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POSTER SESSION 8

Innovative Building Structures

Structures nouvelles de bâtiments

Neuzeitliche Tragwerke des Hochbaus

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Die Hanns-Martin-Schleyer-Halle in Stuttgart dient sportlichen und anderen Großveranstaltungen: Radrennen, Leichtathletik, Ballspiele, Boxen, Eislaufveranstaltungen, Poppkonzerte, Tagungen, Aktionärsversammlungen, Parteitage usw.
Die wichtigsten Daten sind im Poster angegeben.

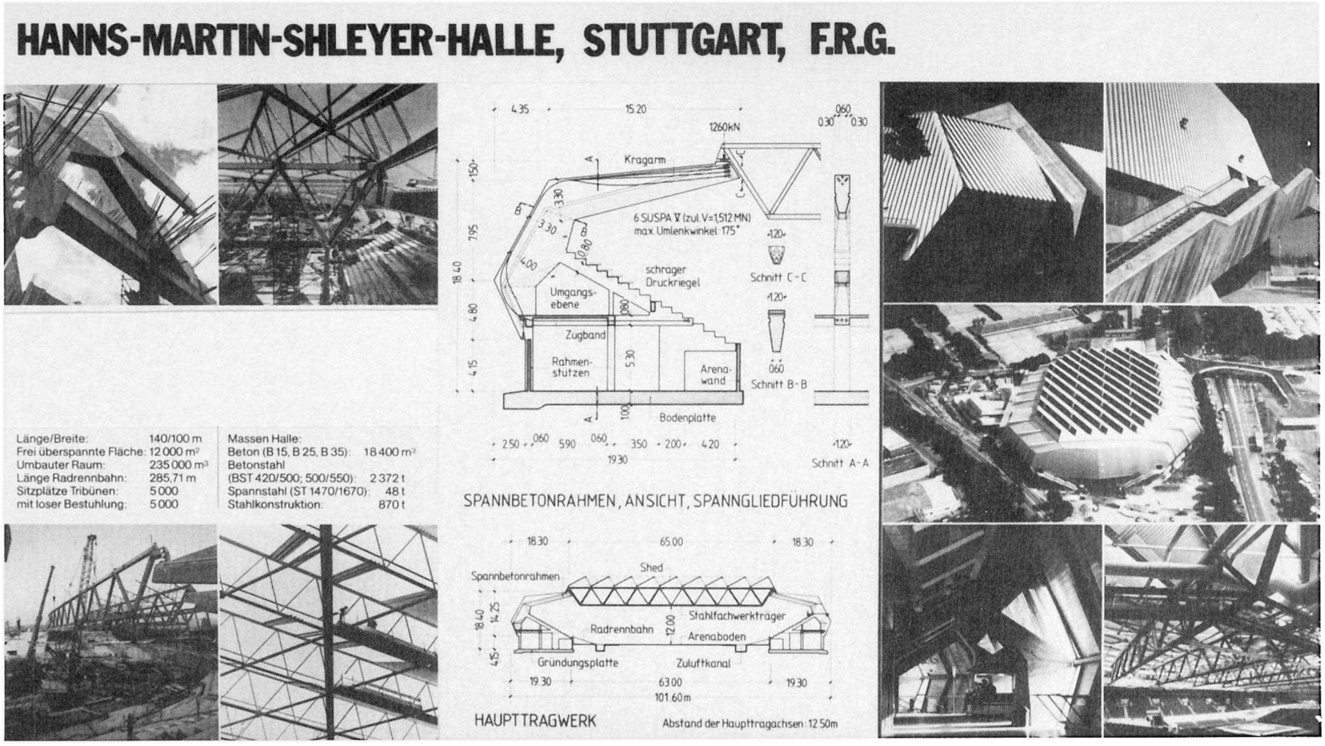
Haupttragwerk: Es besteht aus sich gegenüberstehenden Stahlbeton- bzw. Spannbetonrahmen, auf deren Kragarmen Stahlfachwerkträger aufgelegt sind. Insgesamt sind 10 Rahmenpaare im Achsabstand von 12,50 m angeordnet.

