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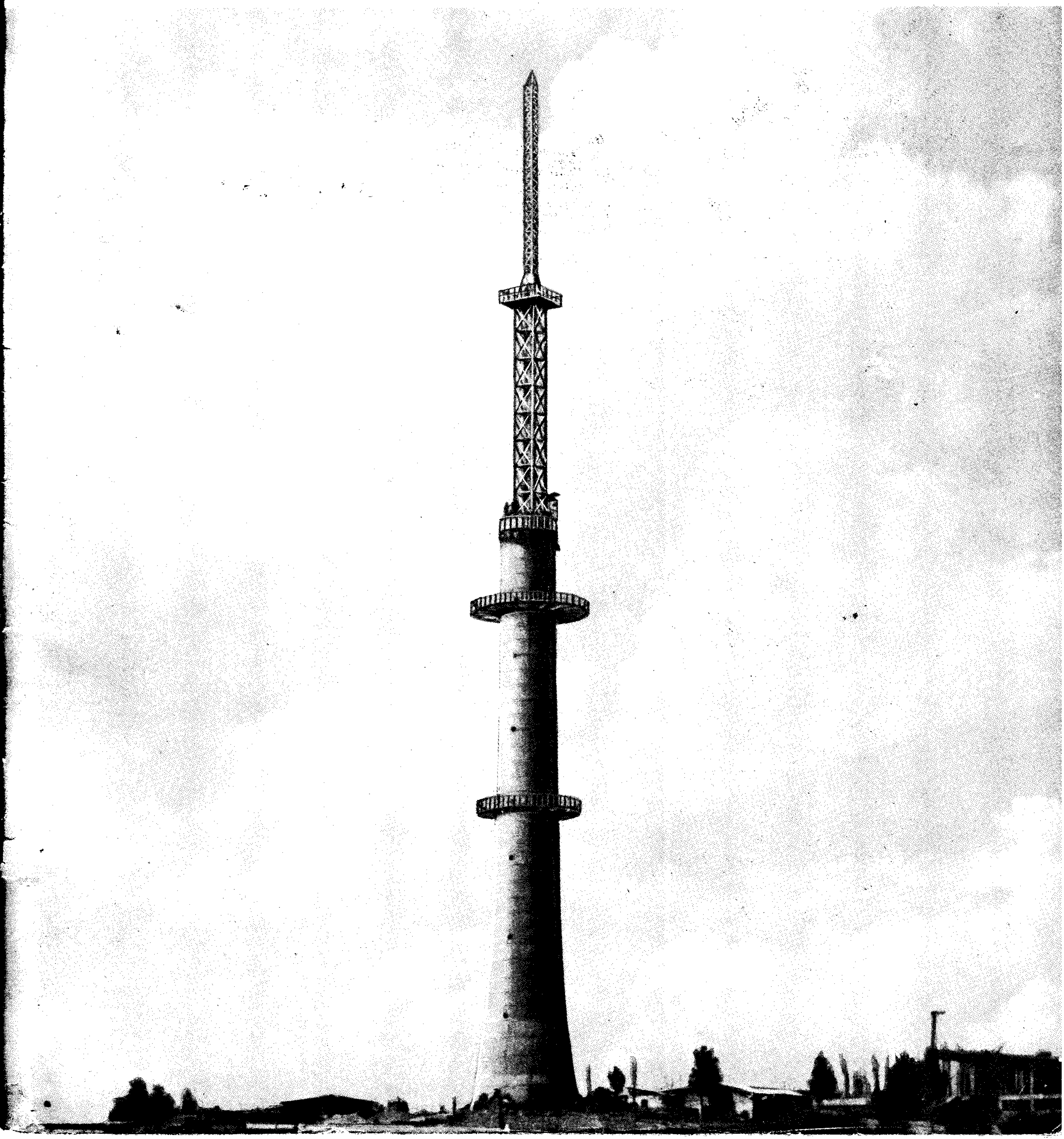

TV tower at Kohima : Design and construction features

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The paper deals with RC-cum-steel slender and tall TV tower, designed and constructed by Gammon India Ltd. In view of its high aspect ratio, the structure is sensative to lateral loads, namely, wind and earthquake. The composite action of the steel mast with the supporting concrete shaft is a special featutre of TV tower construction. The paper highlights broad aspects of design and construction.

