Berlin Hauptbahnhof

(Berlin Central Station)

Case Study
ARCH 631 - Fall 2017

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Overview

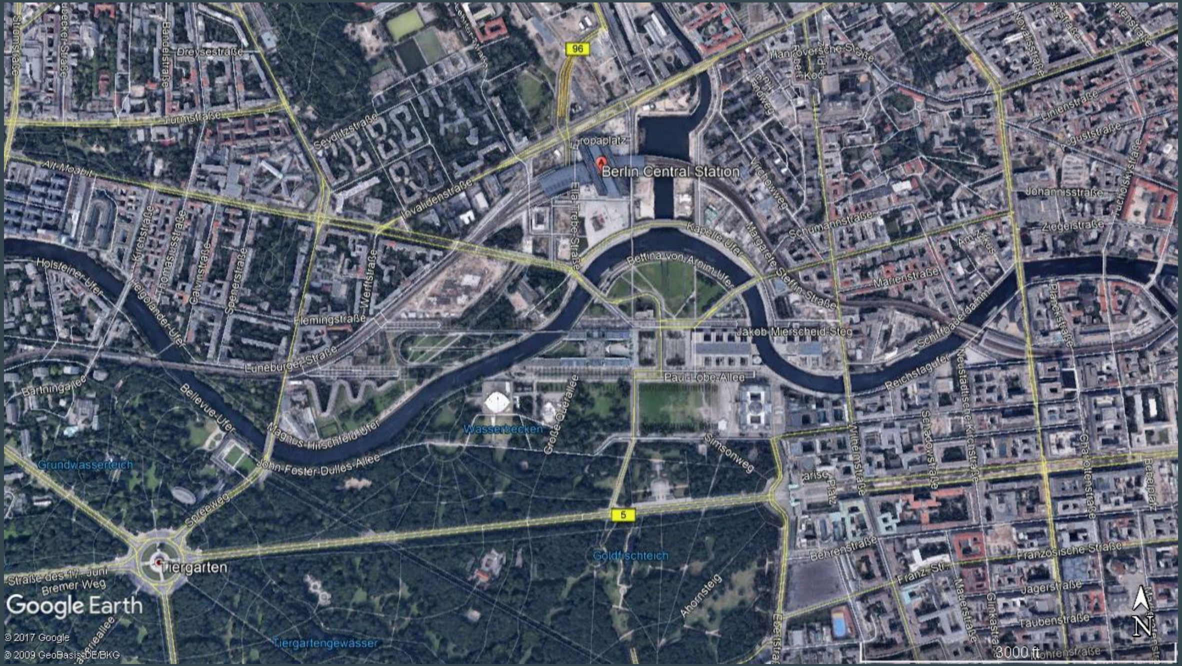
- Location: Berlin, Germany
- Project Duration: 1996 - 2006
- Gross Floor Area: 175,000 m^2 (1.9 million ft^2)
- Site Area: 100,000 m^2 (1.1 million ft^2)
- Client: Deutsche Bahn AG
- Project Cost: $894 million

Background

- Architect: GMP Architects
- Design: Meinhard von Gerkan and Jurgen Hillmer
- Structural Engineer: Schlaich, Bergermann, and Partners
- Lighting Design: Peter Andres and Conceptlicht
- Mechanical: Ingenieurgesellschaft Hopfner

Background

- Europe's largest train station
- Located along the Spree River, north of the Tiergarten
- Located on the site of historic Lehrter Bahnhof
- Central node for tracks in all four cardinal directions
- Apart of a design competition in 1993



Building Specifics

- Area Breakdown
  - Shops and Gastronomy - 15,000 m² (162,000 ft²)
  - Office - 50,000 m² (540,000 ft²)
  - Railway Operations - 15,000 m² (162,000 ft²)
  - Circulation - 21,000 m² (230,000 ft²)
  - Platforms - 32,000 m² (350,000 ft²)
  - Parking - 25,000 m² (270,000 ft²)

- North-South tracks located 15m below ground level in tunnel

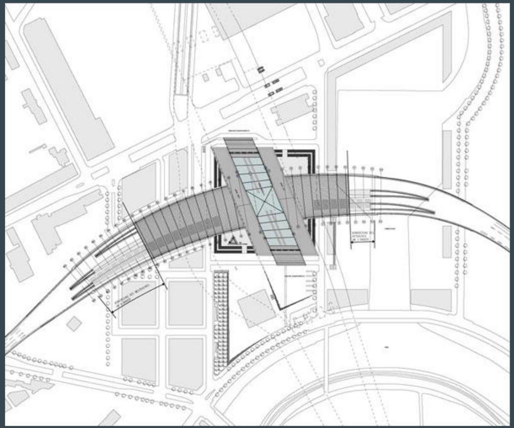
- East-West tracks located 10m above ground level

- Ground level accesses public, individual, and tourist transportation

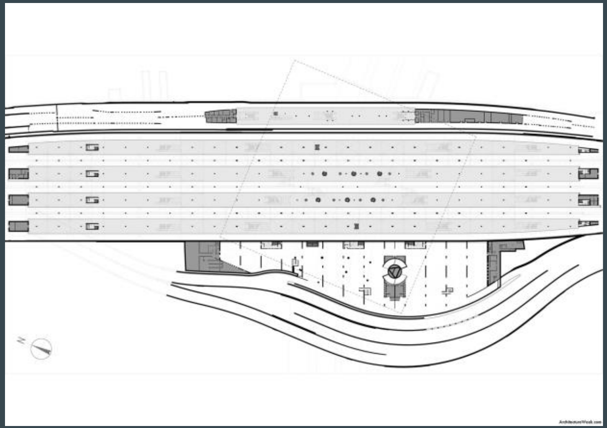
Building Specifics

- Cruciform shape created by crossing of north-south and east-west tracks
- East-West tracks covered by long, curved glass hall
- Five story main hall runs north-south with barrel vault roof
- Two twelve story office buildings flank the sides of the main hall
- Two bridges link the office towers above the east-west hall
- Use of glass allows natural light throughout entire building