Dachkonstruktion: Die geforderte blendfreie Tagesbelichtung wird mit Shedoberlichtern erreicht, die wegen der erforderlichen Nordorientierung um 30° gegenüber der Hallenlängsachse verschwenkt sind. Die Shedkonstruktion besteht auf der Glasseite aus einem feingliedrigen Fachwerk mit Rechteckrohren und gegenüber aus frei gespannten Trapezblechen, die als schubsteife Scheibe ausgebildet sind. Die Hauptträger über dem Arenabereich (Bauhöhe 6,0 m) haben im mittleren Bereich 65,0 m, gegen die Hallenenden bis 50,50 m und 36,0 m Spannweite. Die Ober- und Untergurte bestehen aus geschweißten Hohlkästen mit Außenabmessungen von 40 x 40 cm, die Diagonalen aus Walzprofilen. Sämtliche Binder sind über der Obergurtebene miteinander verbunden, einmal durch die Untergurte der Shedträger und zum anderen durch ebenfalls diagonal verlaufende Verbandsstäbe. Die somit in der horizontalen Ebene steife Dachscheibe überträgt die Windlasten auf die Spitzen der Kragarme. Hier sind für die Auflagerung des Daches bewehrte Neoprenelager angeordnet.

Spannbetonrahmen: Diese sind im mittleren Teil des Posters dargestellt. Aus wirtschaftlichen und technischen Gründen wurden die Rahmen teilweise vorgespannt. Die geknickten und auskragenden Rahmenteile sind oberhalb der Umgangsebene nicht miteinander verbunden.

Tribünen: In den geraden Teilen bestehen die Tribünenstufen aus Fertigteilen, in den gekrümmten Bereichen aus Ortbeton. Sie lagern auf den schrägen Druckstielen der Rahmen auf.

Gründung: Wegen des zu beachtenden Mineralwasserschutzes war eine Tiefgründung beispielsweise mit Betonpfeilern in den tragenden Schichten des Neckarkieses nicht möglich. So mußte das gesamte Bauwerk innerhalb weicher Deckschichten (Auelehm) gegründet werden. Für die Lastabtragung der Rahmen wurde eine große ringförmige Stahlbetonplatte mit größten Außenabmessungen von 154 x 143 m gewählt.


HANNS-MARTIN-SHLEYER-HALLE, STUTTGART, F.R.G.
Länge/Breite: 140/100 m
Frei überspannte Fläche: 12 000 m²
Umbauter Raum: 235 000 m³
Länge Radrennbahn: 285,71 m
Sitzplätze Tribünen: 5 000
mit loser Bestuhlung: 5 000
Massen Halle:
Beton (B 15, B 25, B 35): 18 400 m³
Betonstahl
(BST 420/500; 500/550): 2 372 t
Spannstahl (ST 1470/1670): 48 t
Stahlkonstruktion: 870 t
1260kN
Kragarm
6 SUSPA V (zul.V=1,512 MN)
max. Umlenkwinkel: 175°
schräger
Druckriegel
Umgangs-
ebene
Zugband
Rahmen-
stützen
Arena-
wand
Bodenplatte
Schnitt C-C
Schnitt B-B
Schnitt A-A
SPANNBETONRAHMEN, ANSICHT, SPANNGLIEDFÜHRUNG
Spannbetonrahmen
Shed
Stahlfachwerkträger
Radrennbahn
Arenaboden
Gründungsplatte
Zuluftkanal
101.60m
HAUPTTRAGWERK
Abstand der Haupttragachsen: 12.50m

Sport Stadium at Karlsruhe

Ice Skating Hall at Munich

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The 69 m span of the main stadium could have easily been covered by simple steel girders requiring a depth of about 2.5 m. However by suspending this roof by means of a cable structure and hence creating in addition to the end supports two inner supports for these girders, their depth could be reduced to half of that, i.e. 1.25 m. Thus the whole structure becomes much less heavy with favourable architectural consequences as well for the interior impression as for the outer view of the hall. Detailed comparison revealed that this improvement of the design could be achieved without additional costs.