The reinforced concrete (RC)-cum-steel TV transmission tower at Kohima, Nagaland - north-eastern state of India - is 100-m high and is constructed for the Civil Construction Wing of the All India Radio. The basic dimensions of the tower in regard to base and top diameters, height of RC shaft and profile of steel mast were governed by the functional requirements, and were specified by the All India Radio.

Salient features

The tower consists of a RC shaft, 57.56-m high above ground level and a 42.44-m high galvanised steel mast over it, *Figs* 1 and 3. The external diameter of the shaft is 11.5m at the base and tapers to 5m at the top. Although this tower is similar to many such TV towers built recently in some of the capital cities of the country, it is sleek and slender in view of the curvilinear profile provided to the shaft from base to top, as compared to conical-shaped shaft provided in the other towers. The steel mast, on which TV and FM antennae for II and III Bands are mounted, is fixed to the top slab of the RC shaft by high-strength, friction-grip bolts.

There is a provision in the design for a future extension of the steel mast by 23m for installing Bands IV and V antennae. A steel staircase with precast concrete treads is provided within the shaft for access up 49m level, and in view of the slender shaft, the staircase is a spiral type. There is also a provision for the installation of a lift at a later date. The accessories in the TV tower include two projecting platforms at 30m and 49m levels (where micro-wave dishes are mounted), aviation obstruction lights, internal electrification, lightning protection, provision for installing antennae dishes, RF feeder cables, etc. For aesthetic reasons, eight circular-shaped projecting blocks in concrete are provided at the top of the shaft.

Design

The tower is designed for the loads and the parameters specified by the All India Radio. Dead weights of various fixtures, viz. 80 kN of Band II panels, 60 kN of Band III panels, 11.5 kN of future Bands IV and V, and 5 kN of each of eight micro-wave dishes are included in the design. A total live load of 4.2 kN/m^2 is considered on the platforms and staircase which takes into account 1.2 kN/m^2 for fixtures and fitting.

Wind force forms the major external applied loading in the design of the tower. The basis for calculation of wind pressures acting on the tower is the Indian Standard Code of Practice, IS:875-1964[1]. The tower is designed for a basic wind pressure of 1.5 kN/m^2 up to 30-m height which is equivalent to a wind speed of 160 km/h as per the code and there above increasing in value with height, with a maximum value of 1.99 kN/m^2 at

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the top. For the design, these pressures are enhanced by 10 percent considering gustiness and 100 year return period of the wind. Besides these wind forces, additional wind load acting on the antennae panels are considered which amounts to 100 kN for the Band II panels and 70 kN for Band III panels. The drag coefficients used in the design are 0.7 for the circular RC shaft and the top 1.8-m diameter 23-m high portion of future Bands IV and V, while a value of 2.3 and 2.1 is considered for the squared-shaped steel mast in the portion of Bands II and III, depending on the solidarity ratio of the mast.

