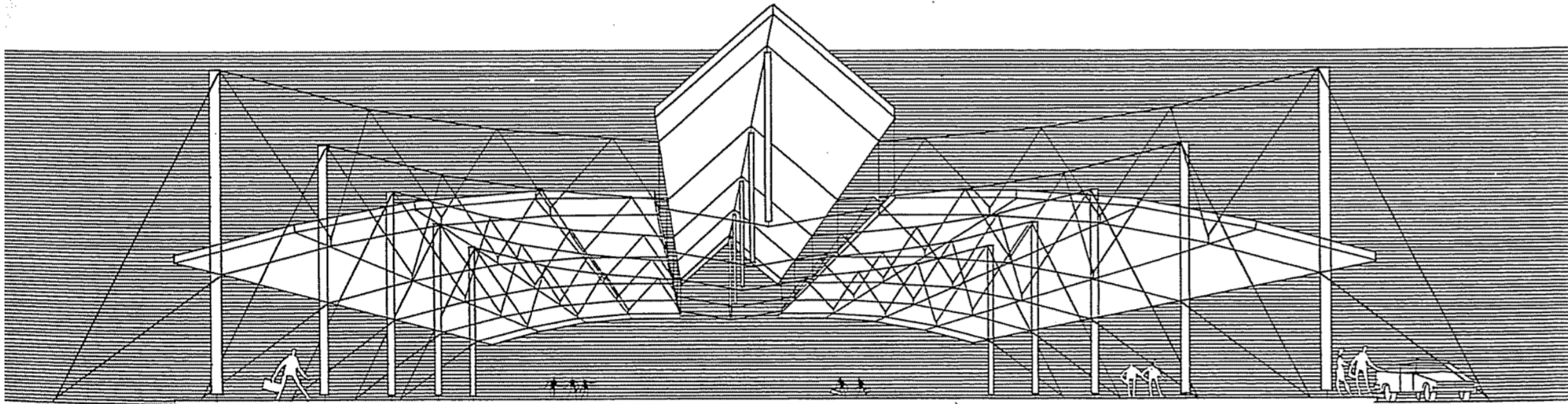


Durch gemeinsame Verwendung von Zugbändern und Spreizstäben für die Ver-
spannung wird die eindeutige Zuordnung zu Tragseil oder Stabilisierungsseil
aufgelöst. Beide Funktionsseile werden mit jedem Belastungsfall beansprucht

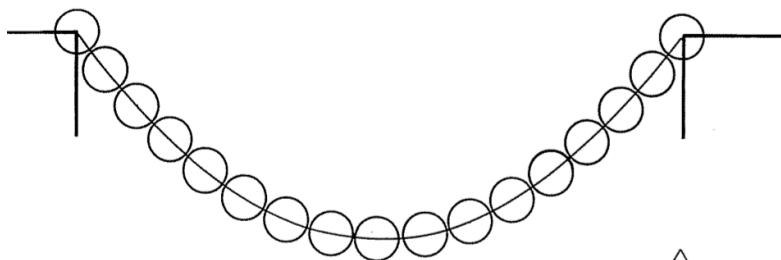
By jointly applying tie-bars and spreader-bars for stabilisation of func-
tional cables the separate distinction of suspension cable and stabilization cable
is dissolved. Both functional cables are stressed with each loading condition



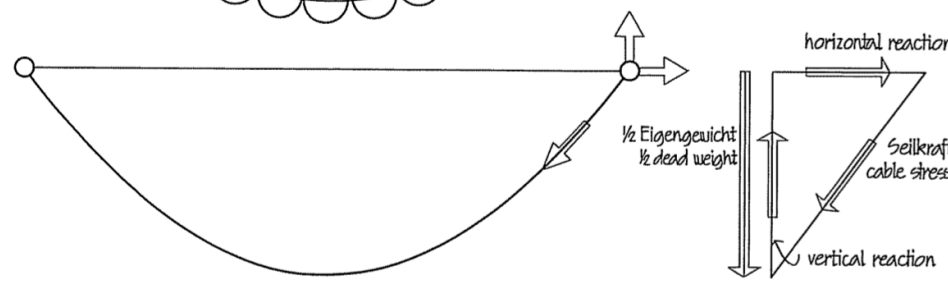




SUSPENSION CABLE AND ARCH – SPANNING MECHANISM (1/2)

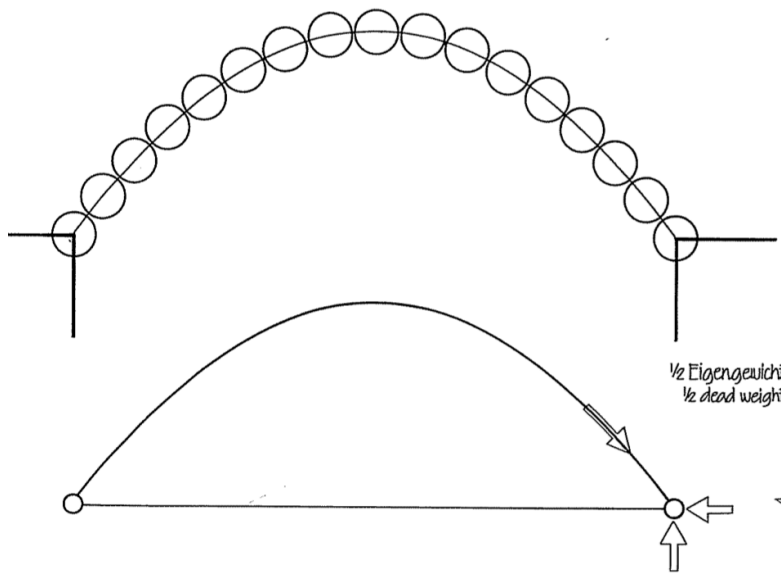


Suspension cable

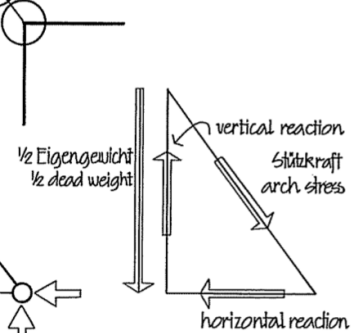


Tragseil suspension cable

Das Tragseil kann nur Zugkräfte aufnehmen. Unter Eigengewicht nimmt es die Gestalt einer Kettenlinie an.
the suspension cable is able to develop only tensile stresses. under its own weight it assumes the shape of a catenary



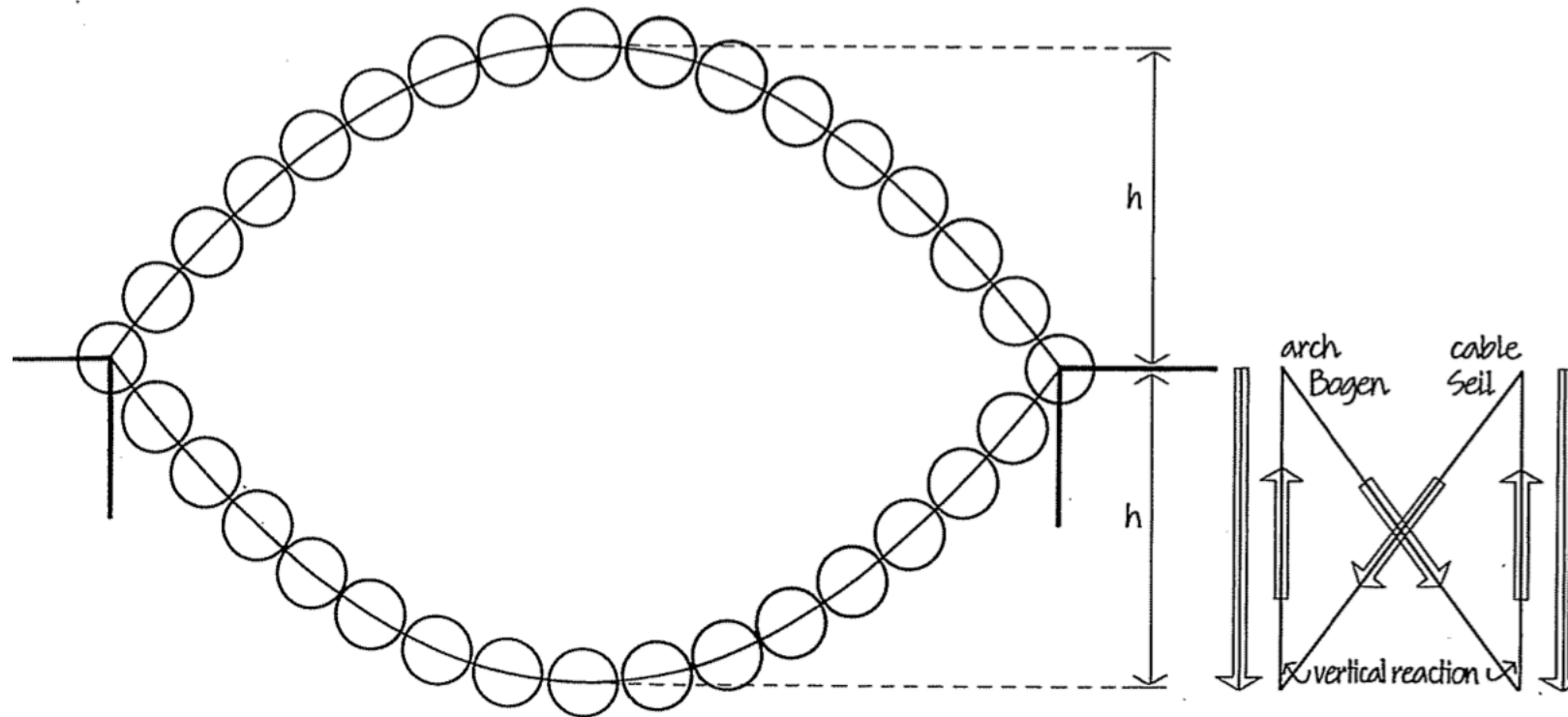
Funicular arch



Stützbogen funicular arch

Das umgekehrte "Tragseil" nimmt nur Druckkräfte auf und zwar von der gleichen Größe wie die Zugkräfte im Tragseil. Die Stützlinie eines Bogens unter Eigengewicht ist daher eine umgekehrte Kettenlinie.
the "cable" turned upside down develops only compressive stresses of the same magnitude as the tensile stresses in the cable. the funicular shape for an arch under its own weight thus is an inverted catenary