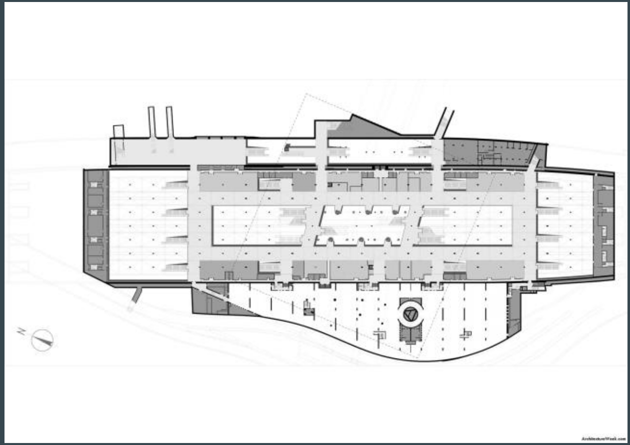
Plans



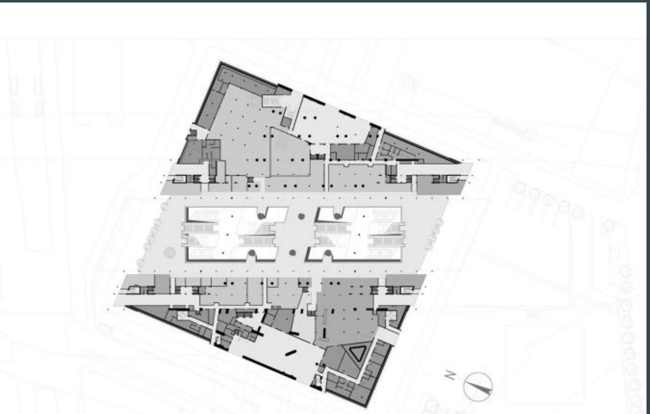
Site Plan



First Level (-2)



Second Level (-1)

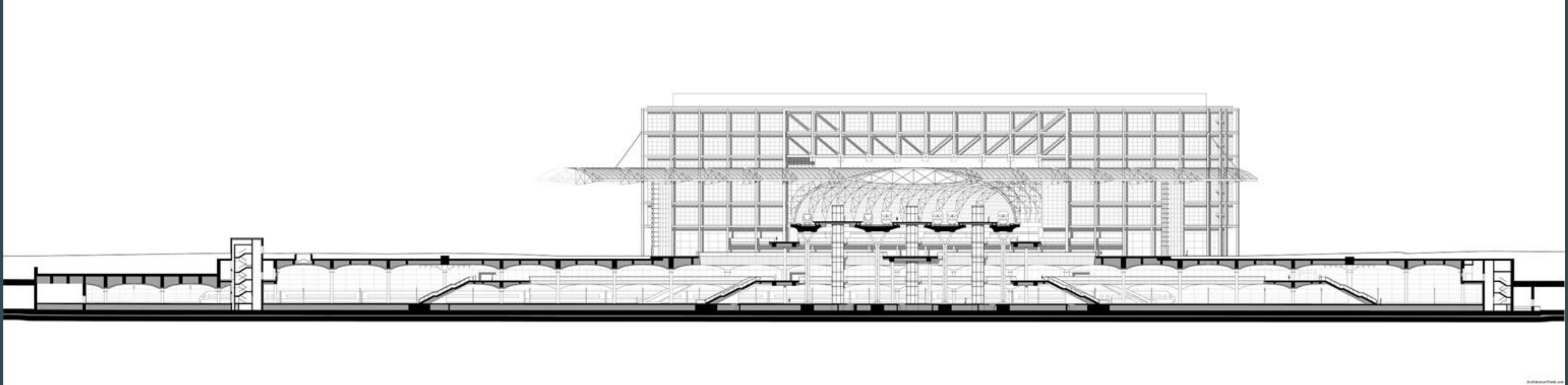


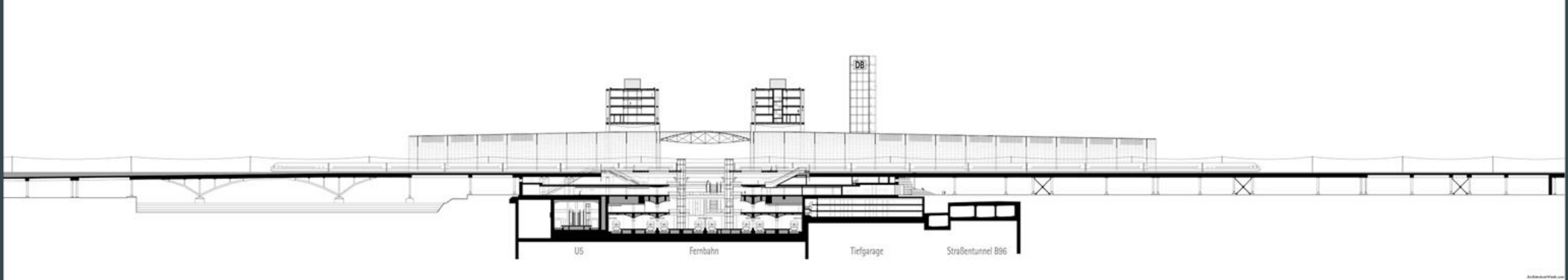
Ground Level (0)

Fourth Level (+1)

Fifth Level (+2)

