TZANEEN DAM TOWER CRANE BASE

DESIGN REPORT

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1. Introduction

1.1. Background:

The tower crane bases are essential components of the Tzaneen dam wall upgrades, serving as temporary structures specifically designed for the construction phase of the project. The overarching objective is to enhance the dam wall's infrastructure, necessitating the creation of robust and temporary foundations to support tower cranes during the construction process. Once the upgrades are complete, these temporary bases will be intentionally demolished, underscoring their transient but critical role in facilitating the construction and upgrade of the dam wall.

1.2. Objective:

The primary objective of this design report is to outline the meticulous engineering and structural considerations incorporated into the tower crane bases. Each base comprises a 5.5m x 5.5m reinforced concrete foundation securely anchored into in-situ rock using rock anchors. A top the foundation sits a 3.5m x 3.5m reinforced concrete plinth, supporting four 1m x 1m reinforced concrete columns spaced at 1.9m center to center with a height of 8m. To enhance structural stability, these columns are braced at 2.5m intervals using Steel I-beam sections. The combined length of the tower crane bases is 12m, culminating in a final top of the column elevation at 692.00m. This report aims to detail the design process, emphasizing safety, efficiency, and adherence to project-specific criteria for successful construction and subsequent demolition.

2. Design Criteria:

This chapter aims to discuss the different design elements that were considered for the specifications of these crane bases. These considerations are based on the loading, site conditions and specific requirements of the cranes for this project.

2.1. Design Loading

The upgrade of the Tzaneen Dam wall required the incorporation of two tower cranes. Below are the two selected cranes and the loading requirements for each crane.

2.1.1. CTT 181 crane

Table 2-1 presents the crane loads associated with the CTT 181 crane. These loads were provided by the crane supplier.

Table 2-1: CTT 181 Crane loads

In-service Crane Loads for 65m Jib No. 8 tower section TS21 22.6 (No wind)					
Hook Height [m]	H [kN]	V [kN]	M [kNm]	R1 [kN]	R2 [kN]
49.5	6	-755	1591	-780	403
In-service Crane Loads for 65m Jib No. 8 tower section TS21 22.6 (Tail wind 72 KM/H)					
Hook Height [m]	H [kN]	V [kN]	M [kNm]	R1 [kN]	R2 [kN]
49.5	32	-755	2496	-1117	740
Out-of-Service Crane Loads for 65m Jib No. 8 tower section TS21 22.6 (Tail wind 151 KM/H)					
Hook Height [m]	H [kN]	V [kN]	M [kNm]	R1 [kN]	R2 [kN]
49.5	108	-658	3052	-1300	971

Out-of-Service Crane Loads for 65m Jib No. 8 tower section TS21 22.6 (Front wind 135 KM/H)					
Hook Height [m]	H [kN]	V [kN]	M [kNm]	R1 [kN]	R2 [kN]
49.5	77	-658	3785	-1573	1244

2.1.2. CTT 202 CRANE

Table 2-2 presents the crane loads associated with the CTT 202 crane. These loads were provided by the crane supplier.

Table 2-2: CTT 202 Crane loads

In-service Crane Loads for 65m Jib 1 x TS21 22.6 C1 + 9 x TS21 22.6 (Rear wind 72 KM/H)					
Hook Height [m]	H [kN]	V [kN]	M [kNm]	R1 [kN]	R2 [kN]
61.95	34	914	2728	-1244	787
Out-of-Service Crane C25 Loads for 65m Jib 1 x TS21 22.6 C1 + 9 x TS21 22.6 (Rear wind 161 KM/H)					
Hook Height [m]	H [kN]	V [kN]	M [kNm]	R1 [kN]	R2 [kN]
61.95	136	766	4244	-1771	1388
Out-of-Service Crane Loads for 65m Jib 1 x TS21 22.6 C1 + 9 x TS21 22.6 (Wind from any side 100 KM/H)					
Hook Height [m]	H [kN]	V [kN]	M [kNm]	R1 [kN]	R2 [kN]
61.95	96	766	4769	-1923	1540

2.1.3. STATIC AND DYNAMIC WATER LOADS

The static and dynamic water loads refer to the different forces exerted onto the crane base by the water spilling over the dam wall. The static loads pertain to the forces exerted by water when it is at rest. Static force is a function of the height of the water.

