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Telecommunications Tower of St. Chrischona, Switzerland

Tour de télécommunications de St. Chrischona, Bâle, Suisse

Fernmeldeturm St. Chrischona, Basel, Schweiz

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SUMMARY

North east of Basle on the hill of St. Chrischona stands an imposing structure of the Swiss PTT. It consists of three basement floors accommodating different technical rooms and a 248 m high telecommunication tower. The tower has a rather new design with a star-shaped cross-section. It is supported by a tripod carried by three widely spaced foundations which contribute considerably to the stiffness and stability.

RÉSUMÉ

Au nord est de Bâle sur la colline de St. Chrischona se trouve un imposant ouvrage des PTT suisses. Il comprend des sous-sols contenant différents locaux techniques et une tour de télécommunications de 248 m de hauteur. La section de la tour en forme d'étoile est une de ses caractéristiques originales. Le trépied, qui supporte le fût de la tour, repose sur trois fondations bien éloignées les unes des autres et donne à l'ensemble une grande partie de sa rigidité et de sa stabilité.

ZUSAMMENFASSUNG

Nordöstlich von Basel auf dem Hügelzug von St. Chrischona steht eine Mehrzweckanlage der schweizerischen PTT. Sie umfasst einen Sockelbau mit verschiedenen Betriebsräumen und einen 248 m hohen Fernmeldeturm. Der Turm weist mit seinem sternförmigen Querschnitt eine neuartige Konstruktion auf. Er hat ein ungewöhnliches Tragsystem mit drei Stielen und weit auseinanderliegenden Fundamenten, die wesentlich zu einer grossen Steifigkeit und Stabilität beitragen.