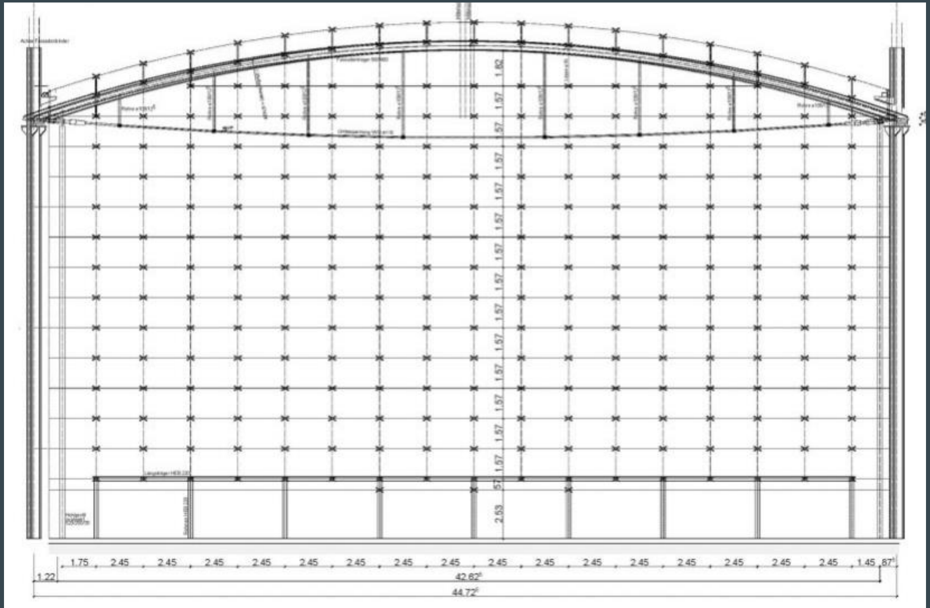
Sections



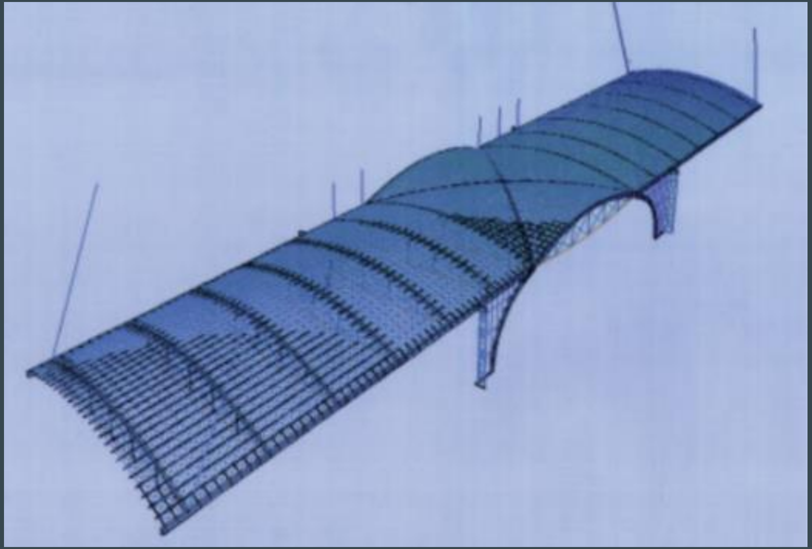


Dimensions

- Structural system of North-South arch roof



Dimensions of the facade with a width of 44.72m and a height of 25 m

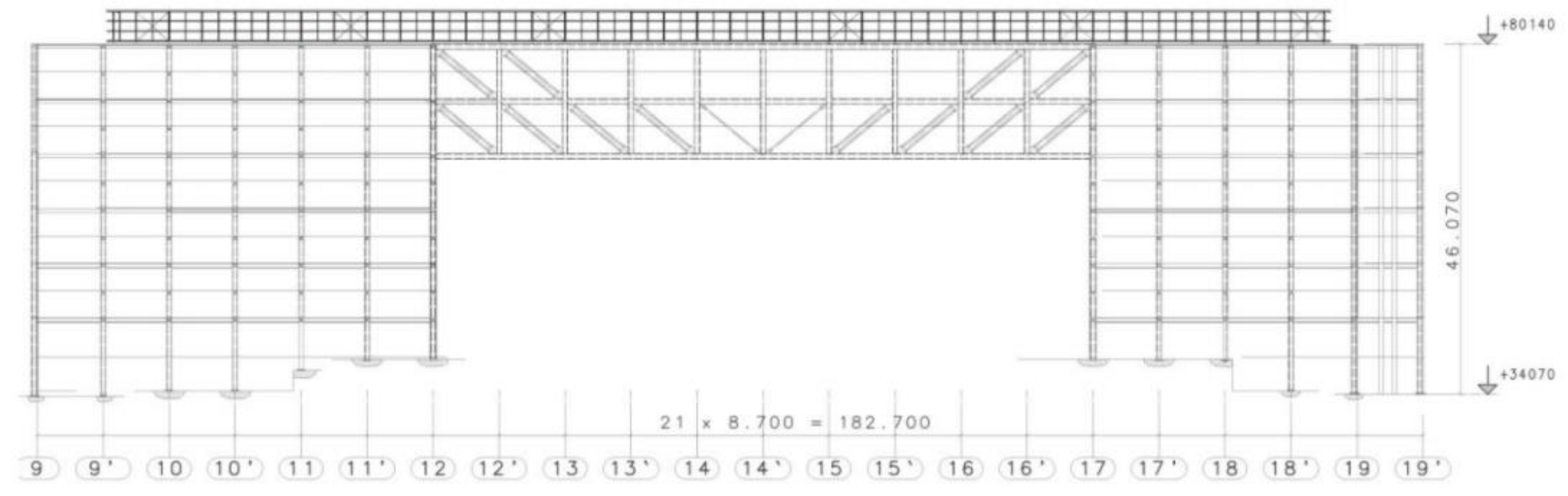


Length: 200m   Width: 44.72m

Span of center cross are 65m and 45m

Dimensions

- Structural system of office building (North-South)



Length: 182.70m Height: 46.07m Each span is 8.70m

Dimensions

- The supporting structure of the roof surface directly covered with glass is provided by a quadrangular network .

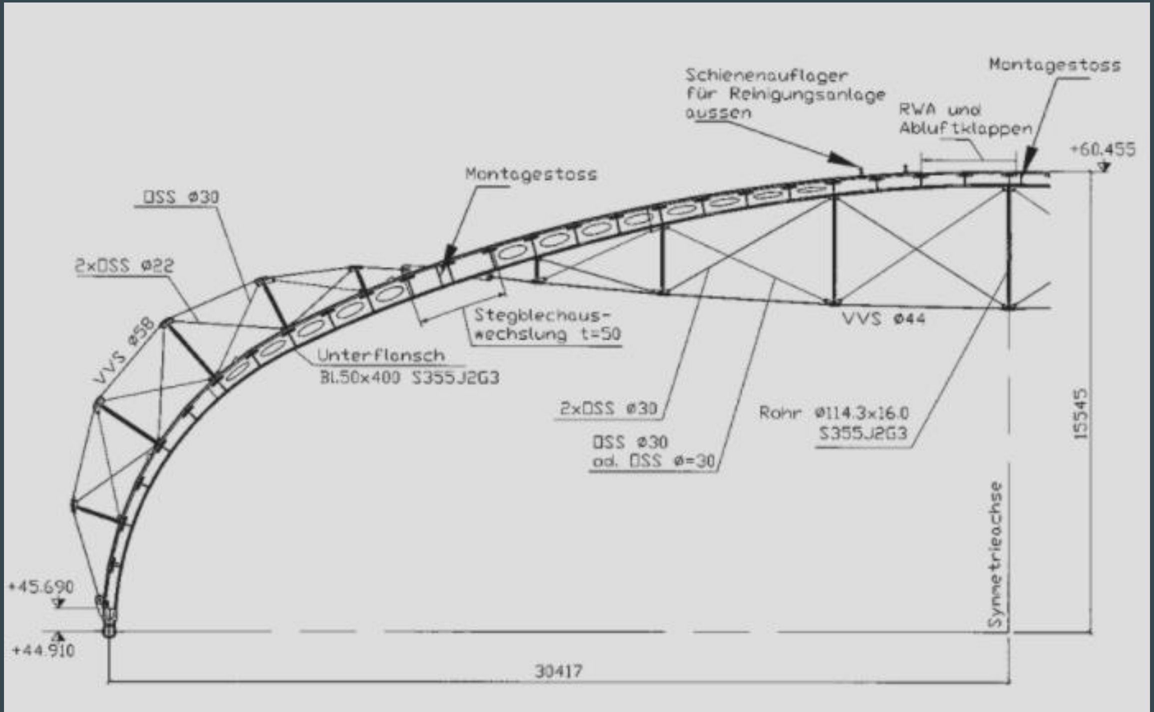
- Mesh sizes of about 1.50 m to 1.70 m formed, which is braced diagonally with ropes.