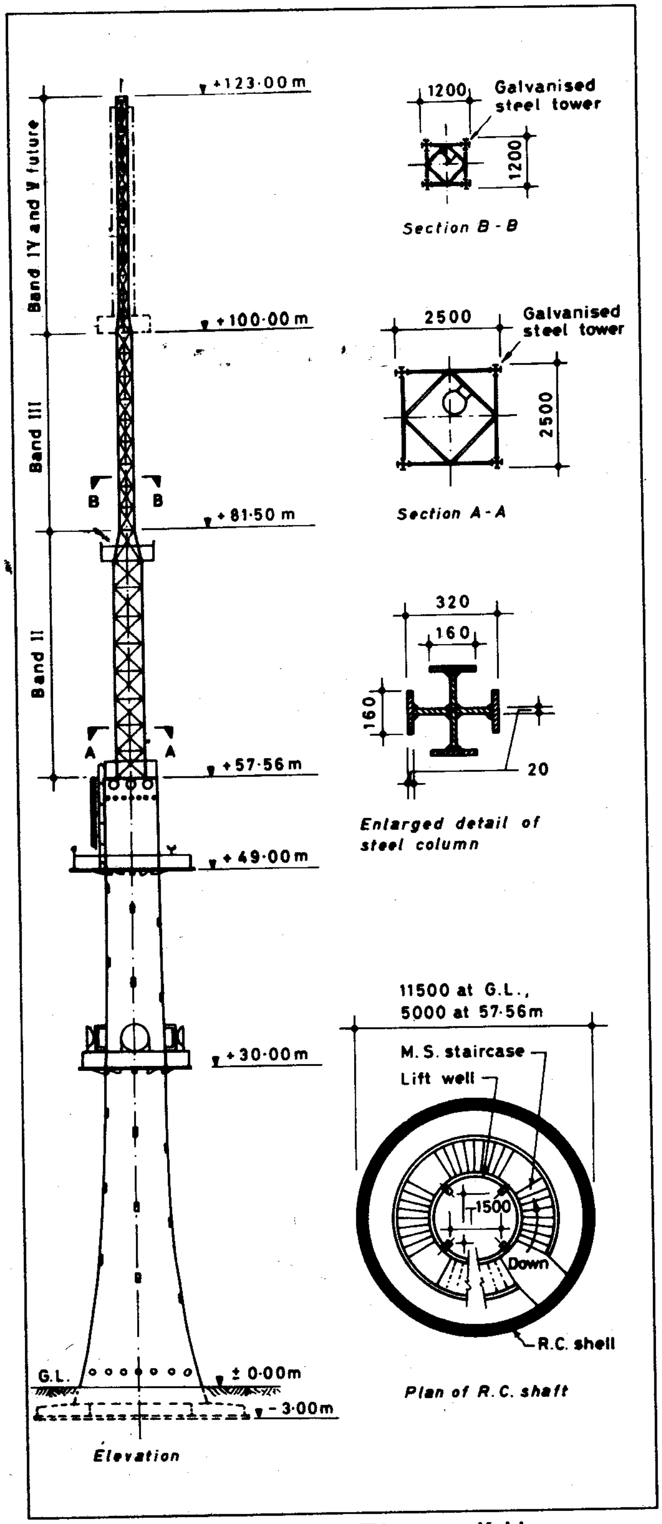

Fig 1 General arrangement of the TV tower at Kohima

The dynamic response of the tower is taken into account by deterministic gust factor approach as developed by Prof. Schlaich of the Stutgart University, which has been adopted in the design of several TV towers in the Federal Republic Germany. It takes a gust factor of 1.35 with respect of 60 percent of calculated static wind pressure. This amounts to a global gust factor of 1.21 (0.6 x 1.35 + 0.4) with reference to the total wind pressure. In the design of the tower mast, the case of wind acting along the diagonal of the square tower which is equivalent to 1.2 x wind forces acting on normal to square side of the tower is found to be more critical. For the functional requirements, the tip deflection of the steel mast is limited to 1° from the polar axis. For satisfying this requirement, some of the diagonal bracing members in the lower elevation of the mast required increased cross-sectional area than those required purely from stress consideration. The calculated tip deflections are 1.119m for the steel mast only (equal to 0.984°) and 1.25m for the complete structure including the shaft (equal to 0.575°). The design considered the secondary effects due to elastic deformation and eccentricity of loads due to deflection which amounted to nearly 5 percent of the calculated along wind moment.