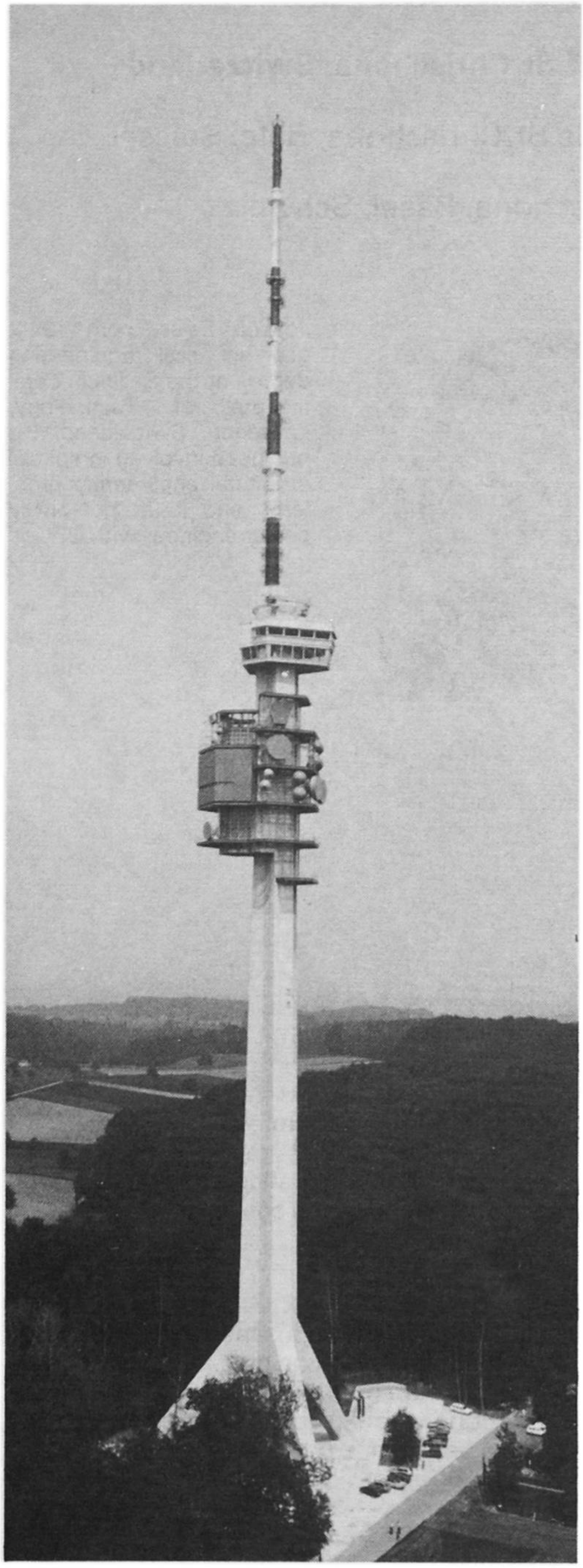

Fig. 1: Aerial view of the tower

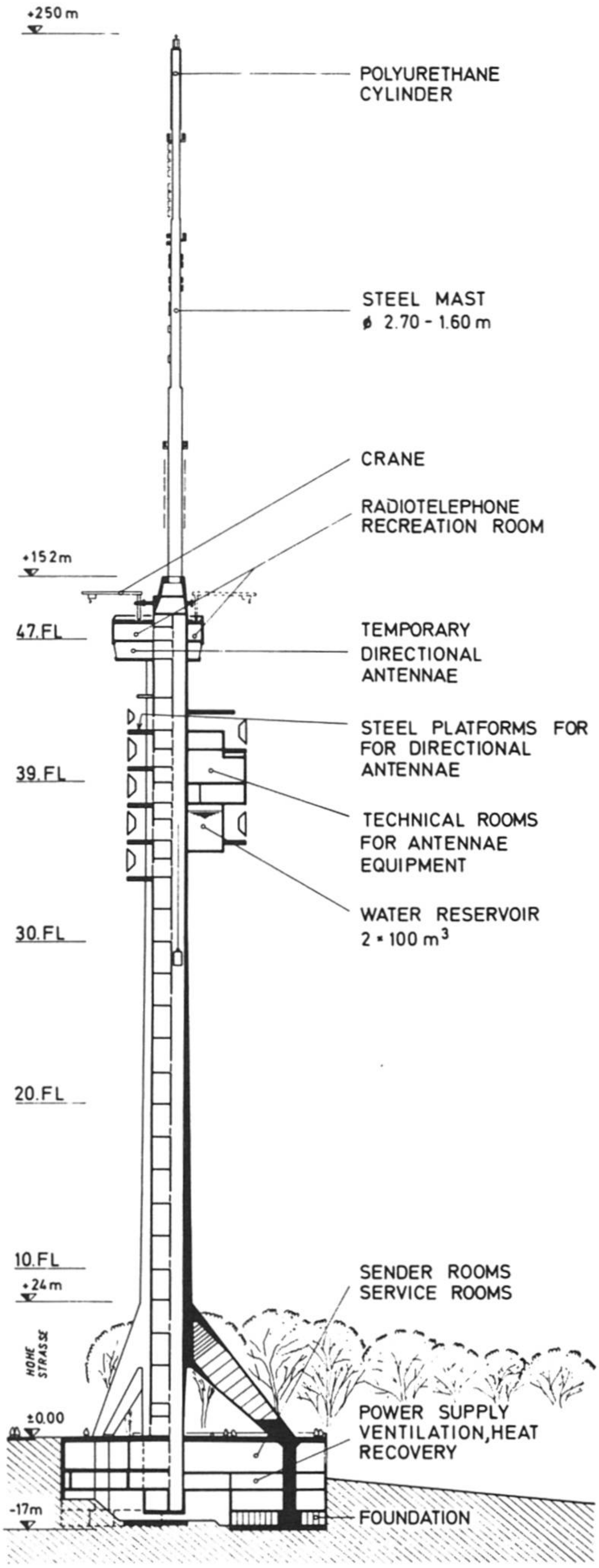

Fig. 2: Vertical section of the tower

1. INTRODUCTION

The TV tower is an important link in the network covering Switzerland. The multipurpose complex of St. Chrischona provides the cantons of Baselstadt and Baselland (nearly 440'000 inhabitants) with 3 Swiss TV channels and 2 radio stations. It is at the same time a supply station for 24 TV and ultra-short wave transformers which are located in the cantons of Baselland, Aargau, Solothurn and Bern. Moreover some very important directional beam connections are accommodated: for the St. Chrischona sender, for TV coverage, for foreign radio and TV programmes as well for telephone connections with Bern, Zurich and Stuttgart.

2. GEOLOGICAL CONDITIONS AND FOUNDATIONS

The subsoil under the multipurpose complex of St. Chrischona consists of trias formations and is located nearly two kilometres eastwards of the Rhine flexure. It consists essentially of red marl minerals and limestone shells. The foundation level consists of colourful marls of gypsum-keuper. When designing the foundation great importance was given to the different decomposition stages of the gypsum-keuper and mosaic-shaped clods in the deep subsoil.

The foundations consist of three widely spaced hollow foundations with inner ribs as stiffeners. Each foundation covers 226 m2. The whole structure was laid out so that the complete dead weight of the structure including the tower slightly exceeds the weight of the excavated soil. The soil pressure under the new loading without wind does not exceed 70 kN/m2. In spite of the sensitive subsoil for settlement it was possible to limit the differential settlements to a minimum, thus reducing the inclination of the tower. The long-term settlement measured to date adds up to 3 to 4 cm and confirms the preliminary estimations.