Dimensions

- Structural system of half arch girder

Width: 30.417m

Height: 15.545m



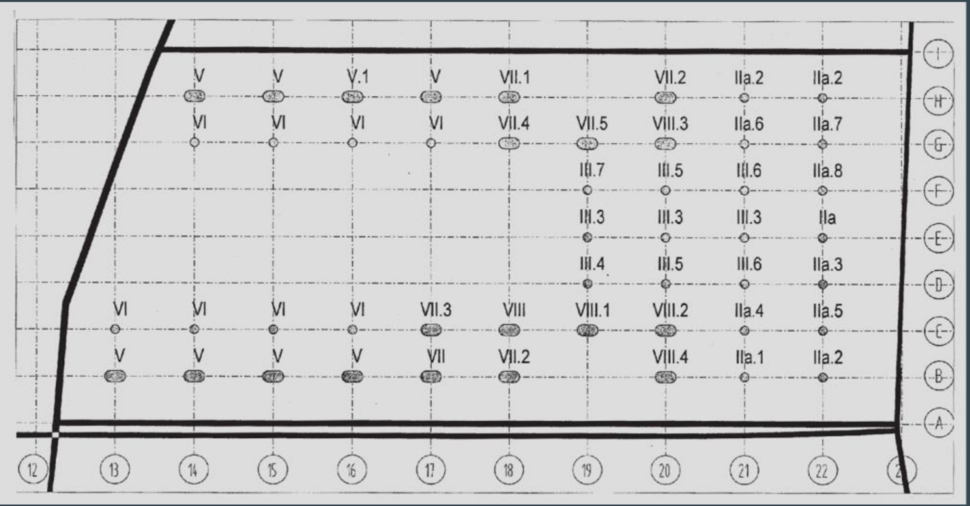
Materials

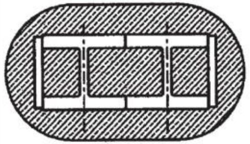
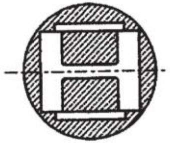
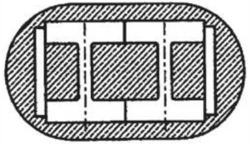
- Concrete
  - 500,000 m^3
  - Foundation/Floors/Tracks
- Steel
  - 85,000 tons
  - 85 miles of steel cable
  - 23 steel trusses
- Glass
  - 27,000 glass blocks in ventilation tower
  - 20,000 m^2/11,800 panels
- Solar Panels
  - Integrated into glass roof
  - 780 panels on the east-west roof

Structural Components

Composite columns

The main structure is formed by the railway tunnels and the supporting ceiling construction. The composite columns are connected rigidly to the structure base and the ceiling.

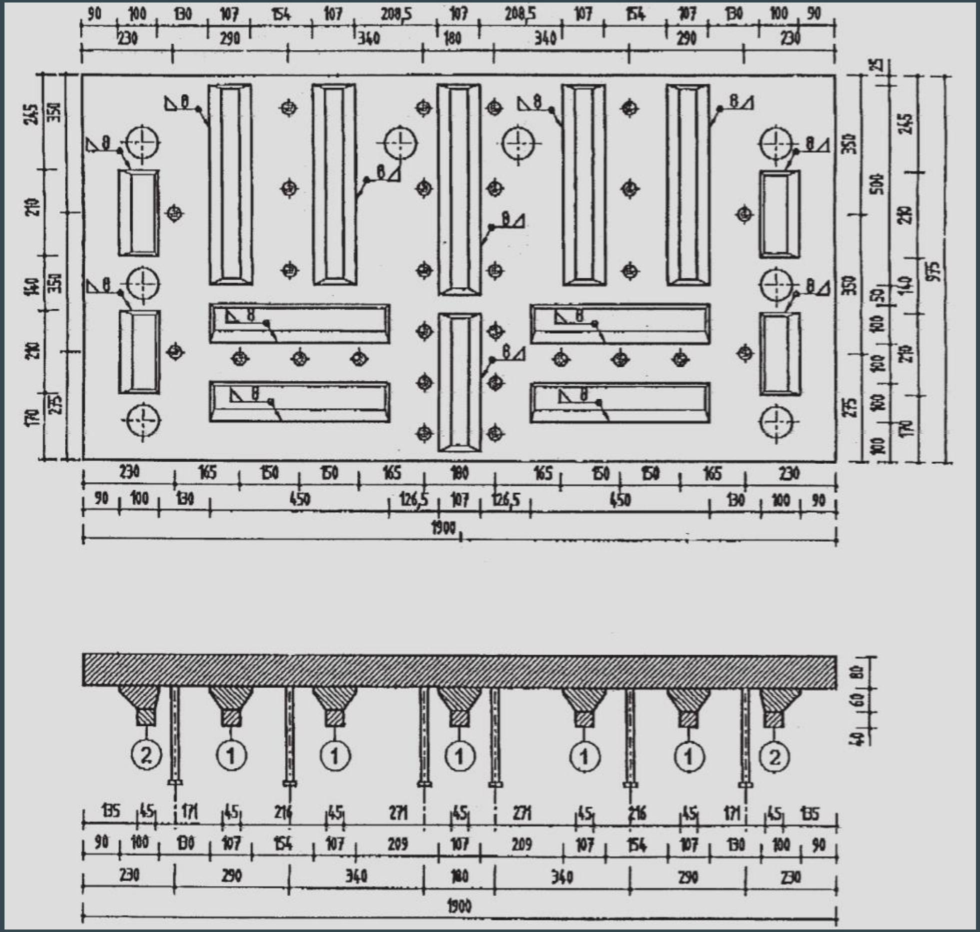


Typ	V	VI	VII/VIII
Querschnitt			
Profil	2 × HD 400 × 634 HISTAR 460	HD × 1086 HISTAR 460	2 × HD 400 × 1086 HISTAR 460 (VII) S 355 K2 G3 (VIII)
	2 × Bl. 45 × 400 S 355 K2 G3	2 × Bl. 45 × 400 S 355 K2 G3	2 × Bl. 60 × 500 S 355 K2 G3
Rohr	762 × 12 S 355 K2 G3	762 × 12^5 S 355 K2 G3	762 × 12 S 355 K2 G3
Beton	B55	B55	B55