The cable structure is of the same type as a self-anchored suspension bridge. Its two masts are octagonal and tapering steel tubes carrying 15,000 kN each. The two main cables and the two guy cables of each mast, which are anchored by soil anchors, consists of two locked coil ropes of 82 mm diameter each. The suspender cables' diameters are 33 mm. All saddles, joints and anchorages are made from cast steel.

The steel grid consists of girders with 1/2 IPB chords and tubular diagonals with diameters between 42 and 70 mm. They are fully welded without any gusset plates. Horizontal stiffening of the grid is provided at its periphery by four vertical trusses having prestressed diagonals made from thin rods. The outer columns following the facade are hinge supported at their base and their top. The grid is covered with corrugated sheets.

The grid was conventionally erected on temporary trestles and loosely connected with the cable structure. The whole roof was simultaneously lifted from its temporary supports and prestressed by hydraulically jacking up the two masts.

The total structural steel quantity for the main hall, including the cables and masts, is only 65 kg/m². For the appendix with its extremely light suspended girders of 18 m span, even 28 kg/m² are needed only.

An already existing ice skating rink has been covered by a translucent cable net structure. The prestressed cables of the nets are suspended between an arch along the axis of symmetry of the structure and edge cables on guyed masts along its circumference. The arch which primarily acts in compression and which is stabilized by the cable net itself is designed as a space truss with triangular cross section. Its members are steel tubes with diameters of 245 mm for the chords and 83 mm for the diagonals. The two-layer-cable nets are formed by galvanized double strands, 11.5 mm diameter each, fixed with aluminium clamps at a mesh width of 75 cm. Their edge cables are locked coil ropes with 60 mm diameter. They are anchored or supported by cast steel joints and knots. As compared to other cable net structures including the adjacent cable net roof for the 1972 Olympic Games, where the facades are usually independent steel structures, in this case the facade has been integrated into the structure: prestressed cables of the same type as used for the cable nets are suspended between the edge cables and the ground. Glass panels are attached directly to them. Such a "membrane facade" consumes a minimum of material and permits an almost unobstructed view from the inside into the surrounding landscape.

The cable net is covered by a wooden grid which carries a white and translucent PVC-coated polyester fabric. The grid spacing is 75/75 cm corresponding to the net in the upper part of the roof along the arch, and narrows continuously towards the lower edges, where the snow weight is a maximum due to the small slope of the roof. This grid scheme contributes to the very generous and pleasing interior of the hall with its increasing translucency from the periphery towards the elevated center. There the eye-shaped slots between the edge cables of the two nets and their suspenders from the arch are covered with clear glass. This permits the arch to be seen from the inside of the hall and makes evident that this is one of the rare cases where the structure is the building or where form follows function.


TWO NEW CABLE ROOFS OVER SPORTS ARENAS IN GERMANY
Sport Stadium at Karlsruhe
Ice Skating Hall at Munich

Tests on Prefabricated Centrifuged Columns

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To satisfy the requirements of the architects and the building owners the structural engineers are induced to curtail the size of the vertical structural members. As an alternative to steel columns the Company Gram S.A., Villeneuve, Switzerland has developed centrifuged concrete columns. These structural members, with an extremely high degree of reinforcement up to 20 % have a very high load capacity, an excellent appearance and a good fire-resistance. In order to observe the behaviour under load and imposed deformations of such columns, the Institute of Reinforced and Prestressed Concrete (IBAP) of the Swiss Federal Institute of Technology, Lausanne (EPFL) has carried out theoretical and experimental studies. These are a part of the more general investigations on columns in buildings presented by R. Favre at the 12th IABSE Congress in Vancouver [1].