3. DESIGN AND CONCEPT

The TV tower of St. Chrischona, Fig. 1, differs from the classical circular shaped towers. It has a star-shaped cross-section and efficiently fulfills the functional requirements imposed by the client. The cross-section is ideal for the formwork because only the outer dimensions vary whereas the inner dimensions of the 5 cells remain constant throughout the height. The outer measurements decrease linear from just above the tripod until 118 m above grade, which corresponds to the level of the accommodations. The tower shaft forms a truncated pyramid with a polygonal base. The thickness of the main peripheral walls varies from 40 to 175 cm, Fig. 2 and 3, governed by the static requirements. The thickness remains constant in the region of the technical floors for functional and constructional reasons. The shaft is supported by 3 legs (a tripod) consisting of three rectangular hollow cross-sections which maintain a constant area of 6 square metres. For operational reasons the lift-well and ducts-well were extended to the basements of the multipurpose complex.

The telecommunications tower of St. Chrischona is located in the northwest corner of Switzerland. Most of the directional beam transmissions are directed to the south i.e. into Switzerland.

This produced the stacking of directional beam aerials on the south side of the tower. In order to create a harmonious impression of the whole tower it was decided to balance the steel antennae platforms with an extension on the opposite side in the form of a reinforced concrete 'rucksack' comprising the upper technical floors, Fig. 4.

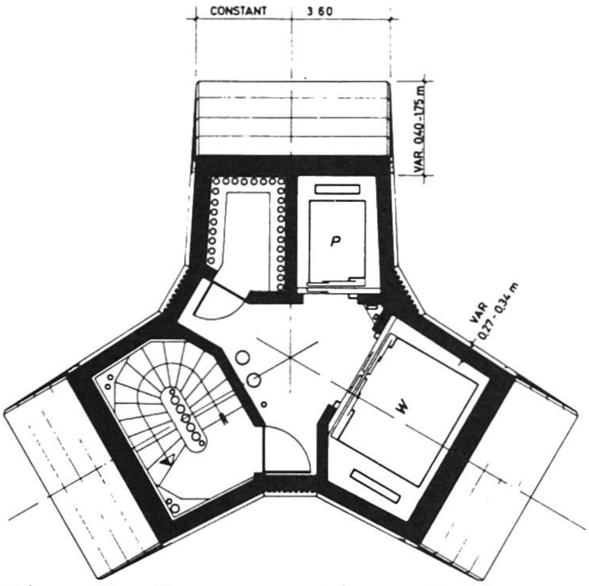

Fig. 3: Cross-section of the shaft

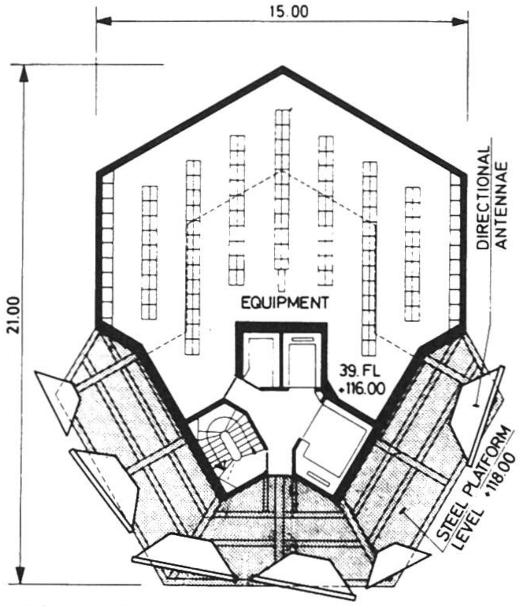

Fig. 4: Asymmetrical outbuildings at 118 m above grade

The underground structure, Fig. 5, has 3 basements which are monolithically bound together. The upper slab incorporates the tension bands which take up the horizontal forces resulting from the inclined tower legs. The vertical forces of the tower are taken up through full cross-section columns and are transmitted to the foundations without coming into conflict with the lay-out of the underground floors. The shaft extension transmits horizontal forces to the central part of the underground structure. During the construction and before the joining of the 3 legs of the tower the shaft was supported and adjusted by hydraulic jacks. Upon completion of the 3 legs the central part was prestressed with incorporated cables and suspended to the upper part of the shaft.

The design of the St. Chrischona TV tower presents the following advantages:

- Practically no disturbances due to tower deflection even with wind speeds attaining 100 km/h (hourly mean time) thanks to extreme rigidity of the shaft and to its widely spaced foundations,

- The numerous high-frequency electrical cables from the underground floors could be directly connected to the tower,

- Slender and elegant appearance of the tower due to light and shadow effect caused by the star-shaped cross-section,

- The chosen cross-section allows an easy connection of asymmetrical outbuildings. It also facilitates the lay-out of the directional beam aerials near the technical rooms and the shortening of the connection distances of the wave conductors thus reducing signal attenuation,

- Elimination of the instationary lateral forces caused by Karmann-effect because of the cornered edges of the shaft, a fact confirmed in wind tunnel tests.