The first five natural vibration mode shapes and frequencies, obtained from the frequency-mode analysis, *Fig* 2, indicate that the fundamental mode contributes predominantly to the dynamic stresses of the concrete shaft, and the second and higher modes are essentially motions of the tower mast portion. Although cross-wind vibrations over part of the concrete shaft is theoretically possible, the critical wind velocity at which this vibration occurs is much lower than the design wind velocity, and cross-wind oscillations, if any, would be relatively insignificant. However, a check was made by calculating Scruton number 'K_s' as given in the chimney code IS:4998-1975[2], considering logarithmic decrement of damping equal to 0.05, and this worked to 45 which is much higher than the minimum required value of 20. There are no significant cross-wind oscillations to be expected for the lattice steel mast as its plan shape and cross-section do not favour periodic shedding of vortices. However, it must be said that the top 23-m high steel mast portion of future Bands IV and V is likely to be affected by cross-wind excitations, as this portion is likely to be of circular cross-section, and it may be necessary to provide helical strakes in this portion to suppress instability to an acceptable level as has been done in the Emley Moor TV tower in U.K.

As Kohima falls in the severe seismic zone of the country, namely, Zone V in IS:1893-1975[3], the design looked into seismic effects on the structure by using response-spectrum

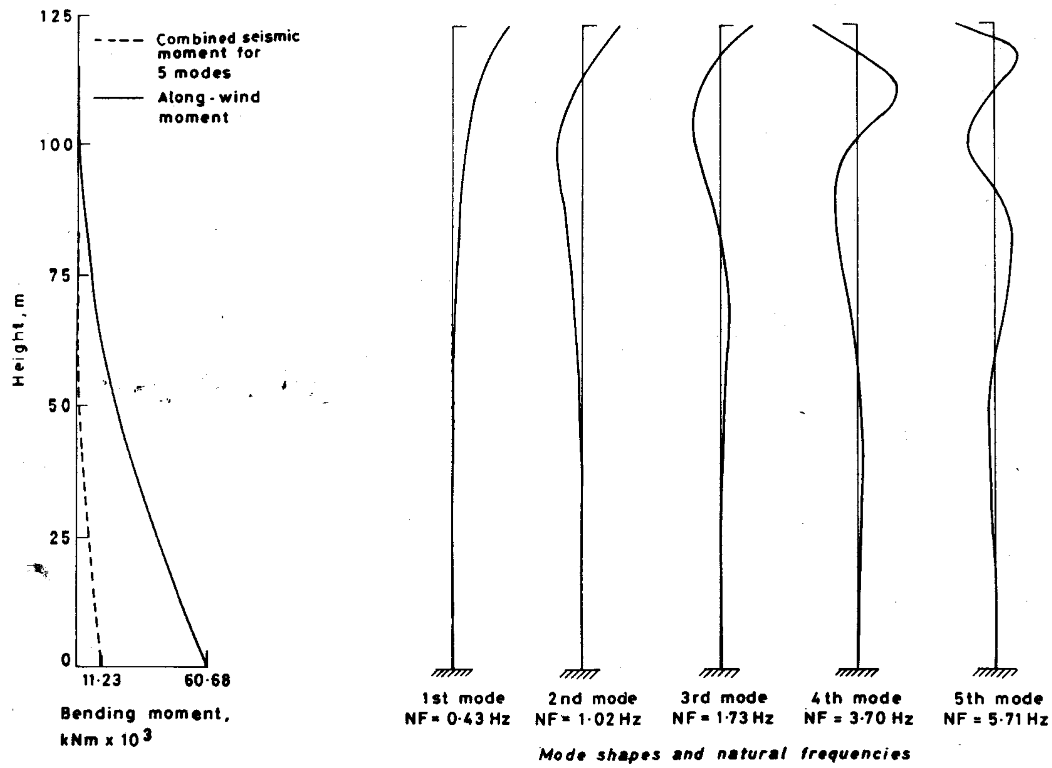

Fig 2 Bending moments,mode shapes and natural frequencies in tower design

method for the first five modes of oscillation, considering 5 percent damping, zone factor of 0.4, soil-foundation factor of 1.0, and importance factor of 1.5. The earthquake moments are calculated on the basis of root-mean-square of the value of the five modes for the combined effect. The seismic displacement is 0.105m in the fundamental mode and 0.122 in the combined first five modes. It can be seen from *Fig* 2 that the seismic moments are not critical in the design, and only wind moments govern the design. At this juncture, it is worthwhile mentioning that the tower has withstood well without any structural distress, the effects of severe earthquake of the magnitude of 6.5 on the Richter scale which occurred in the north eastern states of India, in the first week of August 1988.