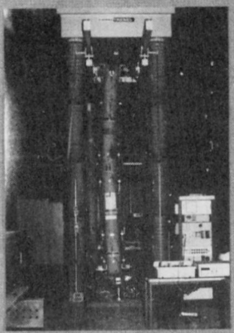
The columns have been tested in a 10000 kN press and the load was applied either using inclined built-in ends (test type I) or linear knife edges (test type II).

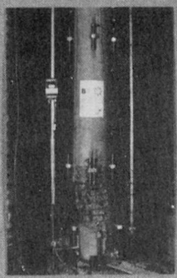
The ten columns which have been tested have a length of 4,00 m and a diameter of 0,29 m; six of them have a longitudinal reinforcement of 8 bars of 34 mm (ρ = 12,4 %) and four have a HEM 140 steel section in the interior (ρ = 18,0 %). The test results [2] demonstrate the high load capacity of centrifuged columns as well as a high degree of ductility. In the tests type I this characteristic allows the column to centre gradually the vertical load, even with imposed angles up to 1,5 %. In the tests type II however, which agree with the usual calculation model of such structural members, columns with both ends hinged and vertical load brought in with an initial eccentricity, the load capacity is much lower.

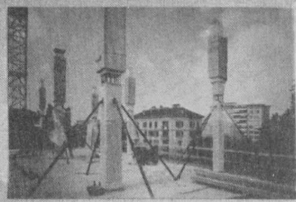
[1] R. Favre, D. Najdanovic, R. Suter, C. Thürlimann
A new Concept for R.C. Columns in Buildings Proceedings of 12th IABSE Congress, Vancouver, 1984.

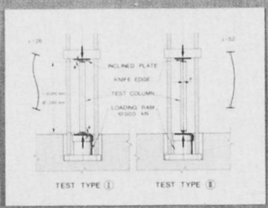
[2] R. Suter, S. Dal Busco
Tests on prefabricated centrifuged columns (test report) Swiss Federal Institute of Technology, Lausanne, 1984.

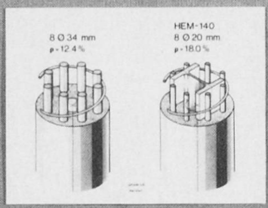
TESTS ON PREFABRICATED, CENTRIFUGED COLUMNS











RESULTS	COLUMN TYPE	HOOP REINF.	TEST TYPE	N_u	NOTES
COLUMN					
A 1		Ø 4 mm	I θ = .008	5170 kN	Hoop failure
A 2		Ø 8 mm	I θ = .007	5770 kN	
B 1		Ø 6 mm	I θ = .013	5740 kN	2nd order
B 2			I θ = .012	5670 kN	
B 3			II e = 30 mm	3240 kN	+29.0 mm
B 4			II e = 60 mm	2420 kN	+36.8 mm
B 5			I θ = .01	5350 kN	
B 6			II e = 30	2790 kN	+39.5 mm
B 7			II e = 60	2100 kN	+42.1 mm
B 8			II e = 60	2680 kN	+33.4 mm

Development of NS Space Truss System

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I.Prefabrication of Components

Bolt connection is adopted in this system in order to avoid site welding of steel pipes. Site welding requires a highly accurate set-up and skilled welders. In addition inspection is difficult. NS Space Truss system offers high accuracy and quality with reasonable cost by utilizing mass production techniques. For example, it takes less then a minute to automatically weld two end cones to a steel pipe in flat position. Because of accurate fit of the components, the system is easy to assemble on site.

II.Bearing Capacity of the Node (see the diagram with the same title)

Bearing capacity of the node depends on load distribution as well as on its configuration. ß-value represents load distribution. Mono-axial tests(ß=0) and bi-axial tests(ß≠0, see photo) were done to define bearing capacity ratio. E.T. and P.T. are the calculated curve for a ring on elastic theory and on plastic theory respectively. Plotted points ⊕ ⊙ X are the node test results and they are analogous to the calculated curve.