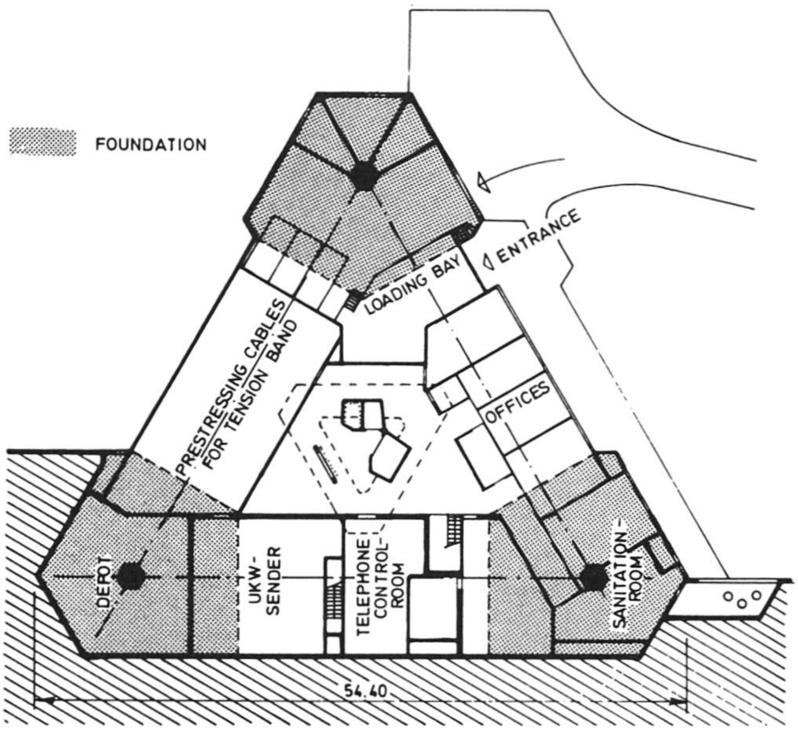

Fig. 5: Basement including the technical rooms

4. WIND EFFECTS

In structural design the usual approach for considering wind effects is to determine a substitution load which produces the same interior forces as that of an extreme wind through a certain return period. This substitution load depends not only on wind and drag coefficients but also on the dynamic behaviour, which is characterized by the proper frequencies and damping. The part of the load which depends on time acts dynamically. A wind produces an irregular (random) loading of the tower which possesses several proper frequencies and vibration modes. The tower, absorbs out of the energy supply of the exterior loadings, those parts whose excitation frequencies approach its proper frequencies and converts this energy input into oscillating movements.

In order to evaluate the overall wind loads and wind induced responses of the tower a study was carried out in a testing tunnel under the direction of Prof. B. Thuerlimann, Swiss Federal Institute of Technology, Zurich and in cooperation with Prof. Davenport, London (Ontario), Canada. A secondary objective of the testing was to provide information on wind induced exterior peak pressures and suctions, effective on particular components of the glazing and cladding.

A scaled aeroelastic model of the tower was constructed on a geometric scale of 1:400 and tested in turbulent boundary layer flow conditions representative of natural wind at the project site. This model was equipped to provide direct measurements of the wind induced response for a full range of wind directions and wind speeds corresponding to full values of up to 65 m/sec at gradient height. The aeroelastic model was later fitted with a limited number of pressure taps to provide estimates of local wind induced exterior pressures. The wind tunnel findings were subsequently combined with a statistical model of the wind speed and direction climate for the area in order to provide predictions of full scale wind induced effects.

The wooded, rolling terrain which surrounds the site of St. Chrischona tower was simulated in the testing tunnel. The probable variation of the mean speed corresponds to a power law speed profile as shown in Fig. 6. The power law exponent a is approximately 0,27 for the tower site.