► Arch/suspension cable combination

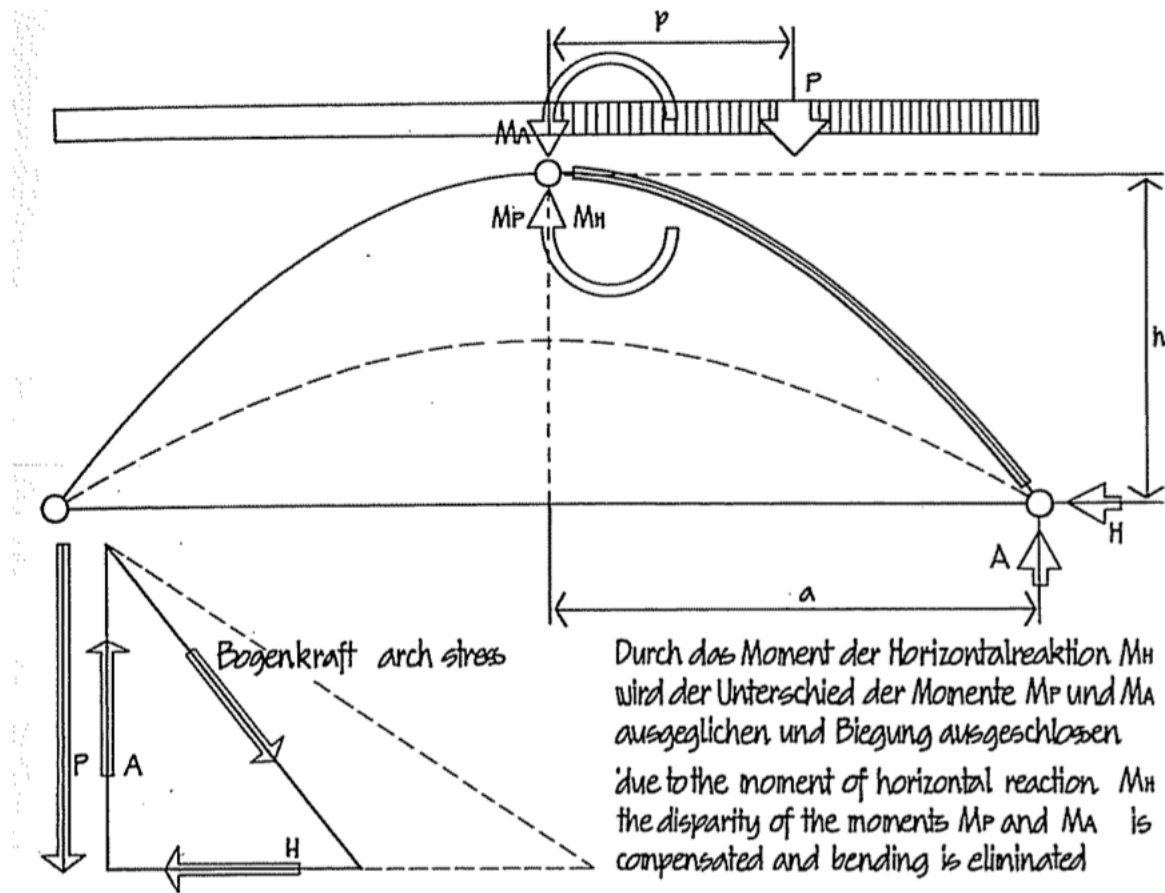


Stützbogen/Tragseil -Verbindung
arch/suspension cable combination

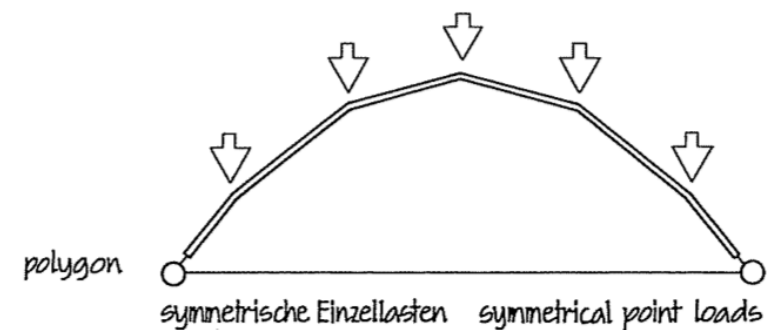
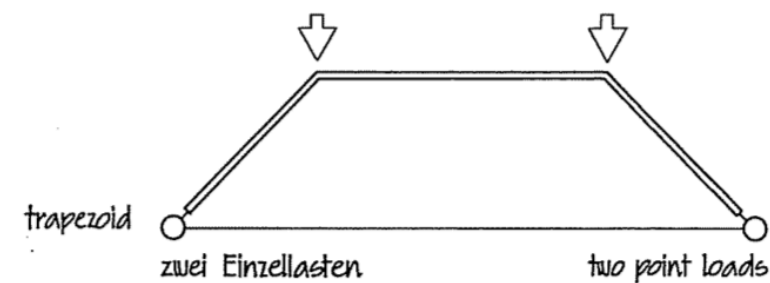
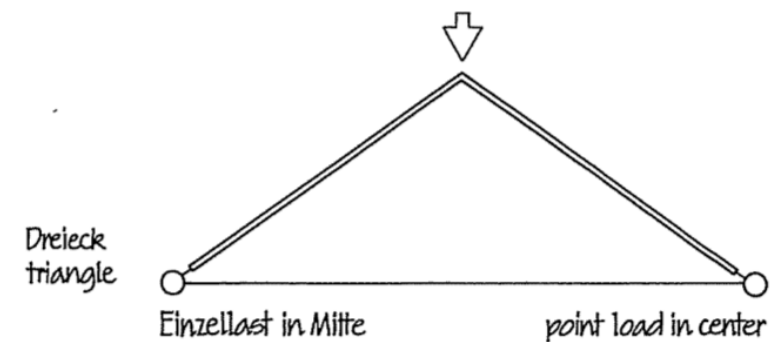
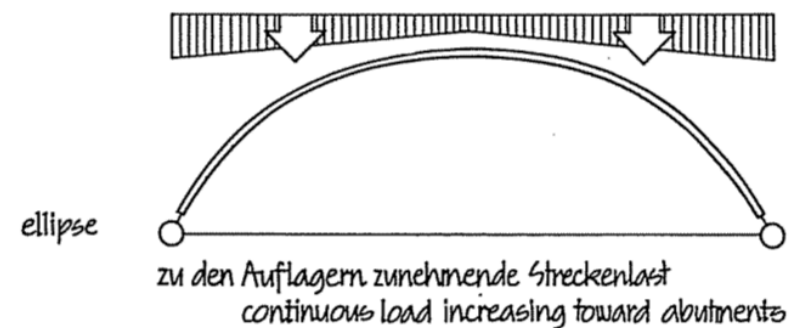
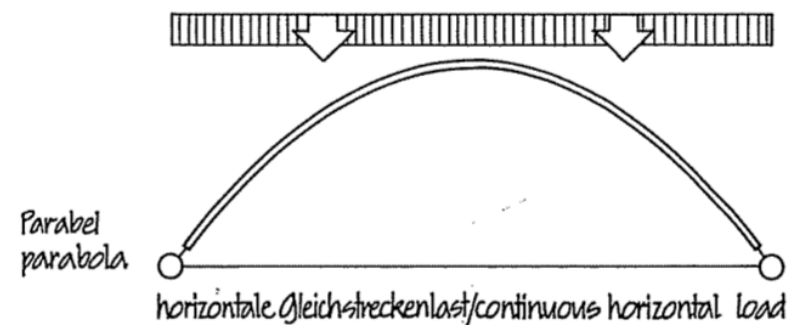
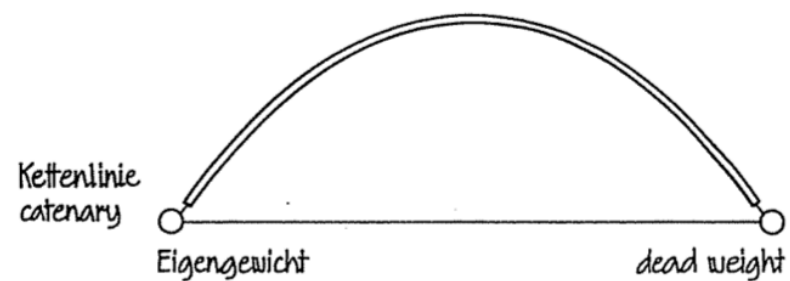
Die Verbindung von Tragseil und Stützbogen
löst keine horizontale Reaktion aus, da die
horizontalen Komponenten beider entgegen-
gesetzt sind und einander aufheben

the combination of suspension cable and arch
will not produce any horizontal reaction since
the horizontal components of both have op-
posite direction and nullify each other