III.Buckling Load of Pipe Members (see the diagram with the same title)

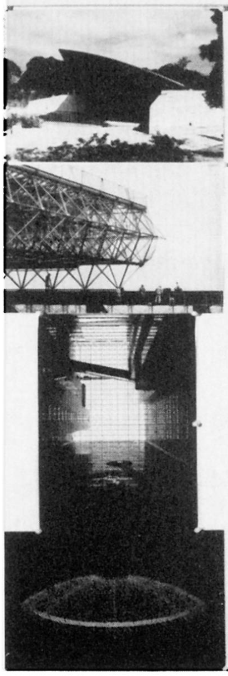
Pipe members and steel pipes of the same lot were loaded to failure. Normalized buckling loads and slenderness ratios are on the diagram. Buckling loads of steel pipes agree well with the value given by AISC spec. formula, and buckling loads of pipe members are larger because of the following reasons;

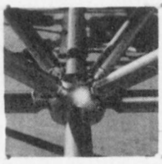
1)Actual pipe member length is approximately 90% of its nominal length which is the distance between the center of the two nodes on both ends.
2)Both ends of pipe members are not free to rotate but are slightly restrained.

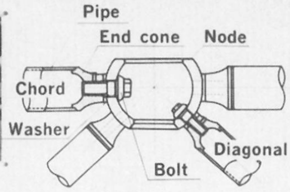
IV.Frame Tests (see the right side of the poster)

Three specimens were loaded to failure to find exactly the stiffness and bearing capacity of frames. Configuration of the three specimens were the same. Target ß-values(-1,0,1) were obtained by changing the location of loading points and supports. The load-displacement relations of specimens are shown on Results of Frame Test diagram with theoretical stiffness and loads, which were calculated on the assumption that joints are pin connections. Stiffness of the specimens agrees well with the theoretical one. Maximum load Px is approximately twice as large as Pa, and is larger than Pc. Stress redistribution was observed through strain measurement of pipe members. Pa is the load at which the axial force of the pipe member with the highest stress of all reaches the allowable axial force defined by AIJ-code;This is true also for Pc and the buckling axial force obtained in the previous tests.(see III)

DEVELOPMENT OF N.S. SPACE TRUSS SYSTEM







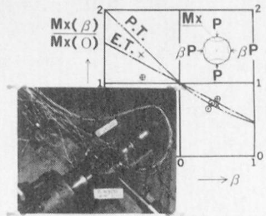
This system has following features;

1) easy application to wide-span structures
2) easy assembly on site
3) easy application to any structural shape
4) high structural reliability

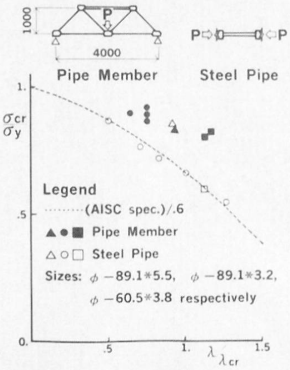
Spherical surfaces of nodes, bolts and washers enable members to be connected without eccentricity of internal forces.

Bearing capacity of components and frames had been experimentally studied before design criteria were fixed.

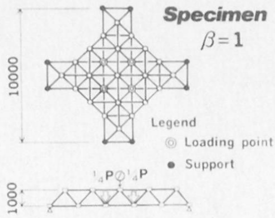
Application of this system to a 200m—diameter dome is now under study.

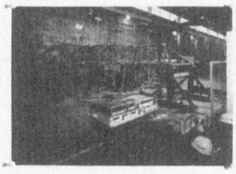


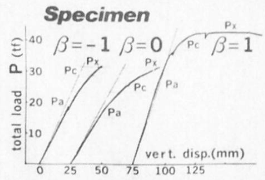
Bearing Capacity of Nodes



Buckling Load of Pipe Members







Results of Frame Test

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