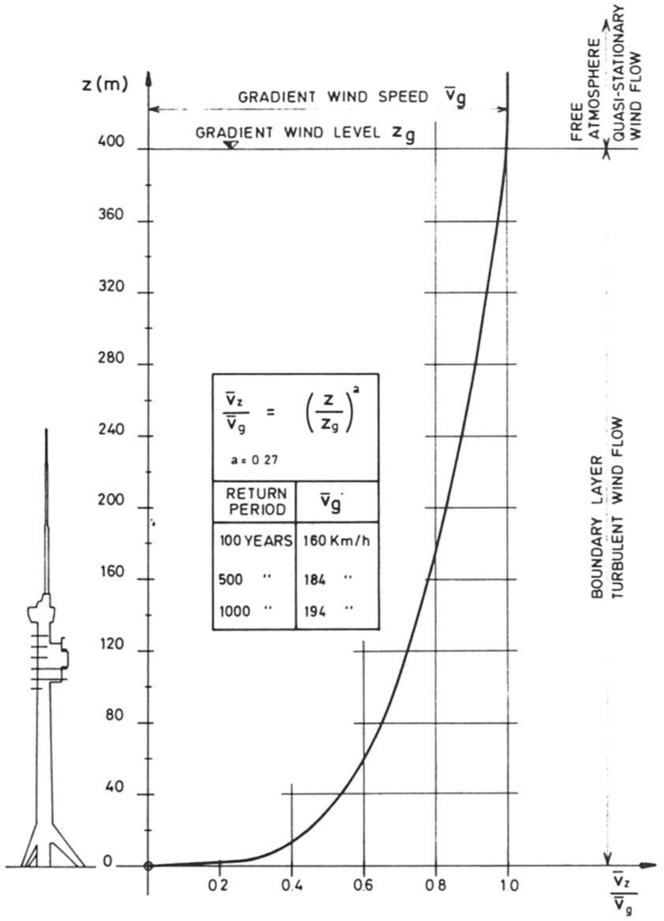

Fig. 6: Wind profile for the tower site

The results of the wind tunnel testing [1] show the following dynamic response:

- there is neither aerodynamic instability nor instationary lateral excitation,

- the dynamic response is significant in comparison to the mean response. The gust effect factor for the tower varies between 2 and 2.5 depending on the wind direction and the roughness of the terrain,

- no great difference was noticed in the dynamic response for different excitation directions.

The analysis of the performance spectra, which define the frequency dependent energy input, gives the following dynamic characteristics of the tower:

- the dynamic response is largely comprised of oscillations in the first two modes of vibration, Fig. 7. A subsequent modification of the steel mast has resulted in a more significant motion of the concrete shaft for the first mode of vibration,

- a significant portion of the dynamic response is due to the excitation by the background turbulence at frequencies below the frequencies of vibration of the tower,

- the wind induced torsional response to the tower was small in comparison to the sway response.

Fig. 8 shows the effective static pressure diagram for a 100 year return period as well as the coefficients of mean drag.

The horizontal loads resulting from an earthquake corresponding to the Intensity 6.1 according to the Swiss Earthquake Risk Map were smaller than the to wind loads. The wind loads were evaluated for a maximum wind speed of 160 km/h.

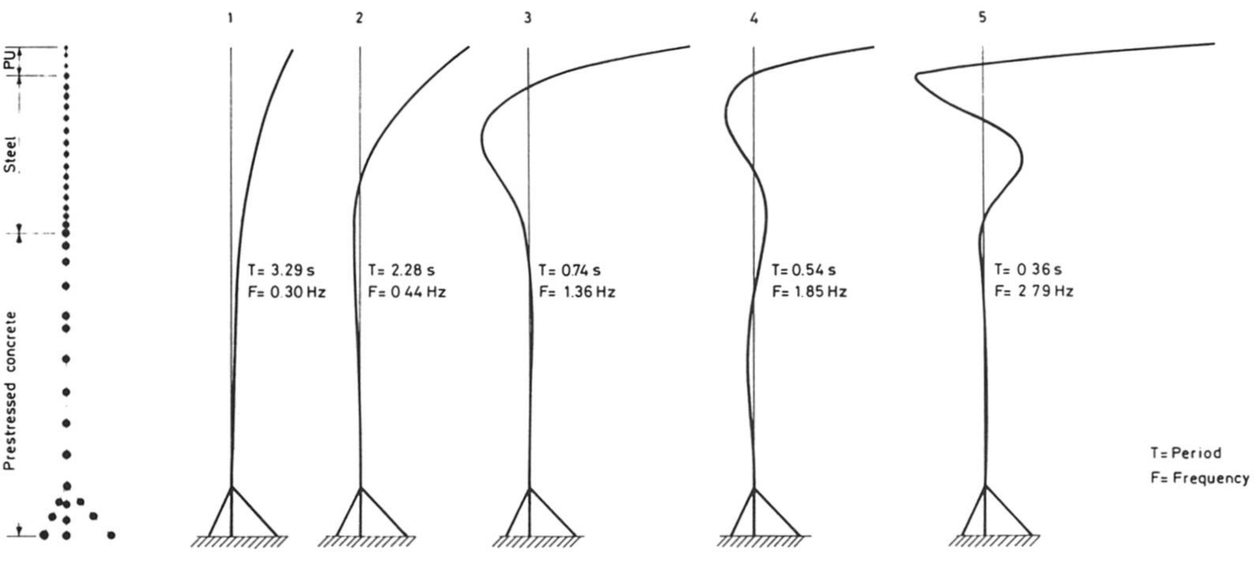

Fig. 7: The first five modes of vibration

The clients, the swiss PTT, imposed the strict condition limiting the inclination of the tower in order not to disturb the functioning of the aerials up to a wind speed of 100 km/h. This meant eliminating the cracks in concrete for such loads thus increasing the stiffness. This, together with some practical considerations led to a combined reinforcement approach using slack reinforcement steel jointed with couplings and prestressing steel cables. Some of the cables were disposed asymmetrically to compensate for the eccentricity of the attached outbuildings.