Structural Components

Base plate

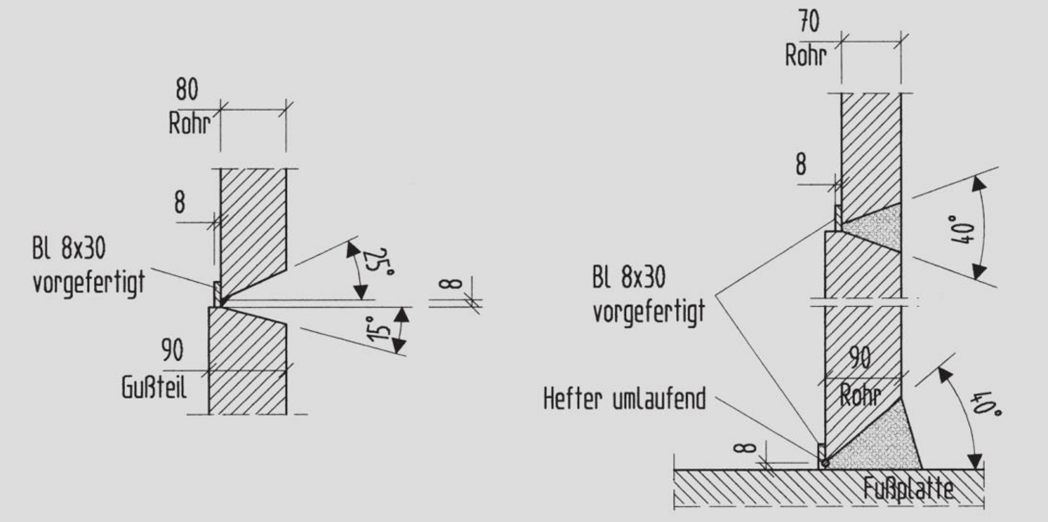
Push strips welded to the base plate. The studs serve as “connecting reinforcement” that is anchored to the base plate. The concrete failure under tensile stress on the anchor was detected after the approval.



Structural Connections

Welded joint between duct and casting of the tree column and welding of the tree columns with induction grinding

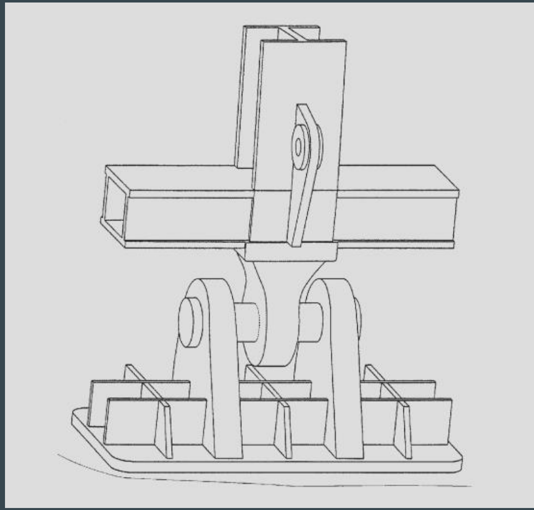
The welds were made with MAG-cored wire, the preheating temperatures were 145-165C, the intermediate layer temperatures 250C, in welding the castings induction loops have been set



Structural Connections

Bottom part of the bearing, footpoint of the truss

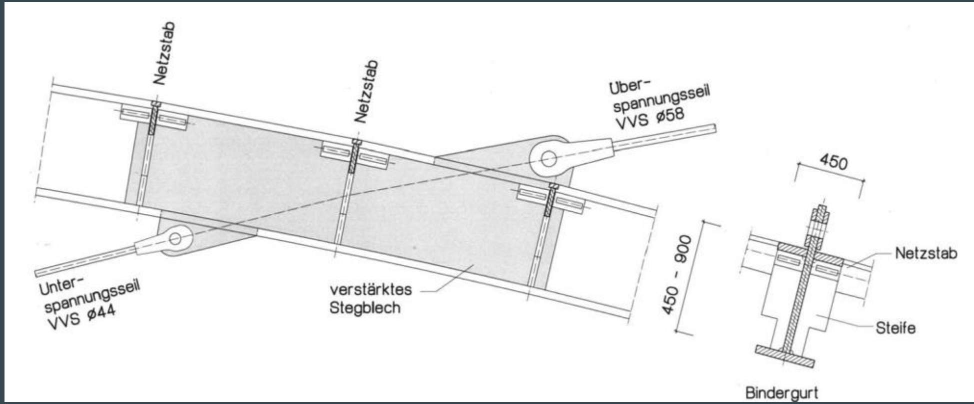
The first step in analysis of a truss is to determine whether the truss is a stable configuration of members.

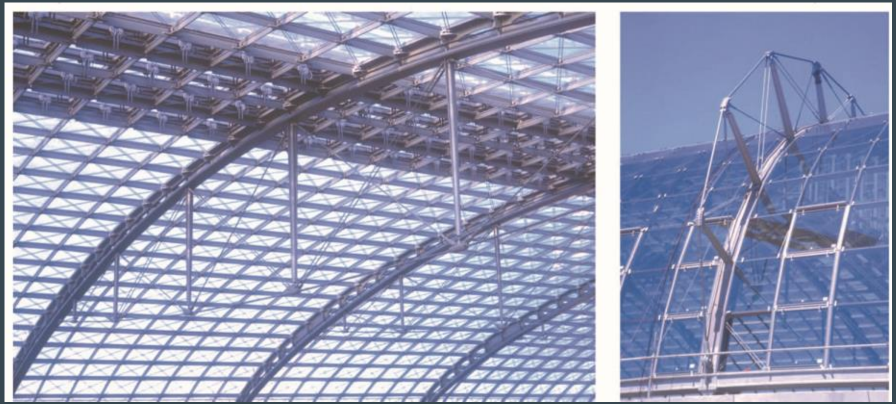


Structural Connections

Connection of the cables to the girder

Cable are used for long spans and in situation that allow the structure to be shaped with a significant depth. Of particular concern are the reaction forces at the connections of the cables to the supporting structure and especially the horizontal components of reactions.





Gravity Loads

LRFD basic Combinations: 1.2D+1.6L+0.5(Lr or S or R)

Dead loads: Load (weight of building materials)

Office Building: concrete floor+steel frame+curtain wall

Station: Dome structure

Live loads: Defined by Occupancy type (Table 1607.7)

Office Building: office building--80 psf

Station: Assembly area--100 psf

Gravity Loads

Snow loads: Defined by snow zone

This project is located in Berlin.

In ZONE 2

SO the snow load is 18lb/sq.ft

Germany: snow

Snow Zone	Snow load		
	kN/m2	kg/m2	lbs/sq.ft.
1	≥0,65	66	14
1a	≥0,81	83	17
2	≥0,85	87	18
2a	≥1,06	108	22
3	≥1,10	112	23

