Direct air-cooled condenser support platform at Matimba Power Station

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Synopsis
The air-cooled condenser unit is the largest of its type in the world. The performance criteria required an economic structure that could meet very strict construction tolerances and would be extremely rigid in order to prevent dynamic response to the giant electrical fans.

Samenvatting
Die lugverkooldesondensereenheid is die grootste en sy tip in die wêreld. Die werklikheidskriteria het 'n ekonomiese struktuur vereis wat die bale streng konstrukties toleransies sou kon nakom en die bale styf sou wees om dinamiessse reaksie op die enorme elektriese wassers te verhoed.

Appearance
The Matimba Power Station deviates from the traditional Escom approach in that the turbine hall is constructed primarily of concrete rather than structural steel. The use of hollow concrete columns in the condenser support structure, which is adjacent to the turbine hall, complements the overall appearance of the power station.

Description
The structure consists of a steel platform supported by hollow concrete columns.

The steel platform is designed to support the A-frames carrying the air-cooled condensers as well as the fans and associated equipment. Provision has been made to carry a crane on top of the platform for the erection of mechanical equipment. The platform is divided into six units to allow for thermal movements. Each unit is 86 m long by 75 m wide and carries 48 fans of 9 m diameter. As each unit is supported by 12 hollow concrete columns, a total of 72 columns were required.

The columns are 21.12 m apart in one direction and 23.60 m in the other. The column size was dictated largely by the very strict horizontal deflection requirement of \( \pm 50 \text{ mm} \) at platform level to prevent damage to the steam ducts from the boiler house. Each column has a 4.5 m external diameter and a 280 mm wall thickness and is 43.48 m high. One internal diaphragm slab is located at the 30.3 m level and another at the 39.7 m level. The main purpose of the diaphragms is to prevent distortion of the column wall by the stays that help support the platform. The columns are closed at the top with capping slabs.

The platform consists of lattice girders 3.0 m deep. To shorten the spans between columns of 21.12 m in one direction and 23.6 m in the other, two 10.56 m and 11.80 m long stays were introduced. From each outside corner of a rectangle formed around a column, 4 stays are angled downwards to connect with each column at level 30.3 m. The main girders have spans of 23.6 m and 21.12 m and the secondary girders' spans are 11.8 m and 10.56 m. The span of the main girder is reduced further by the introduction of short stays projecting downwards to the columns at level 39.70 m. The long stays are laced compression members and the short stays are standard H-profiles.

The platform also utilizes cantilever sections with spans equal to half the distance between columns. Stays were also used to provide further support to the cantilever sections.

The secondary steelwork consists of beams spanning the area between the main girders. These beams support the plates covering the platform, which in turn support the fan rings.

Design
In the design of the columns the single most important design constraint was that maximum horizontal deflection under load at the top of the 43.48 m high column should not exceed 40 mm from the true vertical. Foundations were therefore designed to restrict differential settlement, thus preventing any resultant column movement caused through rotation of the foundation. A finite element analysis utilizing representative rock mass moduli was undertaken and confirmed values well within the design specification. A stiffness design rather than a full strength design was adopted for the columns.

Three alternative column designs were considered before the concrete option was selected:

1. A complete steel column.
2. A combined concrete and steel column with the section above the long stays being fabricated from steel.
3. A combined concrete and steel column with the section above the short stays being fabricated from steel.

From the point of view of cost and speed of construction, the hollow concrete column was considered the optimum solution.

The following alternatives were considered in the design of the platform:

1. Steel platform with stays.
2. Pile platform without stays.
3. Precast concrete elements.

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Phillip Venter obtained his honours degree in civil engineering from the University of Stellenbosch in 1979. Thereafter, he was employed by Bruinette Kruger Stoffberg Inc (BKS), where he was involved in the design of civil structures in concrete and structural steel. He at present holds the position of office manager at the Vereeniging branch of BKS.