The design also looked into the effects of a temperature gradient of 10° C across the RC shaft, and asymmetrical effect of sun radiation, and these were found to be insignificant in the design. For the purpose of natural ventilation inside the shaft, holes are provided in the shaft near ground level and at top elevation to account for ventilation due to stack pressure, considering a temperature difference of 10°C between air inside and outside the shaft, and six changes of air per hour.

The analysis of the steel mast and the RC shaft was carried out by using SAP-IV computer program for various combination of dead + live + wind/seismic loads. A three-dimensional analysis was also carried out for the design of steel mast only, considering wind acting along the diagonal of the square tower. An annular ring foundation, 19-m outside diameter and 9-m inside diameter, at 3-m depth below ground level is provided taking a maximum bearing capacity of soil equal to 250 kN/m^2, and allowing no tension in the soil. The calculated factor of safety against over-turning is 2.19 under minimum dead load condition.

The design of the RC work is done by working-stress method, using permissible stresses as recommended in IS:456-1978[4] for foundations and platforms, and the chimney code IS:4998-1975 for the shaft. The steel work for the mast, staircase and platform beams are designed as per IS:800-1962[5]. In view of the fact that the structure is sensitive to wind loads, increase in permissible stresses in the materials and in bearing pressure of soil normally permitted in the codes are not considered in this design. Each vertical leg of the steel mast is made of two I-shapes, *Fig* 1, by welding of flat sections. In view of the limitations on the availability of large size angle sections in the country, this profile offered the best solution for simple connections with small size splice and gusset plates, as compared to connections when box section made of channels or angles with plates is used for the vertical leg, which leads to large size splice and gusset plates, besides creating local bending problems in the box section at the location of connections.

One of the important features of the tower is the connection of the steel mast with the RC cap of the shaft. The connection is made by using 27-mm diameter high-strength friction-grip bolts of (28 in number) of 10.9 grade conforming to IS:3757-1972 and IS:1367-1967, at each leg of the mast.The maximum design forces acting at the junction are 4110 kN tension, and 130 kN horizontal shear due to wind. The connection to 1.4m deep RC cap is by through-bolts resisting the forces by friction and bearing against concrete.

Construction

The annular foundation, using M20 grade concrete was cast in six segments with vertical keyed joints between the segments. The RC shaft was constructed in M25 grade concrete by jump-form method. In view of the curvilinear profile at the lower section, special steel forms of 1-m height were used for the purpose.For access to the top during construction, tubular steel scaffolding was provided internally with working platforms, and hoist for materials. The speed of shaft construction was generally 3 lifts of shutter per week. For the construction of top slab, temporary false work consisting grid of steel beams supported on the RC shaft was provided. During construction of the shaft, 85 mild steel inserts were provided at the desired elevations, both on the inside and outside surfaces of the shaft, for the purpose of connections to steel members providing lateral support to the internal spiral staircase and lift-frame structure, and to castallated steel beams supporting the external platforms. The cover to reinforcement in foundation is 75mm, and 40mm in the shaft at each face of two layer reinforcement. The laps in vertical reinforcement are staggered, and a minimum lap length of 70 x diameter of bar is provided as per the German practice to account for fatigue and whip-lash action of wind.

As the steel mast was galvanised, the maximum length of any steel member was limited to 6m, and all connections between members of the mast were by bolting only, using 8.8 grade high tensile steel bolts conforming to IS:1364. Welding was restricted to connections of gusset plates to steel members and at the base plate location. The steel mast was erected in segments by using a purpose-made derrick. The tightening of high-strength friction grip bolts at the base of the mast was carried out by using a calibrated torque wrench.

The total volume of work involved are 620m^3 of RC work, 50 t of steel work for the mast, and 25 t for the miscellaneous steel work such as spiral staircase, platform supporting beams, ladders etc.