Source: DIN1055-5

Lateral Loads

The basic lateral loads of buildings in

Berlin is wind load, From WEST, 100MPH

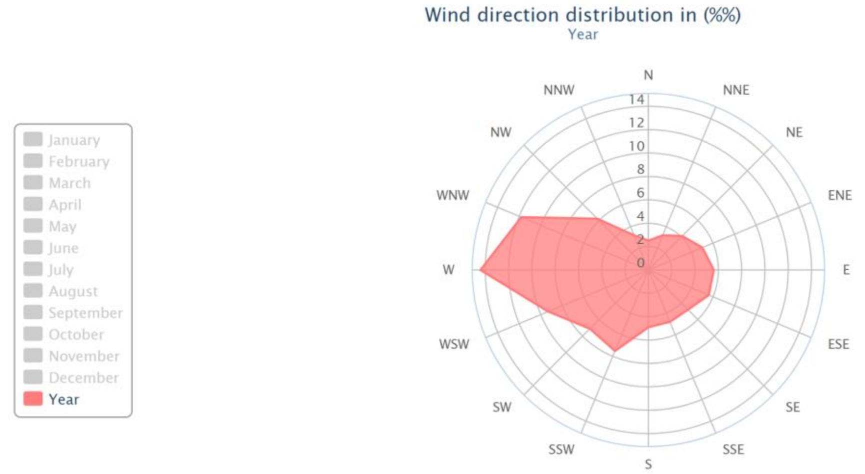


TABLE1604.10

GROUND SNOW LOADS; BASIC WIND SPEEDS; EARTHQUAKE DESIGN FACTORS

City/Town	Ground Snow Load p_g, psf	Basic Wind Speed V, MPH	Earthquake Design Factors	
			Ss	S_1
Abington	45	110	0.26	0.064
Acton	55	100	0.29	0.071
Acushnet	45	110	0.23	0.058
Adams	65	90	0.22	0.068
Agawam	55	100	0.23	0.065
Alford	65	90	0.22	0.066
Amesbury	55	110	0.35	0.077
Amherst	55	100	0.23	0.067
Andover	55	110	0.32	0.075
Aquinnah (see Gay Head)				
Arlington	45	105	0.29	0.069
Ashburnham	65	100	0.27	0.072
Ashby	65	100	0.28	0.072
Ashfield	65	100	0.22	0.068
Ashland	55	100	0.25	0.066
Athol	65	100	0.25	0.070
Attleboro	55	110	0.24	0.062
Auburn	55	100	0.23	0.065
Avon	55	100	0.26	0.064
Ayer	65	100	0.28	0.071
Barnstable	35	120	0.20	0.054
Barre	55	100	0.24	0.068
Becket	65	90	0.22	0.066
Bedford	55	100	0.29	0.071
Belchertown	55	100	0.23	0.066
Bellingham	55	100	0.24	0.064
Belmont	45	105	0.28	0.069
Berkley	55	110	0.24	0.061
Berlin	55	100	0.26	0.068

Analysis (Gravity)

Office Building:

Total of 85000 tons of steel, Curtain wall, Steel deck Concrete floors

1) Dead loads: Steel Frame: 360 lb/sq.ft

   25mm thick Curtain Wall: 12 lb/sq.ft

   Steel deck concrete floors: 8 lb/sq.ft

2) Live loads: Occupancy type--Office Building, 80 lb/sq.ft

   Roof-- Steel deck, 8 lb/sq.ft

3) Snow loads: In zone 2, 18lb/sq.ft

Analysis (Gravity)

Station:

Dome consisting by glass panels.

1) Dead loads: Same material as curtain wall--12 lb/sq.ft
2) Live loads: Occupancy type--Assembly area, 100 lb/sq.ft
3) Snow loads: 18 lb/sq.ft

Analysis (Lateral)

According to the table, wind speed in Berlin is 100 Mph

Calculating the wind pressure: $p = 0.00256 \times V^2$

$p = 25.6$ lb/sq.ft

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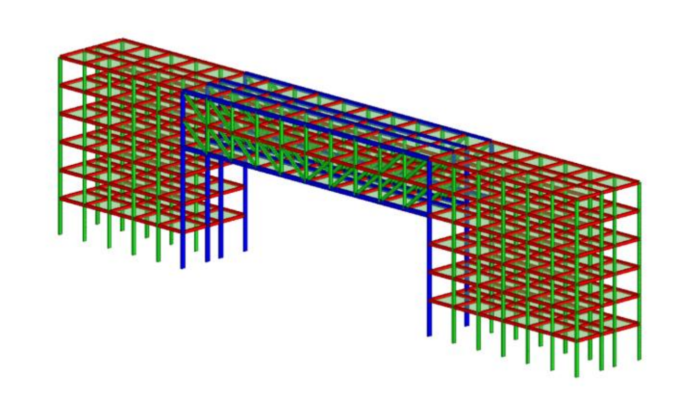
Foundation

- Sandy soil created complexities
- 1.5 million m^3 of soil removed on barges
- Concrete ponds 25m deep were poured for groundwater retention
- Divers constructed diaphragm walls and set concrete base slab in pits before they were drained
- Flat foundation
- Shallow foundation due to water level

Office Building Analysis



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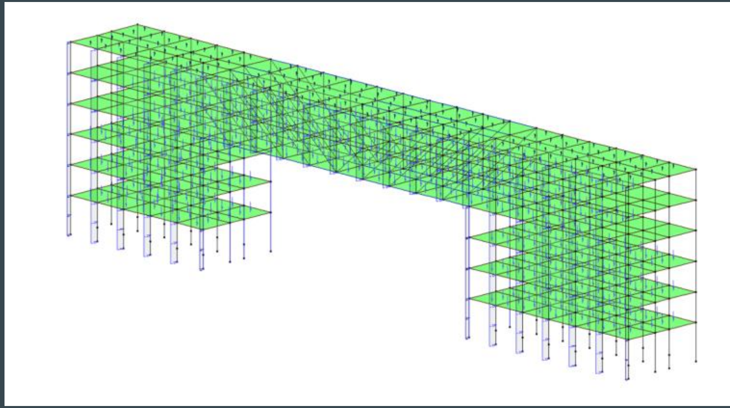
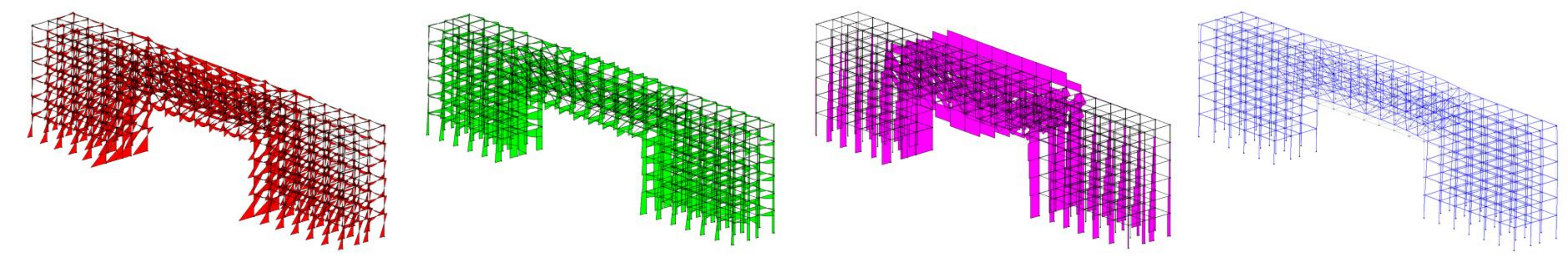
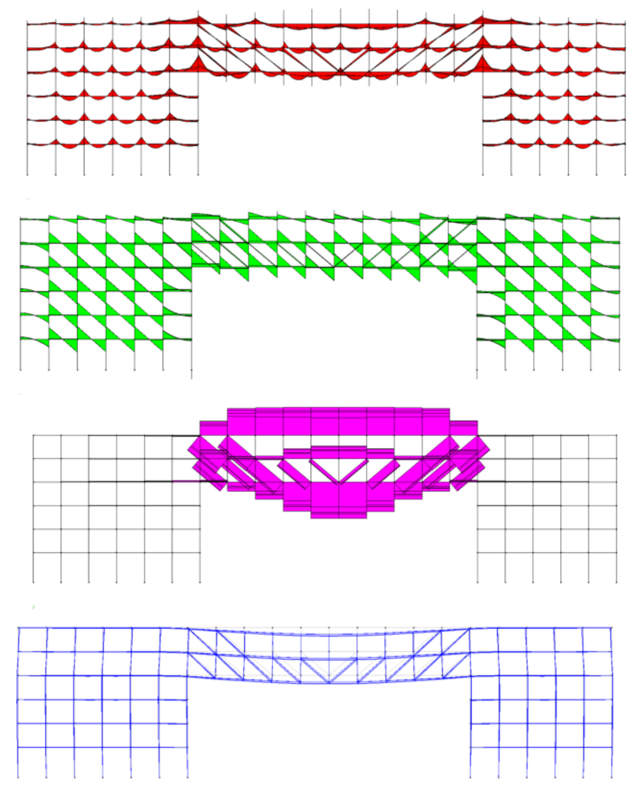