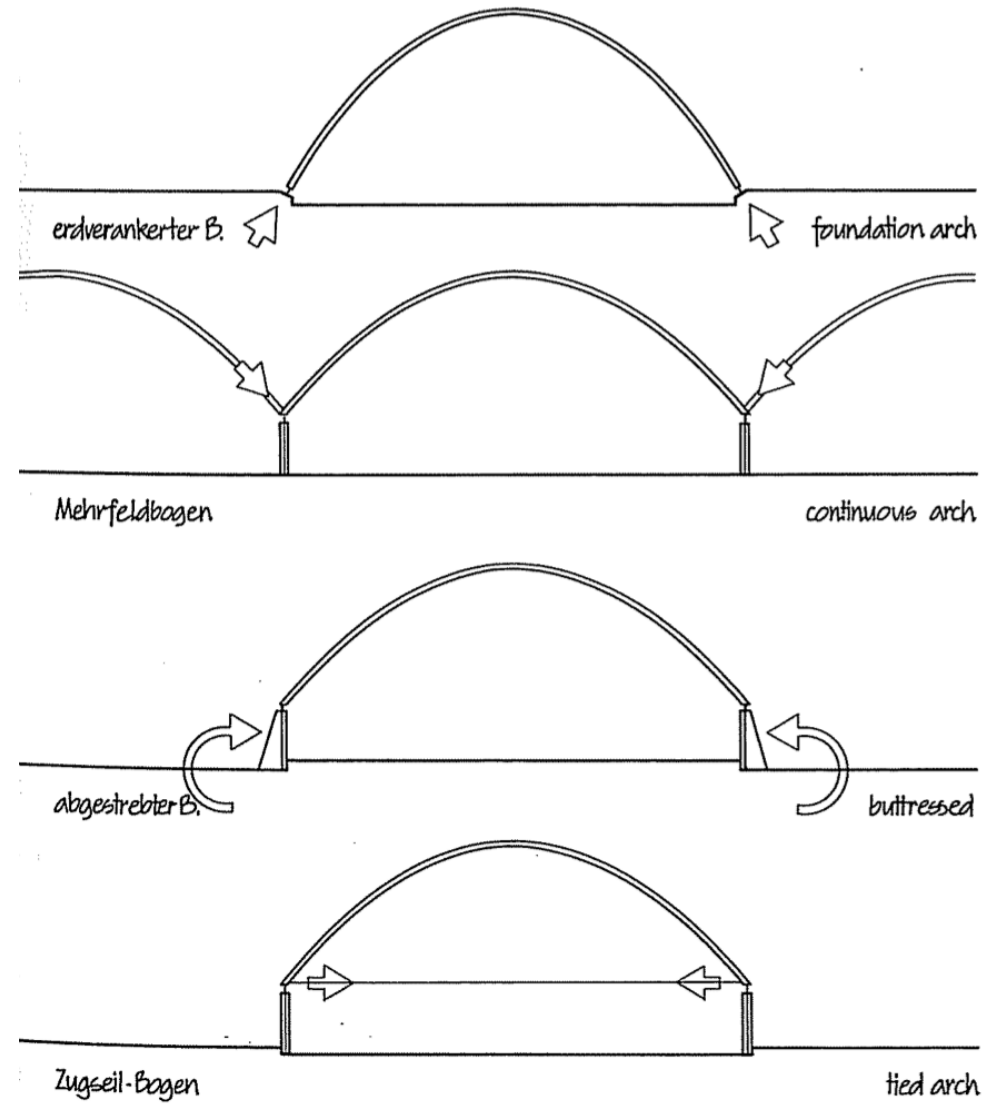
LEVER MECHANISM OF FUNICULAR ARCH



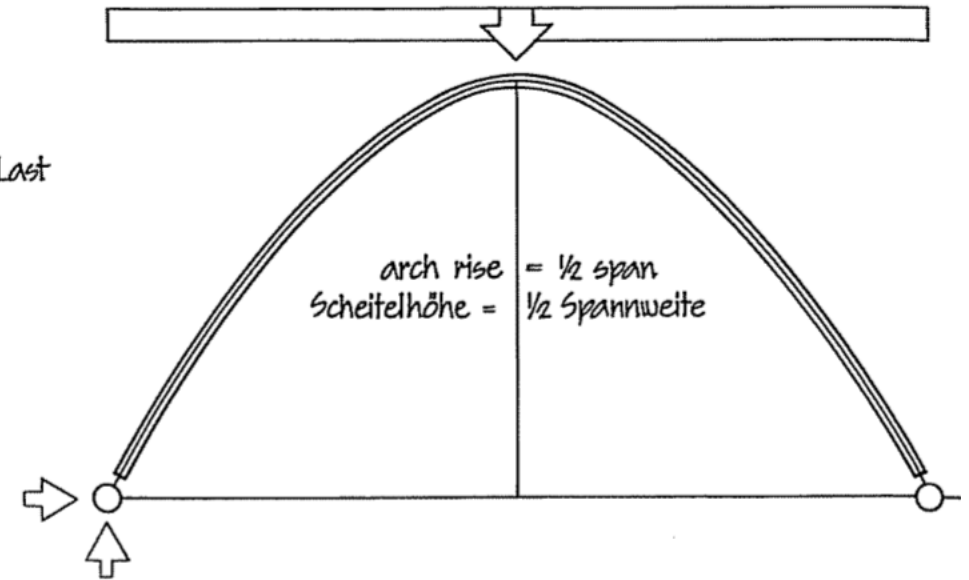
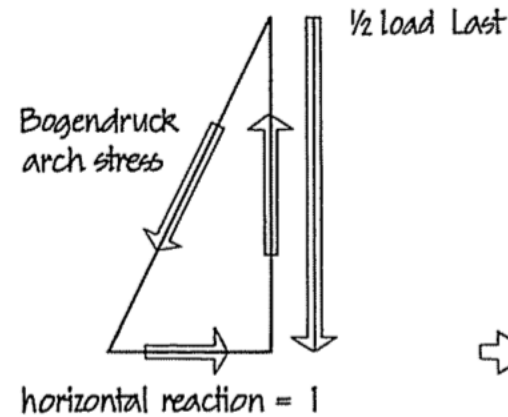
GEOMETRICAL FORMS – DEPENDENCE ON LOAD CONDITION



ARCH SYSTEM CHARACTERIZED BY METHOD OF HORIZONTAL THRUST RESISTANCE

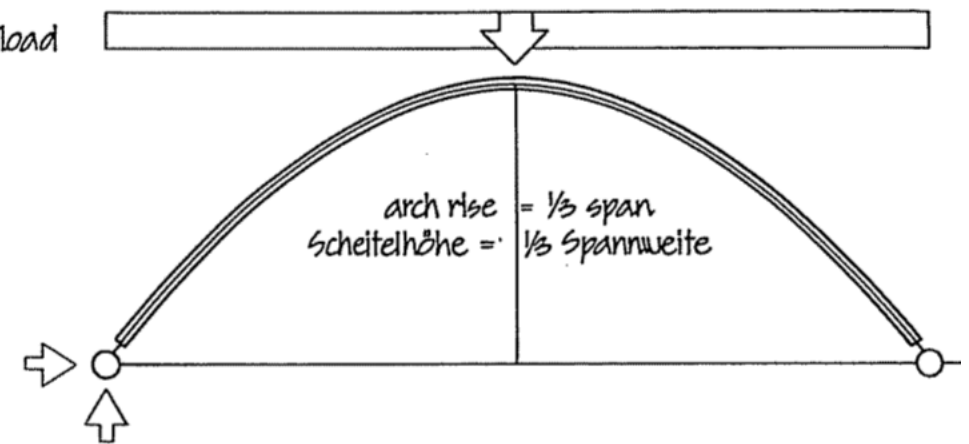
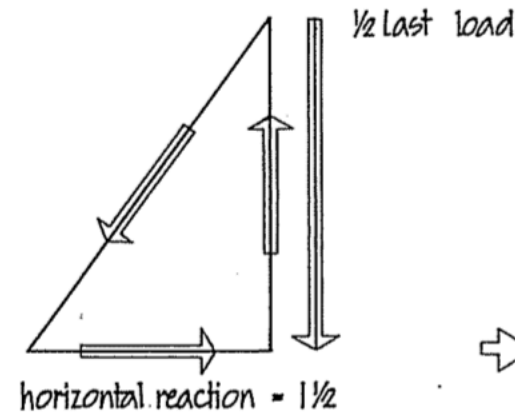