Dynamic water loads result from the turbulence of the movement of water, hence a velocity function. The dynamic water load was calculated utilizing the velocity of a water column over a dam spillway. This water column velocity was calculated as 32m/s. The dynamic water pressure was converted into a static water pressure of 511kPa. This pressure was applied over the base.

2.2. LOAD CAPACITY:

2.2.1. LOAD COMBINATIONS & FACTORS

Multiple load cases were considered for the analysis of the tower crane bases. Each load case of both cranes was analyzed together with the static and dynamic pressure of water exerted onto the base structure. Combinations were analyzed to determine the most severe loading combination. The worst load combination obtained was the crane load's of Out-of-Service Crane C25 Loads for 65m Jib 1 x TS21 22.6 C1 + 9 x TS21 22.6 (Rear wind 161 KM/H) combined with the static water pressure and dynamic water pressure. This load combination was used for the tower crane base design.

2.3. FOUNDATION CONDITIONS:

Due to time constraints on the project, specific geotechnical testing could not be completed for the areas where the crane bases will be placed. These areas were assumed to be solid rock during an inspection. The design was thus created to anchor the crane bases into the rock using rock anchors.

Specific attention was brought to the anchor positions per request from ARQ Consulting Engineers. These anchor positions are required for part of the permanent work on the dam improvement project and must be avoided at all costs. Tampering with the rock at these locations would cause compromise the permanent work and can necessitate serious changes to other designs.

2.4. Deflection Criteria

Due to the slenderness of the tower crane the deflection tolerance is very small. The construction of the foundation must be built withing a tolerance of 1mm horizontal deflection for every vertical 500mm. The same tolerance was used to establish a safe serviceability deflection limit.

2.5. Material Specifications:

2.5.1. Design Parameters

- Young's modulus for class 30/19 concrete = 28 GPa.
- Young's modulus: steel = 200 GPa.
- Coefficient of concrete expansion = 12x10
- Creep factor = 2

2.5.2. Characteristic strength of materials

a) Concrete:

- Blinding = 15/19 MPa/mm
- Mass concrete = 15/38 MPa /mm
- Foundation slabs = 30/19 MPa /mm
- Columns = 30/19 MPa /mm

b) Reinforcement:

Reinforcement to be hot rolled and to comply with the standard specifications for steel bars for concrete reinforcement SANS 920 minimum.

- Mild steel = 250 MPa
- High tensile steel = 450 MPa

2.6. Accessibility and site constraints:

Accessibility to the site will be provided via the draining of the downstream stilling basin.

2.7. Construction Timeline:

An approximated timeline of 2 to 3 months is expected for the erection of both tower crane bases. The final program will be confirmed on the receival of the contractor's program.

3. Tower crane base design

The tower crane base design consisted mainly of three design sections namely Global Stability, Foundation and Prokon Modelling.

3.1. GLOBAL STABILITY DESIGN: OVERTURNING AND SLIDING

Figure 3-1 shows the forces that were considered during the calculations for overturning and sliding of the bases. The Factor of Safety obtained from the calculations are as follow:

Water height acting on Base	FoS Sliding	FoS Overturning
1.5m	1.33	2.08
2m	1.01	1.79