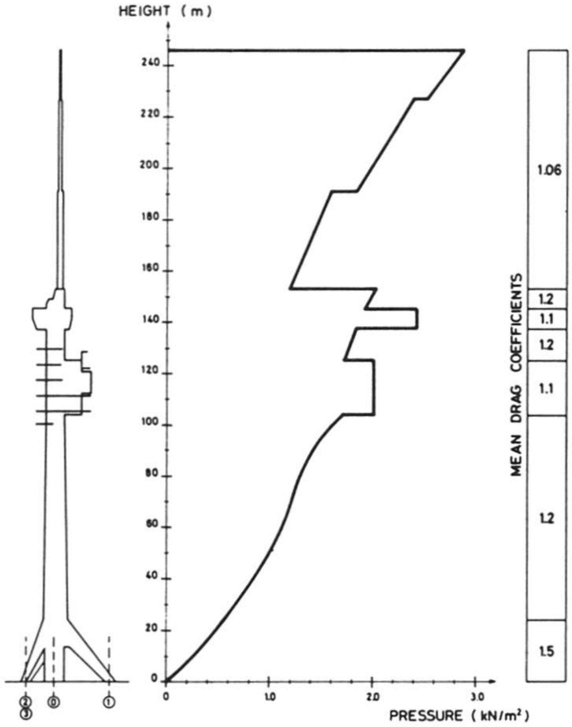

Fig. 8: Effective static wind induced pressure for a 100 year return period

5. DETAILS OF CONSTRUCTION

The excavation for the 3 basements was mainly carried out with 60 degree embankments which were immediately protected with a gunite cover. Some underpinning walls with ground anchors were necessary for the three foundations, Fig. 9. The construction of the basements was conventional. Some challenging problems arose during the phase of joining the inclined legs with their 60 degree radial grid. The crossing of the vertical bars of the columns with the inclined bars of the legs and the horizontal tension bands required utmost precision and coordination, Fig. 10.

The construction of the three legs was carried out with two cantilevered scaffolds each in eight sections of 2.90 m height. The shaft itself was constructed with a self-climbing formwork using automatic climbing mechanism. 51 lifts of 2.90 to 3.05 m were necessary to reach the top of the shaft. In order to cut down construction time and avoid scaffolding problems the legs were erected simultaneously with the central vertical shaft leading upwards with an advance of 4 lifts, Fig. 11. Five days were necessary for the completion of each concreting lift including delays caused by atmospheric conditions and technical interruptions. For the material transport a climbing crane fixed on the outside of the tower shaft was at our disposal. There was only room enough for twelve skilled workers who used a special lift guided on vertical cog-rails in the well of the ware-lift.

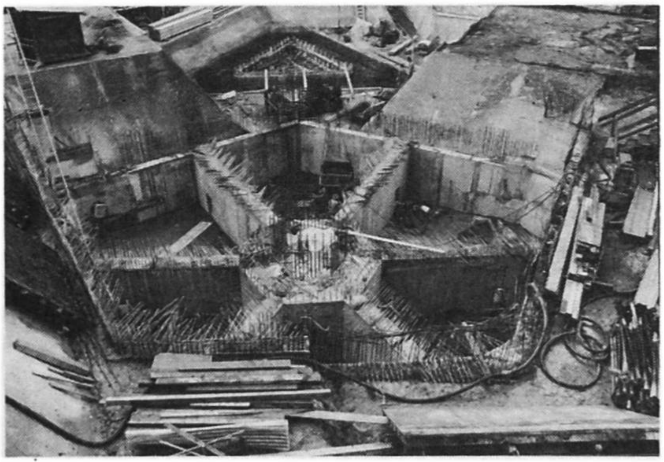

Fig. 9: Cellular foundation under one of the main columns

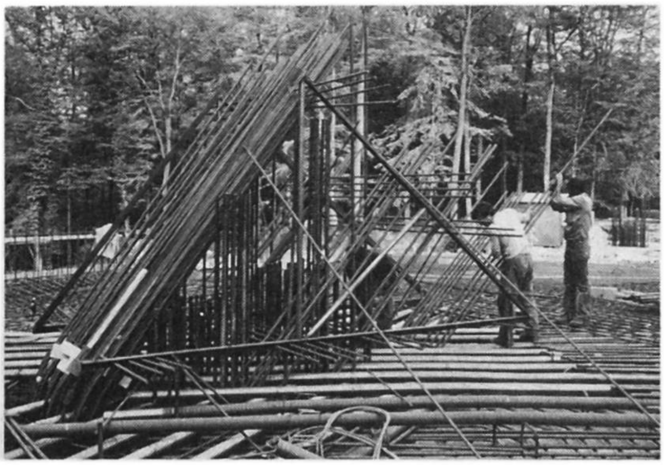

Fig. 10: Connection of the inclined leg with the main column and upper slab of the basement

The exposed surfaces of the tower and the legs had a special rubber structure matrix which helped to obtain concrete of relatively constant colour. The quick-setting concrete made it possible to remove the shuttering and to climb to the next level in only 12 hours after the completion of the concreting. Immediately after the removal of the shuttering the concrete surfaces were treated with a curing compound.