INFLUENCE OF ARCH RISE ON HINGE STRESSES (1/2)

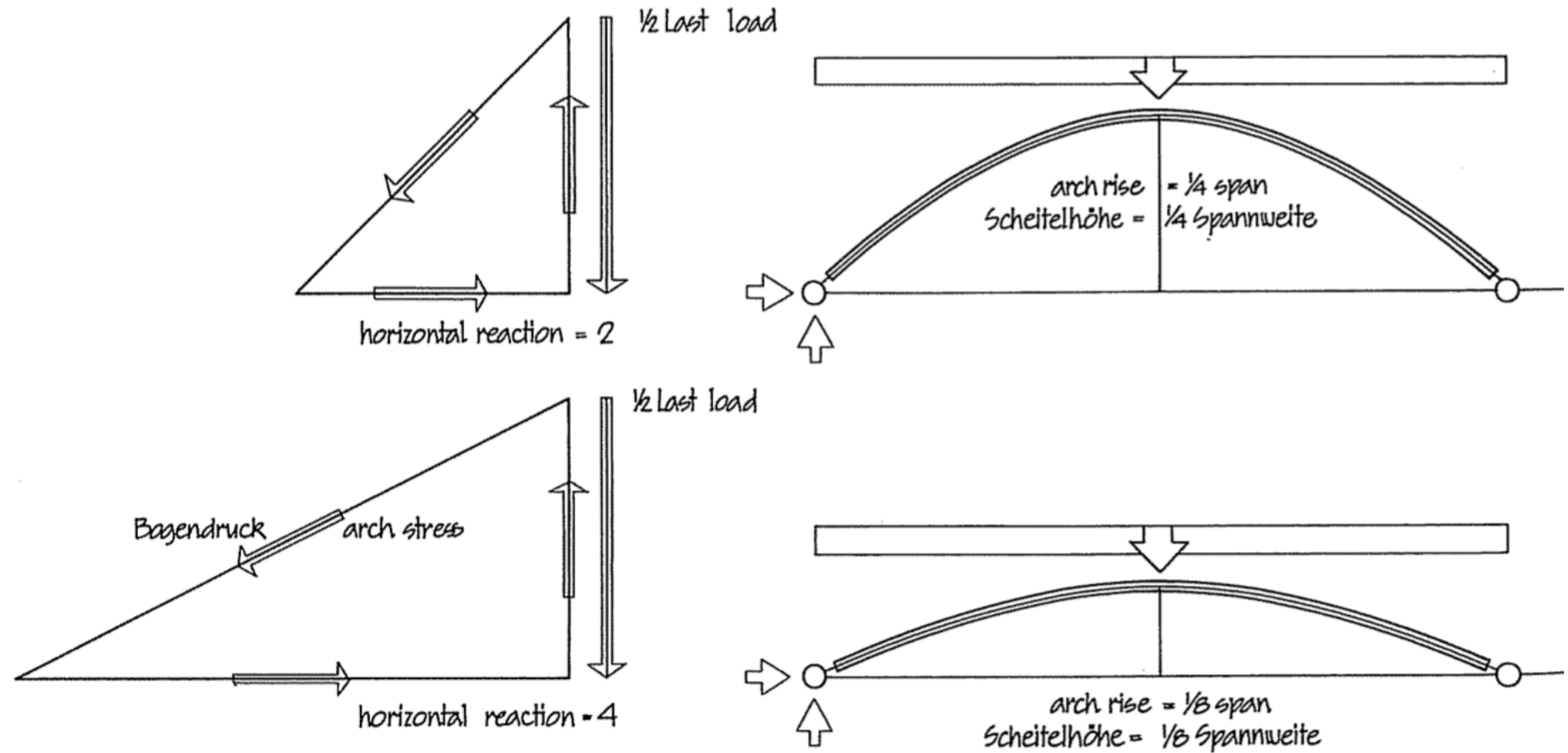


Der Horizontalschub eines Stützbogens ist umgekehrt proportional zu seiner Scheitelhöhe. Zur Schubminderung sollte die Scheitelhöhe so hoch wie möglich gewählt werden.

the thrust of an arch is inversely proportional to its rise. for reduction of thrust the arch rise should be as high as possible

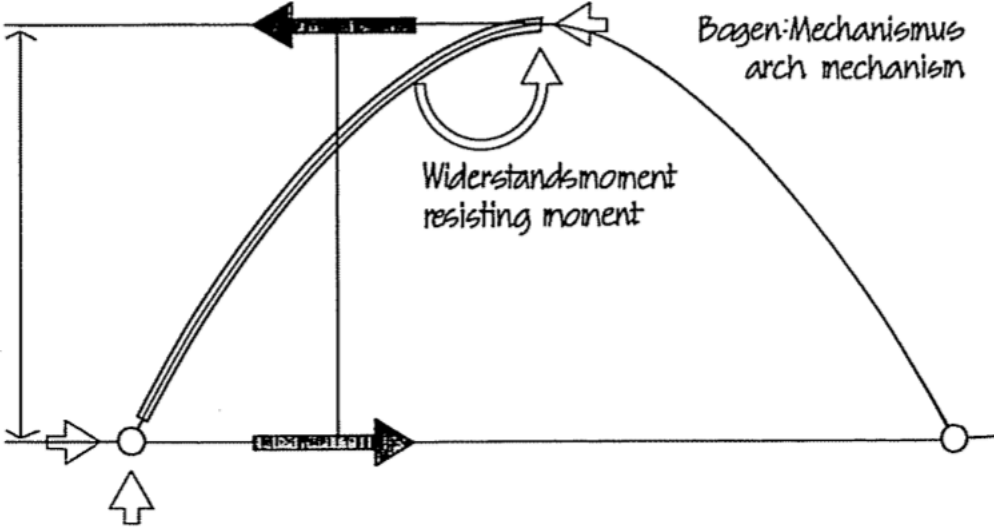
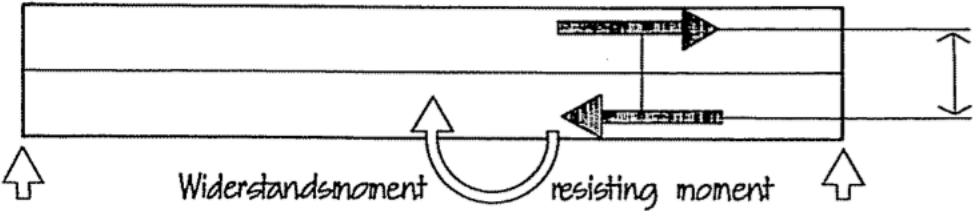


INFLUENCE OF ARCH RISE ON HINGE STRESSES (2/2)