Mz Vy Px Defl.

Office Building Analysis



Mz

Vy

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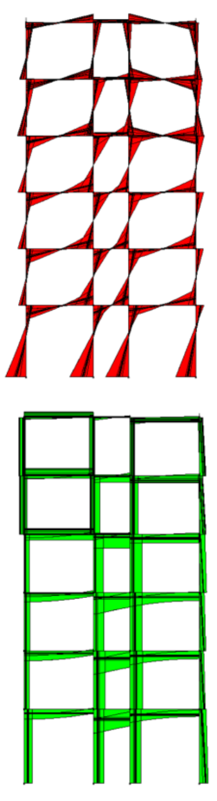
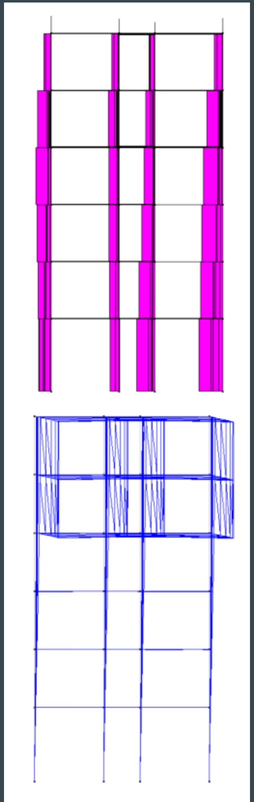


Mz

Vy



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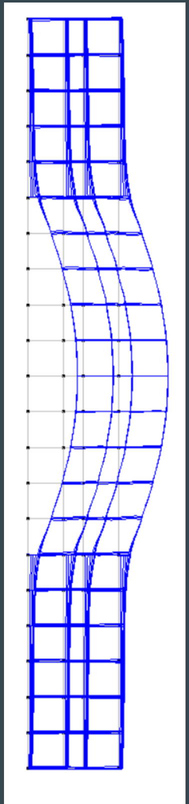


Office Building Analysis

Train Tunnel Analysis

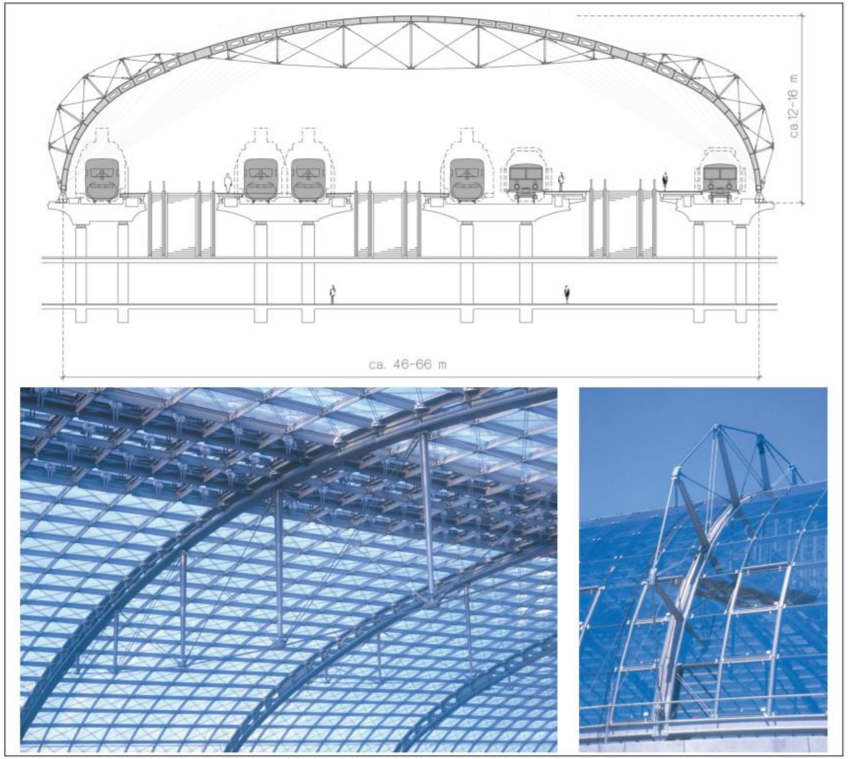


Bild 4. Dachbinder
Fig. 4. Roof girders

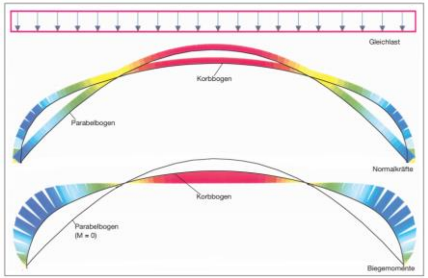


Bild 15. Das korbbogenartige Profil des Daches ist weit weg von der Stützlinienform
Fig. 15. The basket arch profile differs from the thrust line

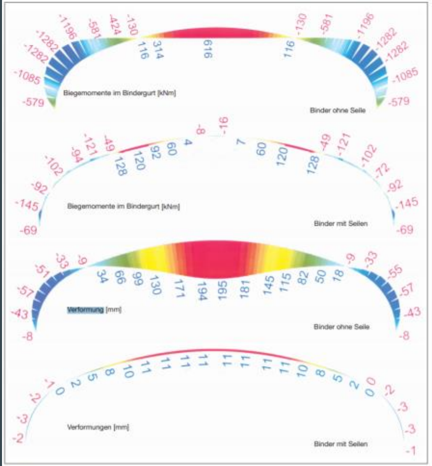


Bild 16. Die Seile sind so geführt, daß unter Gleichlast nur Normalkräfte im Bindergurt auftreten
Fig. 16. The bracing cables are so arranged that only normal forces result in the chord under uniformly distributed loads