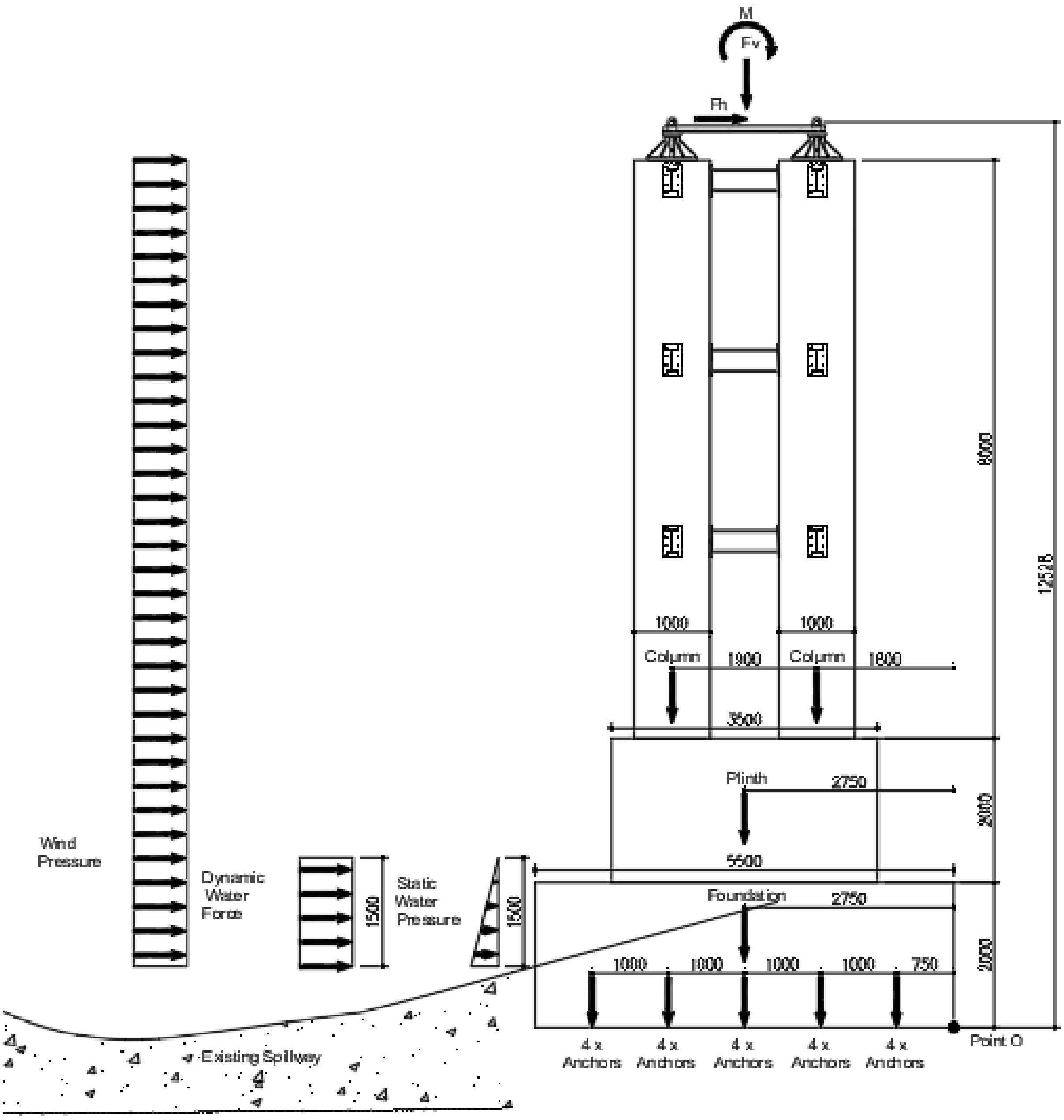

Figure 3-1: Sliding and Overturning Diagram

3.2. FOUNDATION AND ANCHORING DESIGN:

The concrete foundations are large, monolithic, spread footings which will be cast in-situ. The following assumptions were made in the design of these foundations:

- It is assumed that the rock, on which the foundations are cast, is of competent medium to hard rock Granite.
- A bearing pressure of 600 KPa was used in design calculations.
- Competent rock was assumed to be near the NGL surface provided.

The foundations are specifically designed with a capacity to transfer the high shear forces from bottom of the columns into the rock. The foundations utilize a layout of rock anchoring dowels. These will provide the required shear resistance to prevent sliding and overturning of the crane towers. The rock anchoring dowels make use of reinforcing steel bars, which will be embedded approximately 4 meters deep into the rock as shown in Figure 3-2 below. This embedment depth will add enough tensile resistance to allow for the overturning forces and moments. This embedment depth might vary depending on the quality of the in situ rock.