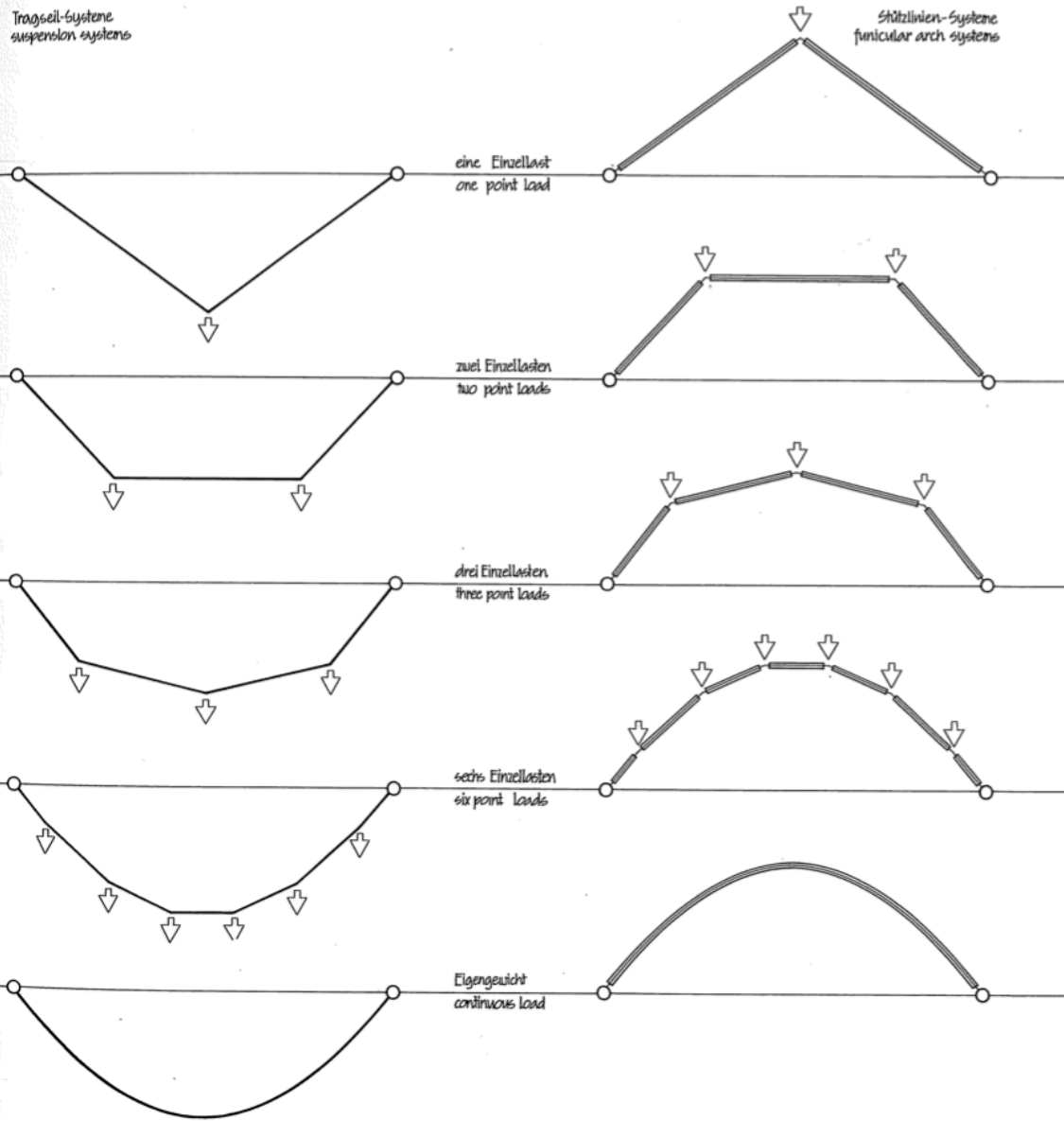
COMPARISON BETWEEN BEAM MECHANISM AND ARCH MECHANISM

Tragbalken-Mechanismus beam mechanism



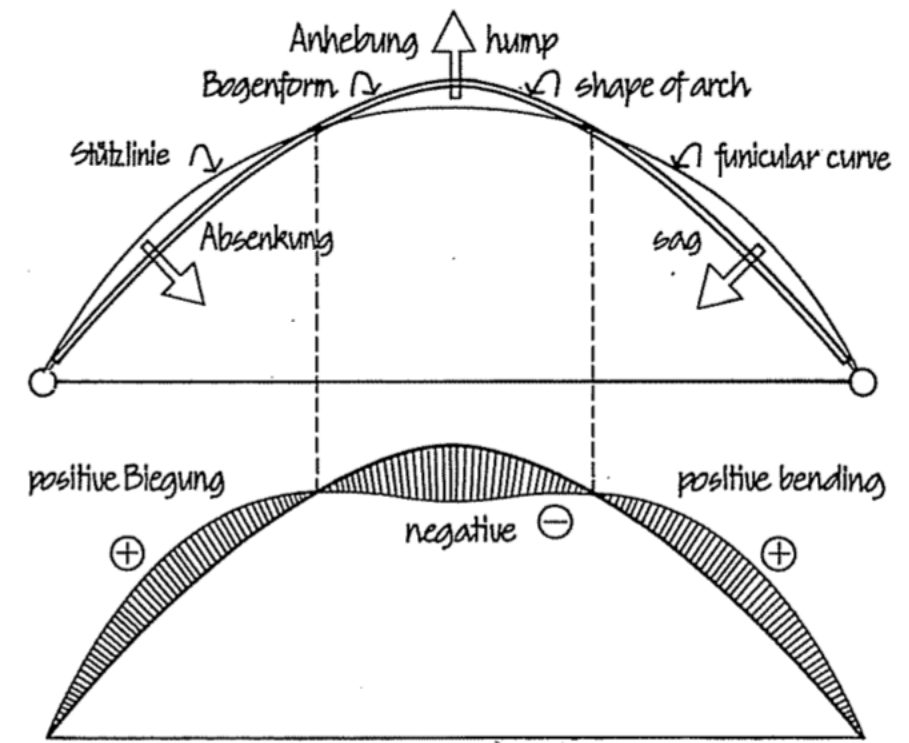
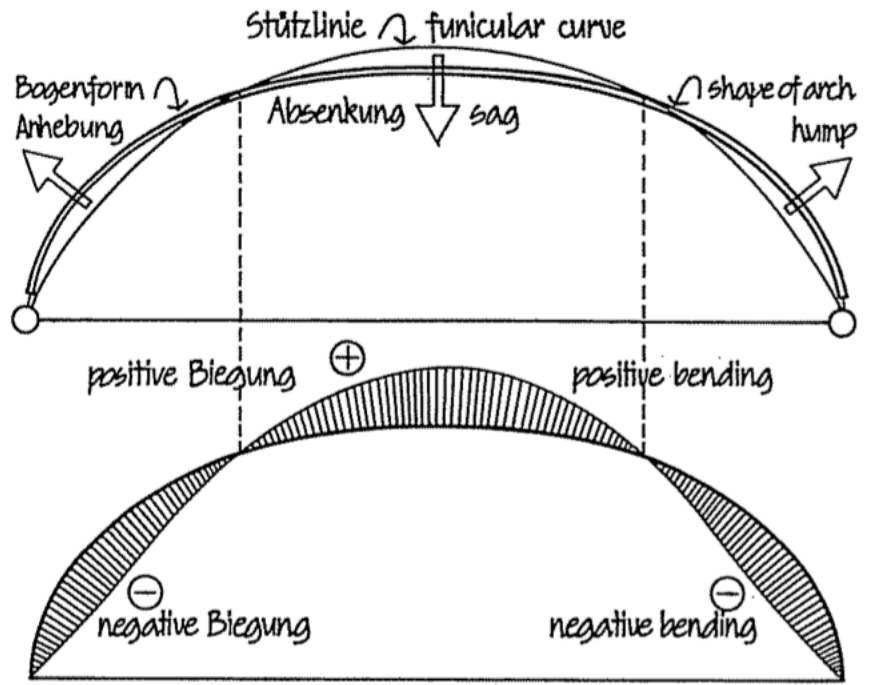
RELATIONSHIP BETWEEN SUSPENSION CABLE AND FUNICULAR ARCH

Suspension systems



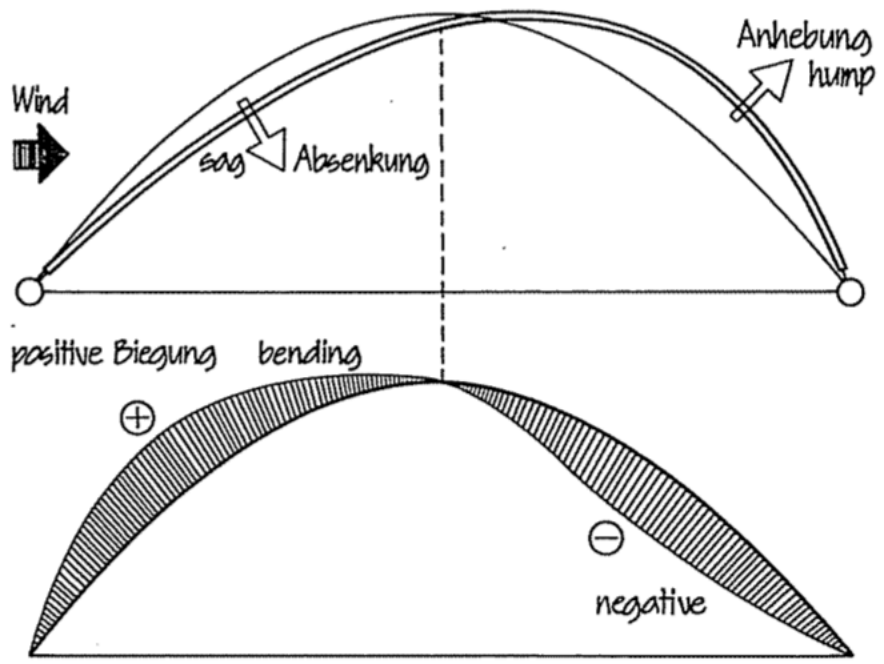
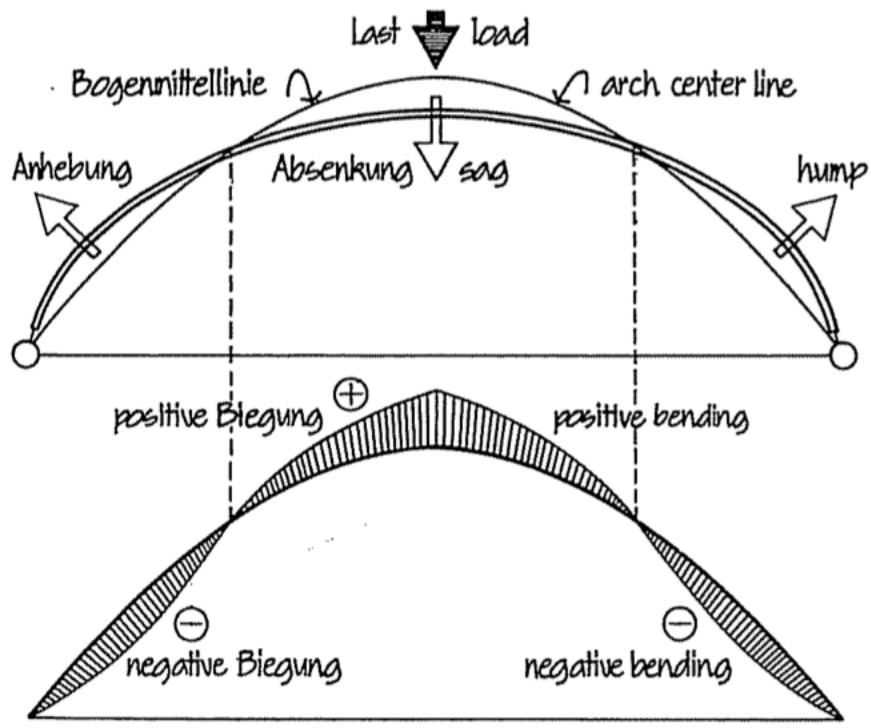
Funicular arch systems

