Design aspects of the turbine hall and auxiliary bay structure of Matimba

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Synopsis
The turbine house structure is subjected to heavy industrial plant loadings. Associated imposed floor loadings are not covered in the SABS design codes. This paper describes the structural concept and design loads used. Restraint actions due to temperature variation, shrinkage and settlements are considered. The design was done in 1982/83.

Samevatting

Introduction
The turbine house consists of six units. It is the nerve centre of the power station, housing the control equipment and the steam-driven turbine generators. The turbine house is located between the boiler house and the cooling structure. The estimated civil construction cost for the turbine house superstructure is R93 million. Approximately 94 310 m$^3$ of reinforced concrete, 15 880 t of reinforcement and 2 950 t of structural steel will be used.

Structural concept
The total length of the six 660 MW units including the end bays is 555 m. The structure is divided into two distinct functional areas: the 33 m wide turbine hall and the 13,8 m wide auxiliary bay, both 33 m high (see Fig 1). These areas are enclosed by massive concrete security walls along the main column lines A, B and C. In the longitudinal direction the columns are spaced at 8,5 m centres. Expansion joints have been provided between and within each unit. This results in longitudinal frames of 51 m and 34 m. The positioning of the off-centre expansion joint was dictated by plant layout.

The turbine hall has a 3 m deep basement area, and floors at 0,0 m, 9,5 m and 16 m levels. The turbine is supported on a reinforced concrete structure that is completely separated from the turbine house owing to vibration considerations. Two 100 t overhead cranes and two 12,5 t semiportal cranes run the length of the turbine hall.

The auxiliary bay has a 3,8 m deep basement, five main structural floors and two cable reserves. The auxiliary bay houses the power station control rooms, electrical switchgear, battery rooms, airconditioning plant, workshops and general offices.

The major structural elements have the following dimensions:

### Columns
- A line: 1.9 m × 1.0 m
- B line: 2.0 m × 1.2 m
- C line: 1.8 m × 1.2 m

### Internal turbine house
- 1.0 m × 1.0 m

### Beams
- In turbine hall: 0.7 × 1.5 m
- In auxiliary bay: 0.7 × 1.25 m in cross direction, 0.6 × 1.5 m in longitudinal direction

Design history
In mid-1981 one of the designers, Mr A Peters, went to MAN in Germany to gain experience in the design of turbine house structures. A preliminary design in the last quarter of 1981 determined optimized element sizes for the final design. This design was started in February 1982 with the receipt of plant layout and load plans from MAN. The layouts were based on an indirect dry-cooling system. Construction was planned to start in June 1982. Before this date, however, Escom decided to award the cooling contract to GEA for a direct dry-cooling system, resulting in major changes. MAN provided new layout and load plans in July 1982. All affected structural frames were reanalysed and foundations redesigned. The turbine house design was substantially completed by April 1983. Construction actually started in July 1982 and estimated completion of construction is 1990.

Design
Primary load cases
Primary load cases considered were dead, imposed, wind and crane loads. Wind and crane loads were calculated in accordance with SABS 0160.

Turbine house
Imposed and traffic loads for the turbine house floors were determined from the recommendations of the German code VGB technische Vereinigung der Grosskraftwerksbetreiber EV for thermal power stations. They allow a reduction of the high imposed load of the 16 m operating floor level when designing the main support beams and columns. Typical turbine hall floor loads are 30 kN/m$^2$ for the 16 m level and 15 kN/m$^2$ for

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Major plant loads in the turbine hall include the following:

- 4 high pressure heaters: 1,800 kN each
- Feedwater tank: 4,600 kN
- 3 boiler feed pump assemblies: 900 kN each
- Condensate tank: 1,700 kN
- 4 mounting points for stator lifting device: 2,000 kN each

The 16 m operating floor level serves as a laydown area for the turbine parts.

Typical loads are as follows:

- HP rotor: 118 kN
- IP outer casing: 340 kN
- LP outer casing: 300 kN

The A-line partly supports the GEA exhaust ducts leading to the cooling structure. There are four load points on each unit at the 33 m level of 740 kN. One A-line column also provides two horizontal restraints to the 5 m diameter exhaust ducts. These loads are 420 kN at 26.9 m and 50 kN at 10.0 m.

Auxiliary bay

Imposed loads for the auxiliary bay were determined from historical data on previous stations. These vary from 7.5 kN/m² for switchgear areas to 10 kN/m² for battery rooms and cabling reserves. The 0.0 m suspended floor slab accommodates several 30 t transformers. The auxiliary bay structure also supports the hot and cold reheat pipeline expansion loops at the 36 m level. There are nine point loads of 300 kN each. The C-line columns support platforms from the boiler house at 16 m and 23 m. These loads range from 250 kN to 1,050 kN on each column.