Two special working platforms with shutterings and special devices were necessary to facilitate the construction of the concrete outbuildings. The platforms had a load of about 300 kN. The outbuildings were jointed to the shaft with Swiss-Gewi couplings. Upon completion of the concrete parts the working platforms were lowered stage by stage to the level of each steel antenna platform. The suspension consisted of three hydraulic grabbing devices which were governed and synchronized by a pump-aggregate.

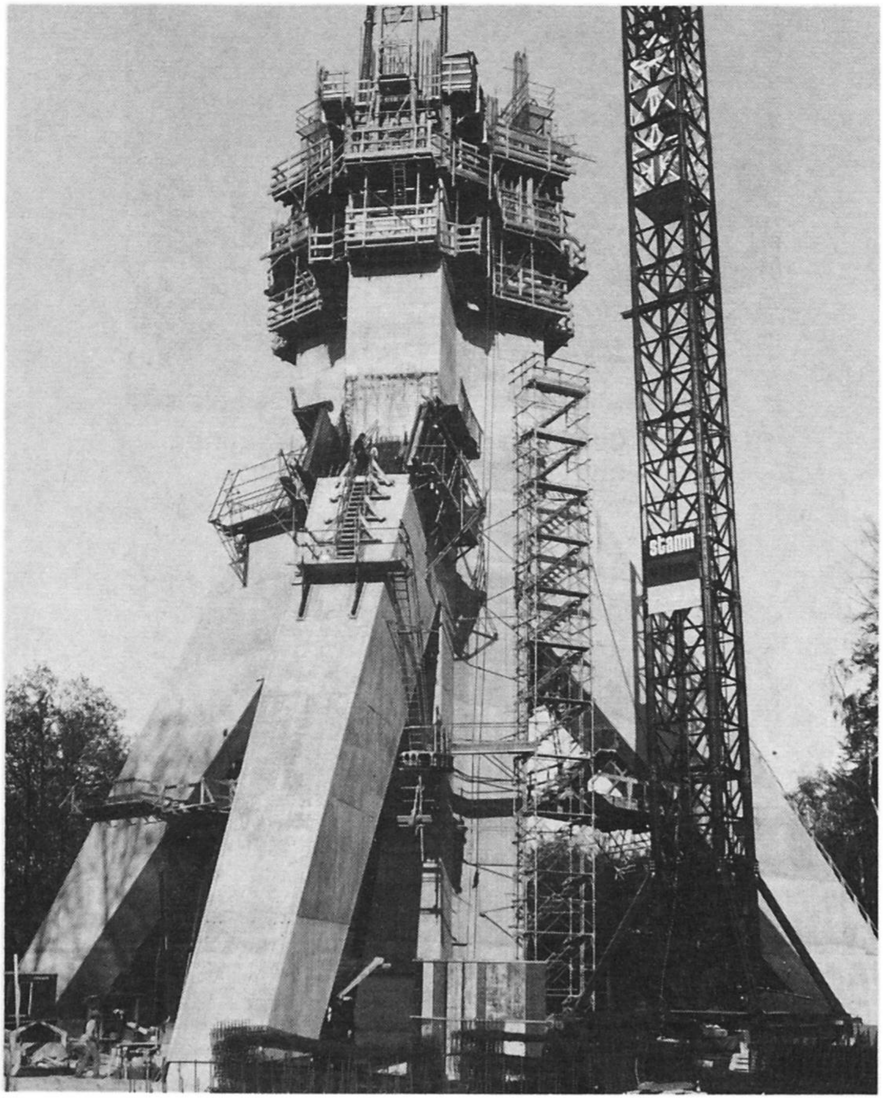

Fig. 11: The tripod supporting the tower with the shaft leading upwards

The main cantilevered beams of the steel platforms (Fig. 12) were welded to special steel plates already incorporated in the walls of the shaft. This special steel (Z-steel) is characterized by an isotropic structure.

The steel mast was designed and supervised by the Engineering Consultants Hitz and Partner in Worblaufen, Switzerland. The steel mast was fixed to the top of the concrete shaft with 36 prestressed smooth steel bars, 36 mm diameter, each bar prestressed up to 890 kN. The wreath-shaped footing of the steel mast was overpressed in order to eliminate a split opening of the joint. This measure was taken to avoid fatigue due to great stress fluctuations.