BENDING DUE TO DEVIATION OF CENTER LINE FROM FUNICULAR CURVE



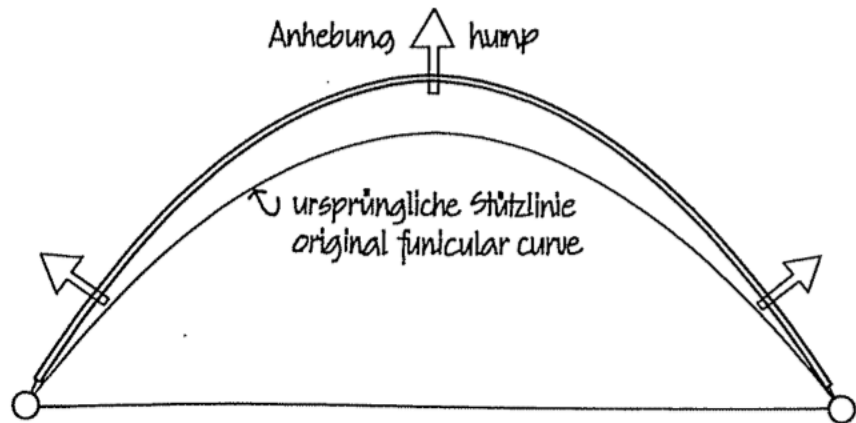
Jede Abweichung der Bogenmittellinie von der Stützlinie bewirkt, daß der Bogen sich entweder hebt oder senkt, und verursacht dadurch Biegung
any deviation of the arch center line from the funicular compression line will cause either hump or sag of the arch resulting in bending

BENDING DUE TO ADDITIONAL VERTICAL OR HORIZONTAL LOADING



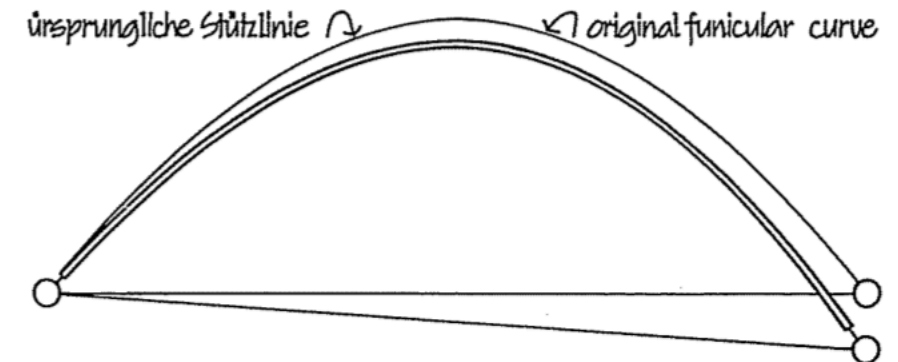
Jede Zusatzlast bewirkt, daß die Bogenform sich ändert und somit die Mittellinie von der Stützlinie abweicht. Es entsteht Biegung
any additional load will cause deflection of the arch and hence deviation from the funicular line of compression resulting in bending

Temperaturveränderungen thermal changes



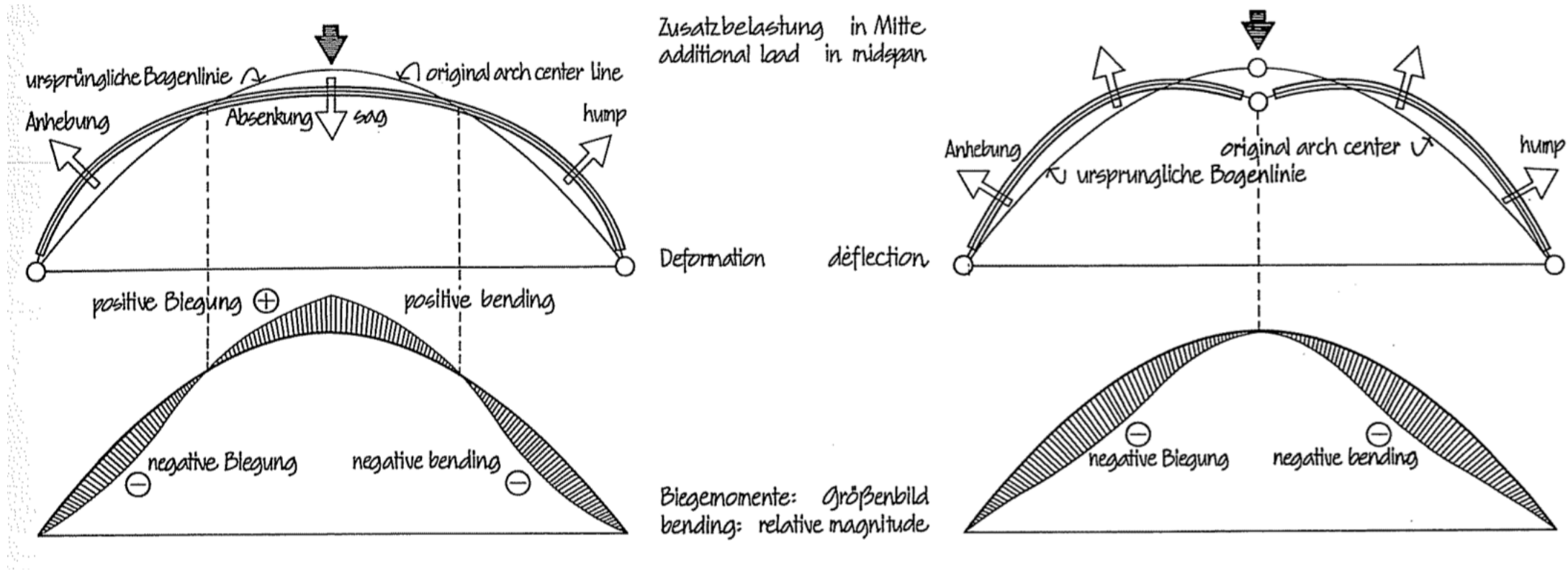
Ausdehnung (Kontraktion) durch Temp. Änderung verursacht Biegung
extension (contraction) due to thermal changes introduces bending