Alan Parrock graduated from the University of Natal in 1972 and thereafter joined the Natal Roads Department, working in the geotechnics, materials and construction divisions. A stint at the National Institute for Transport and Road Research of the CSIR followed, before he joined Bruinette Kruger Stoffberg (BKS) in 1978. He is at present an Associate in the Geotechnical Division in Pretoria.
Alternative 1 proved to be the most economical and practical solution. Probably the most demanding part of the design was the concrete-to-steel connections and the connection where four stays meet at one point. The platform was designed so that deflections due to self-weight and equipment load were minimized to ±15 mm.

The structural system chosen was a statically indeterminate system consisting of trusses in two directions supported by a series of inverted pyramids formed by the long stays.

In the design of the platform a number of possible load cases had to be considered, as follows:

1. Dead load.
2. Normal equipment loads.
3. Partial equipment loads (three possible load cases).
4. Temperature.
5. Erection loads due to movement of crane.

Forces in the structure due to the erection of both the platform and the mechanical equipment were found to be critical. To erect the mechanical equipment an overhead crane had to be used on top of the platform. A detailed sequence of erection was worked out to determine the minimum number of crane positions and the shortest travelling distance of the crane between lifting positions. For reasons of economy, in the permanent structure a temporary set of strongbacks was introduced. The purpose of the strongbacks was to transfer the crane loads to the girder nodes in order to prevent bending moments in the top chords of the trusses.

A complete dynamic analysis was performed to determine the forces in
the structure due to vibration of the electrical motors driving the fans. The effect of one or more of the fan blades breaking off and therefore increasing the out-of-balance of the motor/fan set was also investigated. The different modes of frequency of both the platform and motor/fan set were calculated to ensure that resonance would not occur at normal operating speed.

To calculate the forces in the structure under all load cases, a three-dimensional analysis was performed.

A second-order analysis was performed to investigate the overall stability of the platform. As a result of this analysis, it was found to be necessary to brace the short stays to the column caps to prevent out-of-plane buckling.

**Construction and erection**

Before the footings of the columns were cast, each foundation was inspected for compliance with the design parameters. Any inferior rock was removed and replaced with mass concrete, which was cast as soon as possible after excavation and inspection to prevent thermal loosening.

The columns were constructed using a purpose-made hydraulic sliding shutter without the use of any craneage. Construction of the columns proceeded at the rate of approximately two per month. The finished columns are all of good smooth appearance and are pleasing to the eye. The maximum deviation from the vertical over the full height has never exceeded 10 mm.

The steel elements were fabricated in a workshop near Johannesburg and transported to the site. The first section, supported by four columns, was pre-assembled on site complete with fan rings and lifted into position as a unit. The overhead crane was then assembled on the platform. The remaining parts of the first unit were then lifted by means of the overhead crane and bolted into position. The allowable construction level tolerances for these elements was ±15 mm.

**Quality control**

The support columns were constructed by means of a sliding shutter.

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**Close-up view of column and underside of platform during erection**

The very limited concrete demand due to the slenderness of the column required a high quality concrete mix design and strict quality control to enable the sliding platform to keep moving.

Because of the heavy loads and possible vibration of the platform, very strict quality control was also necessary for the testing of welded connections and the installation of high friction grip bolts.

**Conclusion**

The fine construction tolerances achieved, together with the vast size of the seemingly unending rows of columns, present not only a very impressive display but also a very good example of the structural use of concrete and steel.

**Credits**

The following parties are associated with this project:

- **Owner:** Escom
  Megawatt Park, Sandton

- **Main contractor:**
  GEA Aircooled Systems (Pty) Ltd
  Rivonia Road, Sandton

- **Structural steel contractor:**
  Genrec Steel Structures (Pty) Ltd
  Dekema Road, Wadeville

- **Design engineers:**
  Bruintjie Kruger Stoffberg Inc
  Pretorius Street, Pretoria

- **Civil contractors:**
  Concor Industrial (Pty) Ltd
  Central Avenue, Mayfair, Johannesburg