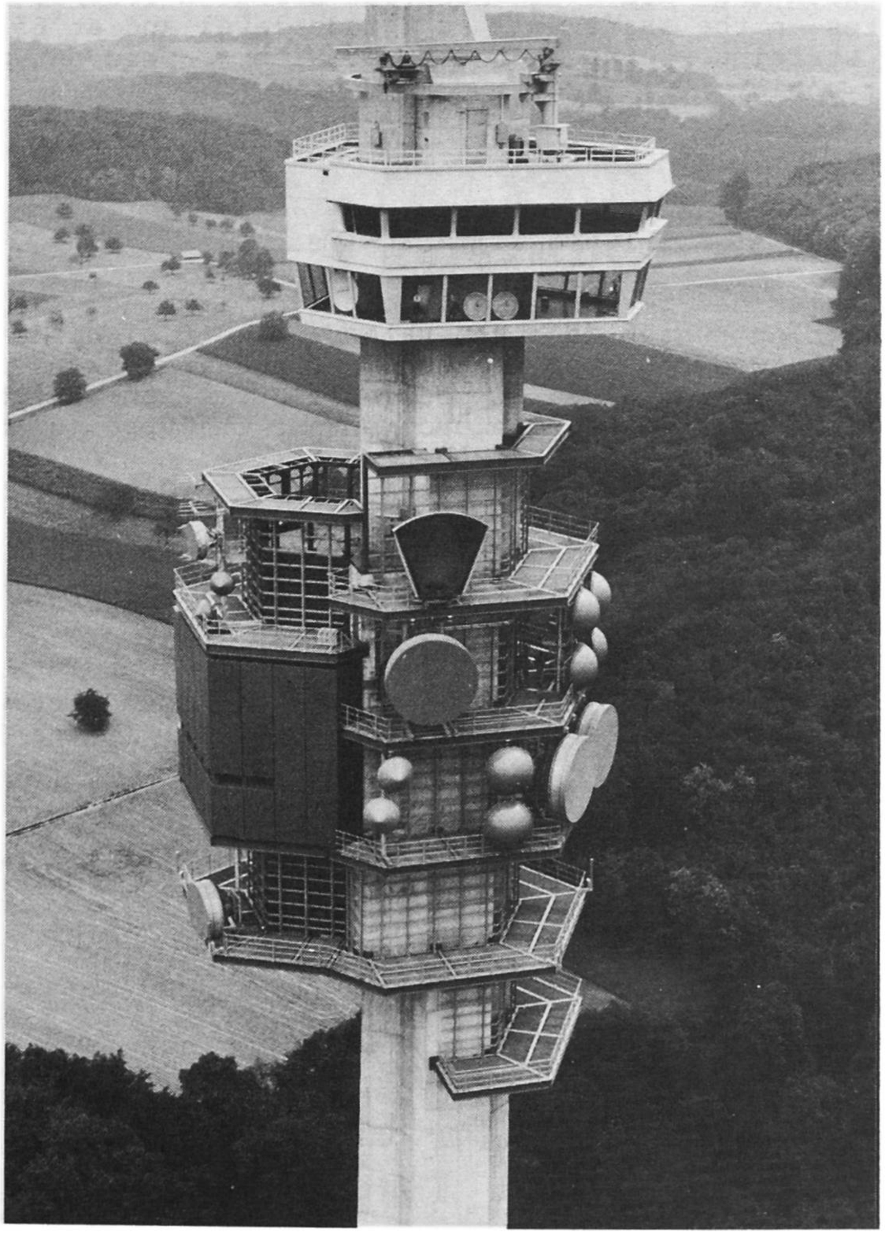

Fig. 12: Upper and lower accommodations and the steel platforms

6. SURVEY AND MEASUREMENT

The basis of the surveying and measuring was an adjusted and equalized triangle at the centre of which was the tower shaft.
The three corners of the triangle consisted of three concrete pedestals with centering plates. The measuring of the foundations and the tower to the height of 42 m above grade was carried out from this triangle. An additional fixed point was located at the lowest platform of a neighbouring steel mast.

The measuring of the upper part of the shaft was carried out by manual horizontal adjustment with optical precision plumbs. Nadir und Zenith measurements were carried out. All these measurements were taken with the aid of 13 cantilevers with restricting centering plates in the shaft-well at grade level and at 65 m above grade. The starting points were fixed with a precise polygonal measurement chain.

7. PROTECTION AGAINST LIGHTNING

Special measures had to be taken because of the need to protect against lightning which can generate a potential difference of 10'000 Volts between the top of the tower and the ground. For this reason some bars were welded or coupled all over the height of the shaft and connected to the reinforcement in the upper slab of the underground structure and from there earthed. A steel sheathing covers the whole surface of the cables duct and is connected to the continuous steel bars.

REFERENCES

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