Fundamentsetzungen foundation settings

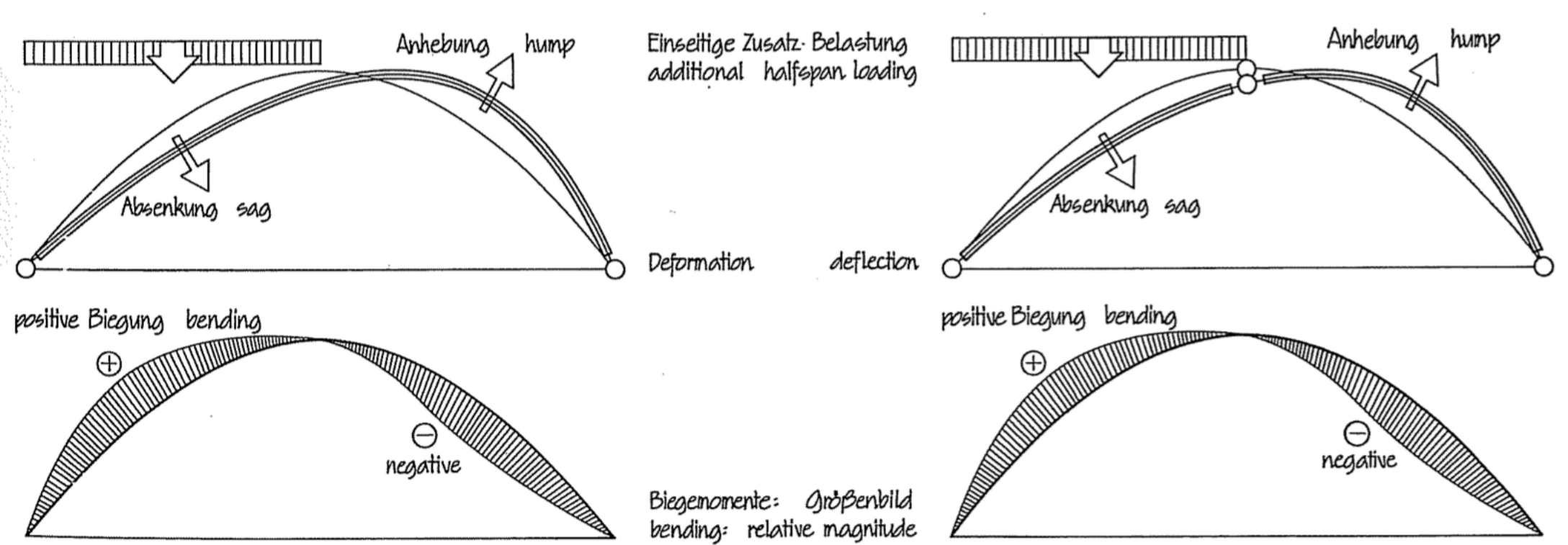


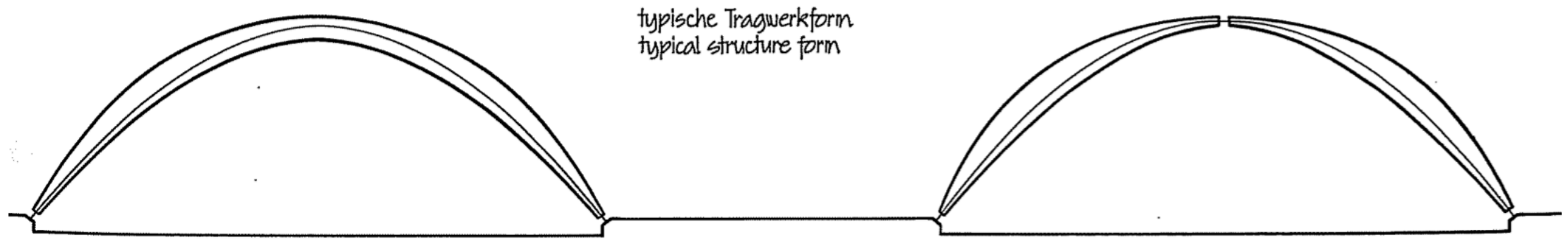
verschobene Belastung durch ungleiche Setzungen bewirkt Biegung
different loading caused by unequal setting produces bending

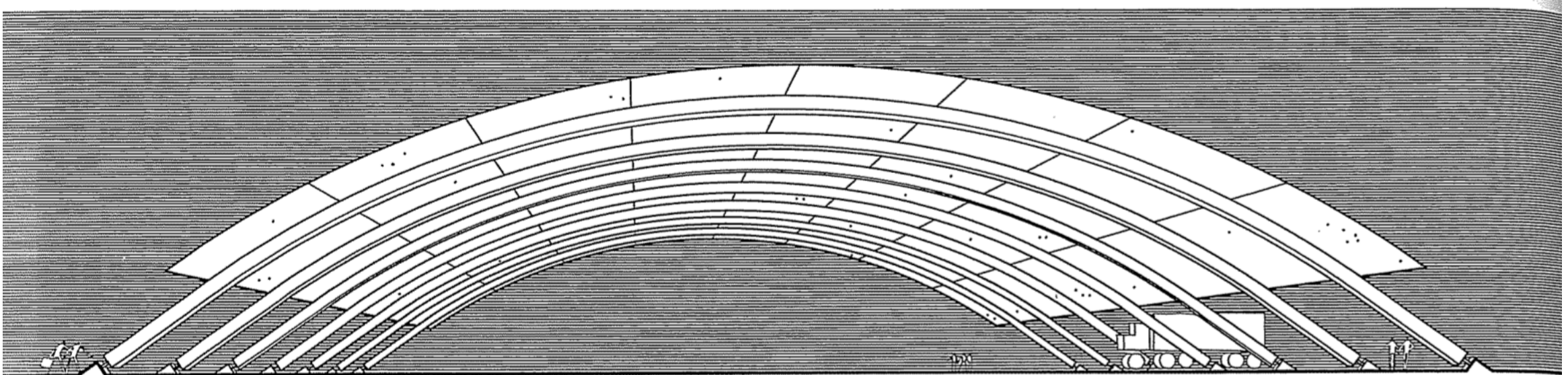
COMPARISON BETWEEN TWO-HINGED ARCH AND THREE-HINGED ARCH (1/3)



COMPARISON BETWEEN TWO-HINGED ARCH AND THREE-HINGED ARCH (2/3)



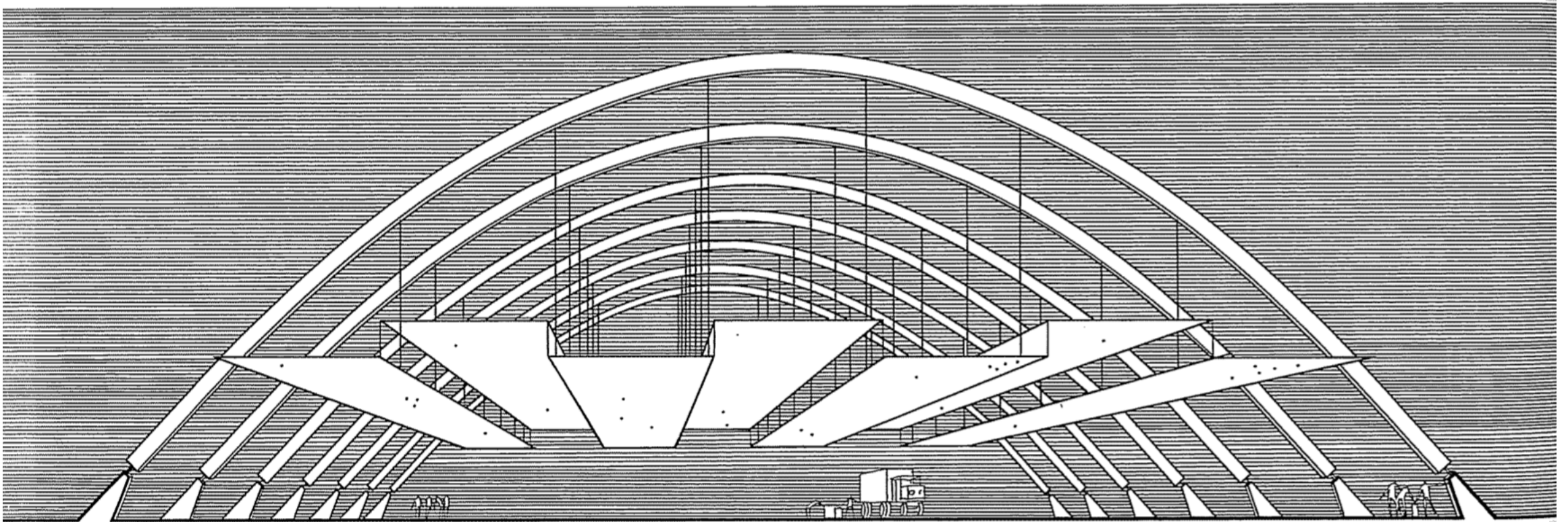




Erdrverankerte Bögen mit aufliegender gewölbter Dachkonstruktion
foundation arches with curved roof structure on top

Form der Stützlinie: Kettenlinie
funicular curve: catenary

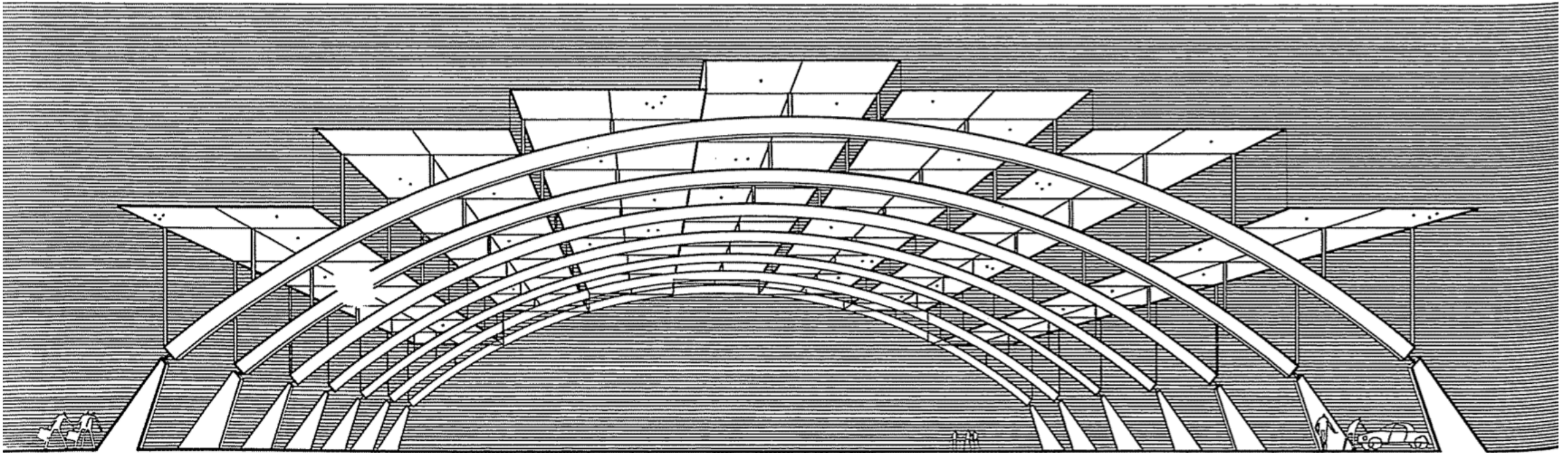
Scheitelhöhe = $\frac{1}{5}$ Spannweite
arch rise = $\frac{1}{5}$ span