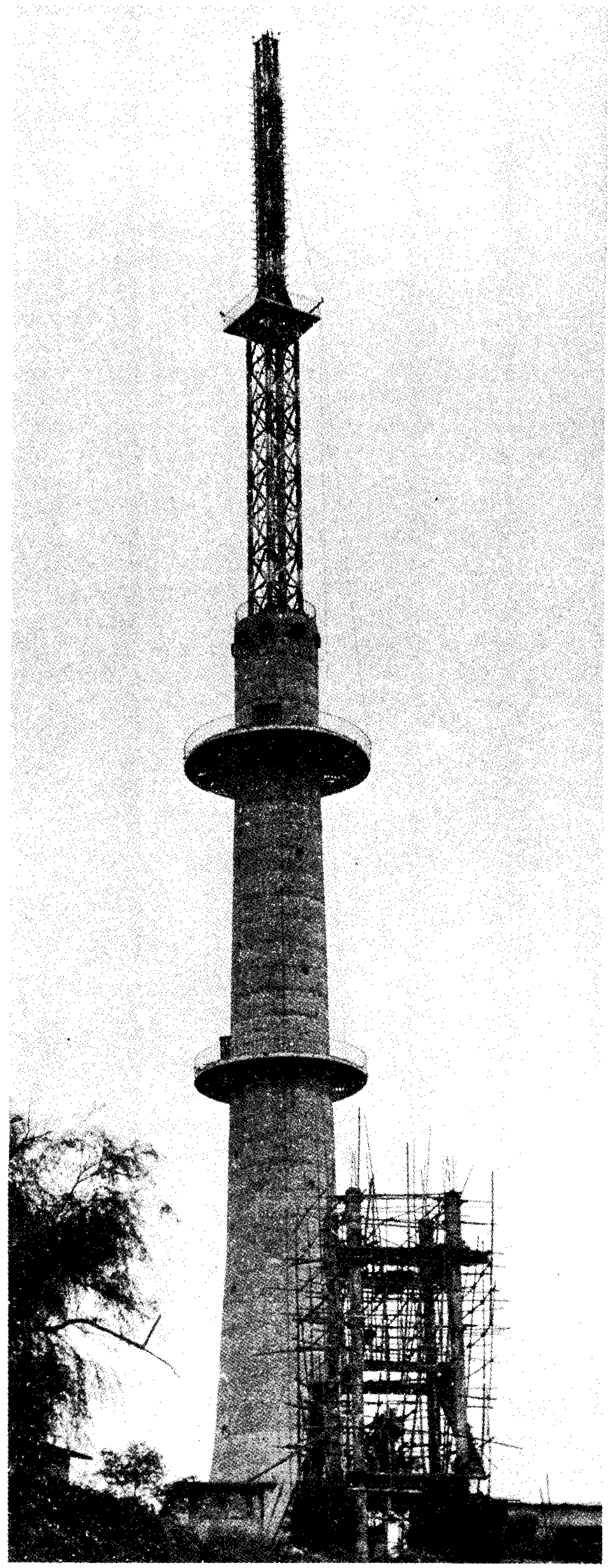

Fig 3 A view of the Kohima TV tower nearing completion

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References

1 ______ *Indian Standard Code of Practice for Structural Safety of Buildings*, Loading Standards (Revised), IS : 875-1964, Bureau of Indian Standards, New Delhi.

2 ______ *Indian Standard Criteria for Design of Reinforced Concrete Chimneys* Part I- Design Criteria (First Revision) IS : 4998(Part I)-1975, Bureau of Indian Standards, New Delhi.

3 ______ *Indian Standard Criteria for Earthquake Resistant Design of Structures* (Second Revision), IS : 1893-1975, Bureau of Indian Standards, New Delhi.

4 ______ *Code of Practice for Plain and Reinforced Concrete*, IS : 456-1978, Bureau of Indian Standards, New Delhi.

5 ______ *Code of Practice for General Construction in Steel* (First Rivision), IS: 800-1962, Bureau of Indian Standards, New Delhi.