Atrium Analysis

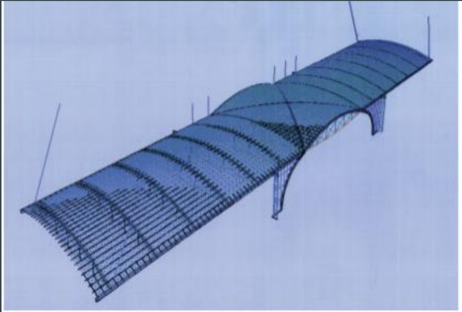


Bild 5. Tragsystem des Nord-Süd-Daches
Fig. 5. Structural system of North-South-roof

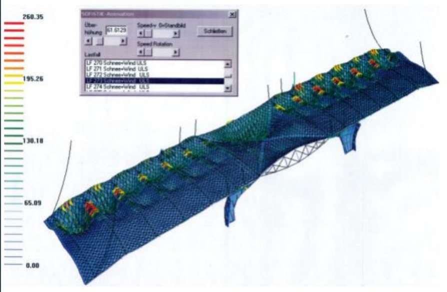


Bild 11. Spannungen und Verformungen im Lastfall 273 (Eigengewicht, Vorspannung, Schneeverwehung und asymmetrischer Wind)
Fig. 11. Stresses and deflections of load case combination 273 (dead loads, pre-stress, snow and asymmetric wind loads)

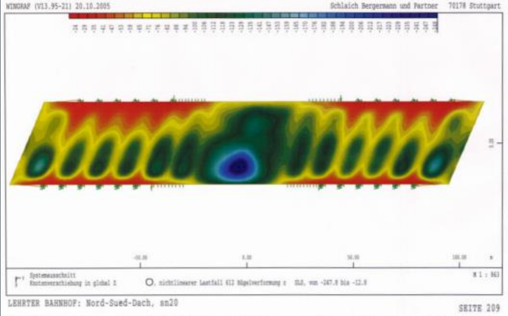


Bild 12. Vertikale Verformungen im Lastfall 612 (Eigengewicht, Vorspannung, Schneeverwehung, asymmetrischer Wind, Vertikalverschiebung Bügelbauten, Anhängelasten, Dachbefahranlage)
Fig. 12. Vertical deflection of load case combination 612 (dead loads, pre-stress, snow, asymmetric wind loads, support movement and live loads)

Bild 8. Ansicht Seilbinder
Fig. 8. View of the cable-span girder

Bild 14. Binderseilklemmen
Fig. 14. Clamps of girder cables

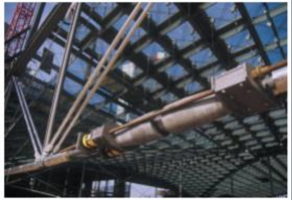
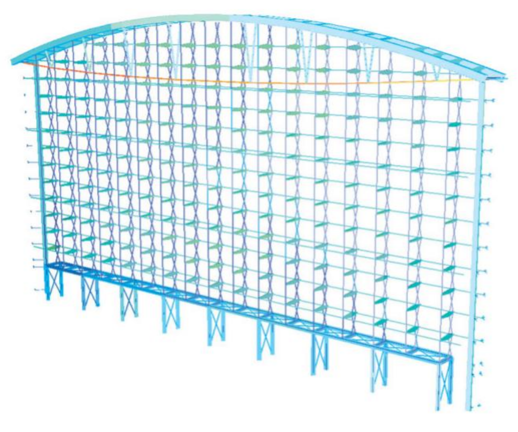


Bild 22. Hydraulische Pressen zur Seilvorspannung
Fig. 22. Hydraulic press to pre-stress the cables

Atrium Curtain Wall Analysis



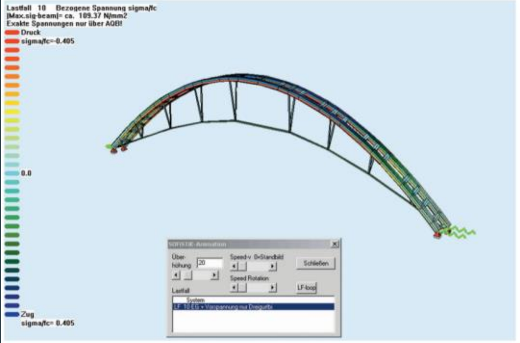


Bild 17. Dreigurtbinder mit vorgespanntem Unterspannungsseil (Überhöhung 20fach)
Fig. 17. Arched girder with prestressing

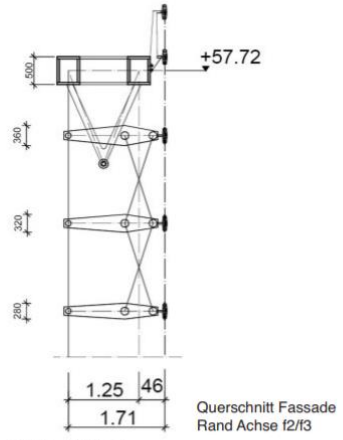


Bild 2. Seilbinder
Fig. 2. Cable girder

Bild 7. Ansicht der unteren Glasschwerter
Fig. 7. View of the glass fins over the portal frame

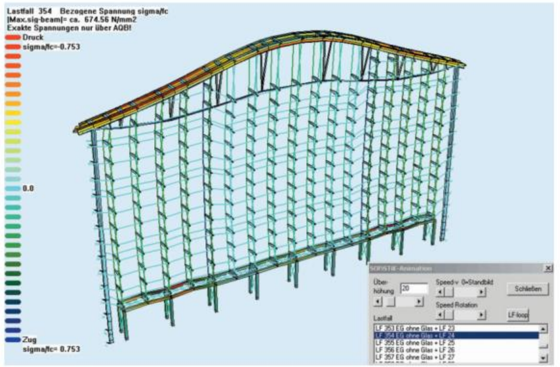


Bild 18. Vorspannung der fünf äußeren Seilbinder
Fig. 18. Prestressing of the five outer cable girders

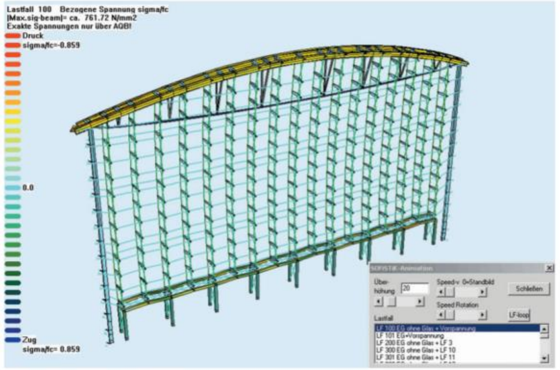


Bild 20. Vollständig vorgespannte Fassade
Fig. 20. Completly prestressed facade

References

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