Secondary load cases

Owing to the long and stiff frames, secondary effects had to be considered. Temperature, shrinkage and creep effects were assessed according to the CEB design code. Differential settlements were assessed to Hawkins, Hawkins and Osborn recommendations. Because major elements were in excess of 700 mm, a 10 °C temperature differential for seasonal changes was considered.

A long-term shrinkage strain of 0.00045 was considered. This strain was reduced by 60 per cent as a result of the creep in concrete. A further reduction of 33 per cent was justified when the sequence of construction was taken into account. Using a coefficient of thermal expansion of 12 × 10⁻⁶°C, this shrinkage corresponds to a further drop in temperature of 10 °C.

The structure was founded on spread foundations designed to a maximum bearing pressure of 3 MPa. All the major foundations were founded at 5.3 m below the terrace level. Settlements for these foundations were determined from Boussinesq's theory. It was recommended that the differential settlement be taken as equal to the total settlement. This was because of the variable nature of the rock and the many horizontal joints in the sandstone layers. A 3 m differential settlement of alternate foundations and various other settlement patterns were induced onto the structure.

Load combinations

The primary load cases were combined using the design load factors as specified in SABS 0100 and SABS 0162 for the wind and crane load combinations. The secondary loadings were combined using the load factors as specified in the South African bridge design code TMH7. The seasonal temperature differential was factored by 1.3 and the shrinkage and the various settlement load cases were all factored by 1.0. The maximum positive and negative load cases from the secondary combina-
tions were then combined with each primary load combination.

Substrate rotation
Owing to the proximity and exceptionally heavy load (80 000 kN) of the main boiler house columns, Hawkins, Hawkins and Osborn recommended that the effect of substrate rotation be added to the adjacent C-line columns. The recommended design rotation was 0.025° and the additional settlement was 3 mm.

Auxiliary bay load distribution
A grillage analysis was done to determine the floor load distribution between the intermediate support beams and the much stiffer in-frame beams. This resulted in the stiffer beams being allocated double the distributed floor loading on the intermediate beams.

Pinned roof structure
The roof trusses were designed to act as struts (or ties) between A, B and C line columns. This was done to limit relative movement at crane rail level to within allowable crane operating tolerances. This decision complicated the design of the steel roof structure and the designers had to consider the effects due to temperature in much more detail.

Working space for the construction cranes
To this end the beams between grid lines B and BX were detailed such that they could be constructed after the rest of the turbine hall had been completed.

Security hardening
The security hardening required certain walls and floor slabs to be designed to resist blast and penetration effects.

Computer software
The gable ends of the structure were analysed using PAFEC, a three-dimensional structural analysis program. High torsional forces were
experienced on the edge columns owing to the wind loadings. The rest of
the structure was analysed with a two-dimensional frame analysis pro-
gram. Owing to the large variations in frame geometries and loads, all
frames had to be analysed. A total of sixteen cross-frames and seven-
teen longitudinal frames were analysed. The frames had up to eight
primary and five secondary load cases. In addition there were up to
fifteen load combinations.

A program was developed to cope with this large amount of data and
load cases. The program first analysed the primary and secondary load
cases. It then combined the secondary load cases to determine the
maximum positive and negative force envelopes. Thereafter the primary
load cases were combined and the secondary force envelopes were
added. All the forces for each element were calculated at tenths of
intervals along the length of the member. These forces were given in the
local axis system. The amount of output was limited to the absolute
minimum by introducing selective printing options.

A program, using the geometry input from the frame analysis program,
was developed to determine the effective lengths of the columns for the
braced and unbraced frames. The column, beam and foundation designs
were also done with programs developed by the design team.

Concrete versus steel
Steel and concrete options were evaluated and a concrete structure
up to the 33 m level with steel roof trusses and steel crane girders was
chosen. This option proved to be more economical than an all steel
structure. Another factor in this choice was the fact that the turbine house
had to be extensively hardened for security reasons. The concrete walls
were more compatible with a concrete frame. The longer construction
period required for the concrete option was considered and could be
accommodated. An important benefit of the concrete option was the
larger labour force required over the long construction period. Matimba
Power Station is in a very remote rural area and has provided for the
socio-economic upliftment of the local community.

Conclusion
The strategic location of the designers close to the Escom decision-
makers improved communication and the flow of information. Decisions
affecting the structure could be assessed quickly. The in-house design
provided Escom with the expertise, experience and continuity necessary
to improve on future turbine house designs. Turbine house designs for
Kendal and Majuba Power Stations have subsequently been success-
fully completed.

The additional time and cost associated with the inclusion of second-
ary effects in the design was justified by the importance and value of
equipment housed within the structure.

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