Abgestrebte Bögen mit abgehängter horizontaler Dachkonstruktion
buttressed arches with suspended horizontal roof structure

Form der Stützlinie: parabolisches Polygon
funicular curve: parabolic polygon

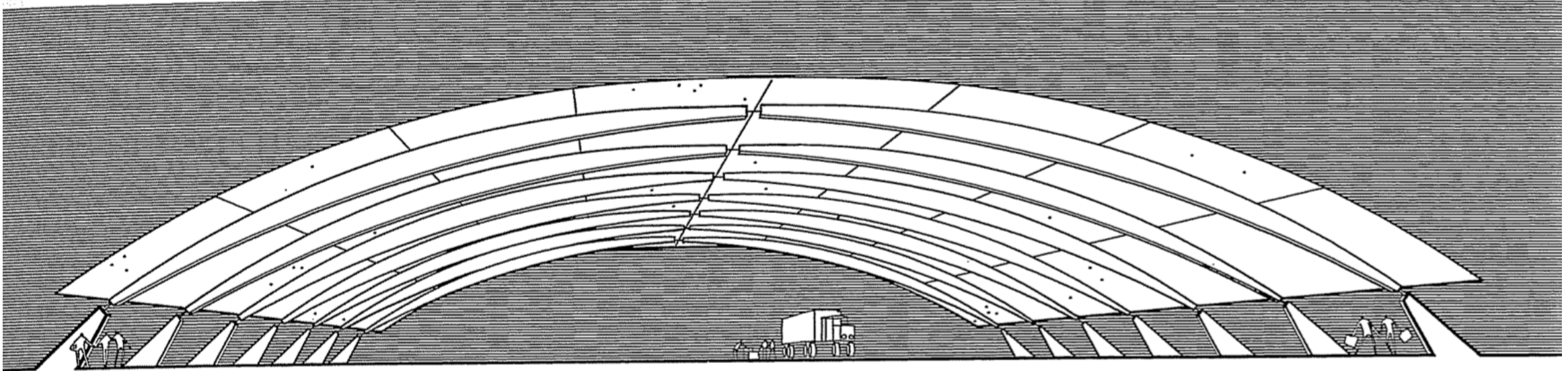
Scheitelhöhe = $\frac{1}{3}$ Spannweite
arch rise = $\frac{1}{3}$ span



Abgestrebte Bögen mit aufgesetzter horizontaler Dachkonstruktion
buttressed arches supporting horizontal roof structure atop

Form der Stützlinie: parabolisches Polygon
funicular curve: parabolic polygon

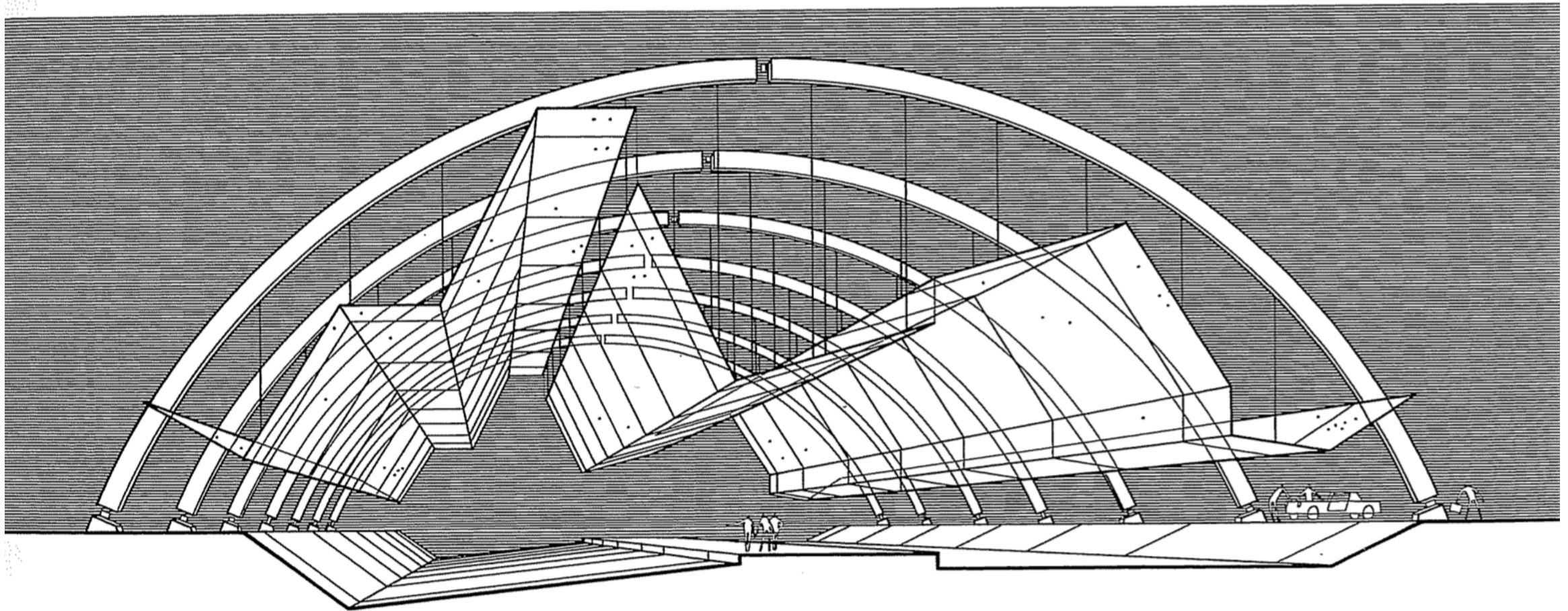
Scheitelhöhe = $\frac{1}{5}$ Spannweite
arch rise = $\frac{1}{5}$ span



Abgestrebte Bögen mit aufliegender gewölbter Dachkonstruktion
buttressed arches with curved roof structure atop

Form der Stützlinie: Kettenlinie
funicular curve: catenary

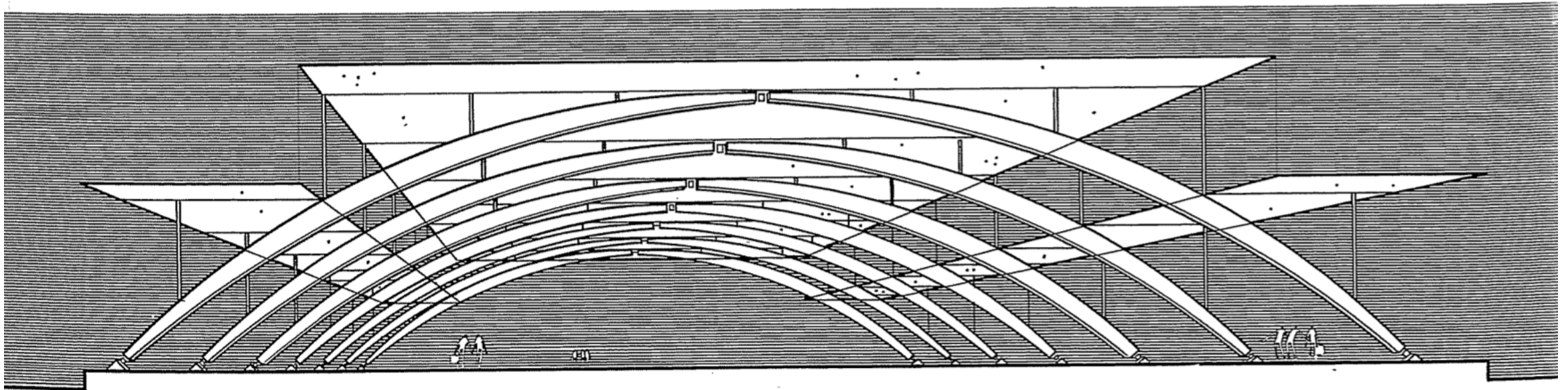
Scheitelhöhe = $\frac{1}{7}$ Spannweite
arch rise = $\frac{1}{7}$ span



Kreisförmige erdverankerte Bögen mit abgehängter freigestalteter Dachkonstruktion
segmental foundation arches with suspended free-form roof structure

Form der Stützlinie: unregelmäßiges Polygon
funicular curve: irregular polygon

Scheitelhöhe = $\frac{1}{3}$ Spannweite
arch rise = $\frac{1}{3}$ span



erdverankerte Bögen mit aufgesetzter horizontaler Dachkonstruktion
foundation arches supporting horizontal roof structure atop

Form der Stützlinie: parabolisches Polygon
funicular curve: parabolic polygon

Scheitelhöhe = $\frac{1}{5}$ Spannweite
arch rise = $\frac{1}{5}$ span