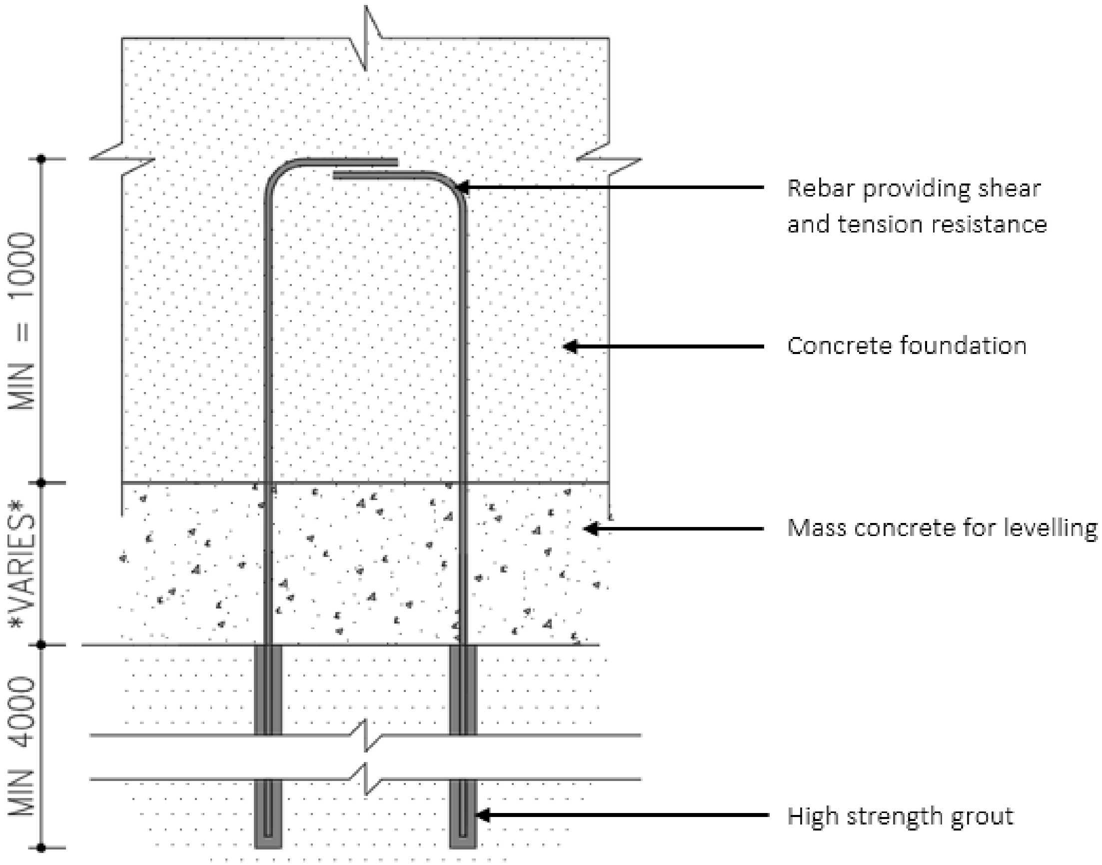

Figure 3-2: Rock Anchor Dowel Detail

3.3. PROKON MODELING

The design of the Tower Crane base was executed using the Prokon software. With the aid of the frame analysis module, the Tower Crane base was modelled utilizing a combination of shells and beams. Each section of the Tower Crane base was allocated to specific elements for the structure.

Throughout the design and modelling process, all elements constituting the Tower Crane base model underwent thorough analysis considering relevant load cases. The load cases were derived from various factors such as the self-weight of the crane base, crane loads as provided on the tables in Section 2.1 above, water static loads and the dynamic impact loads from water.

The Tower Crane base model comprises essential elements, including a monolithic concrete foundation, a reinforced concrete plinth, four reinforced concrete columns and strategically incorporated 305 x 165 x 54 steel I beams. The steel I beams play a crucial role in bracing and stabilizing the concrete columns, contributing to the structural integrity of the overall design. For a visual representation, refer to Figure 3-3 which illustrates the layout of the Tower Crane base as modelled using Prokon Software.

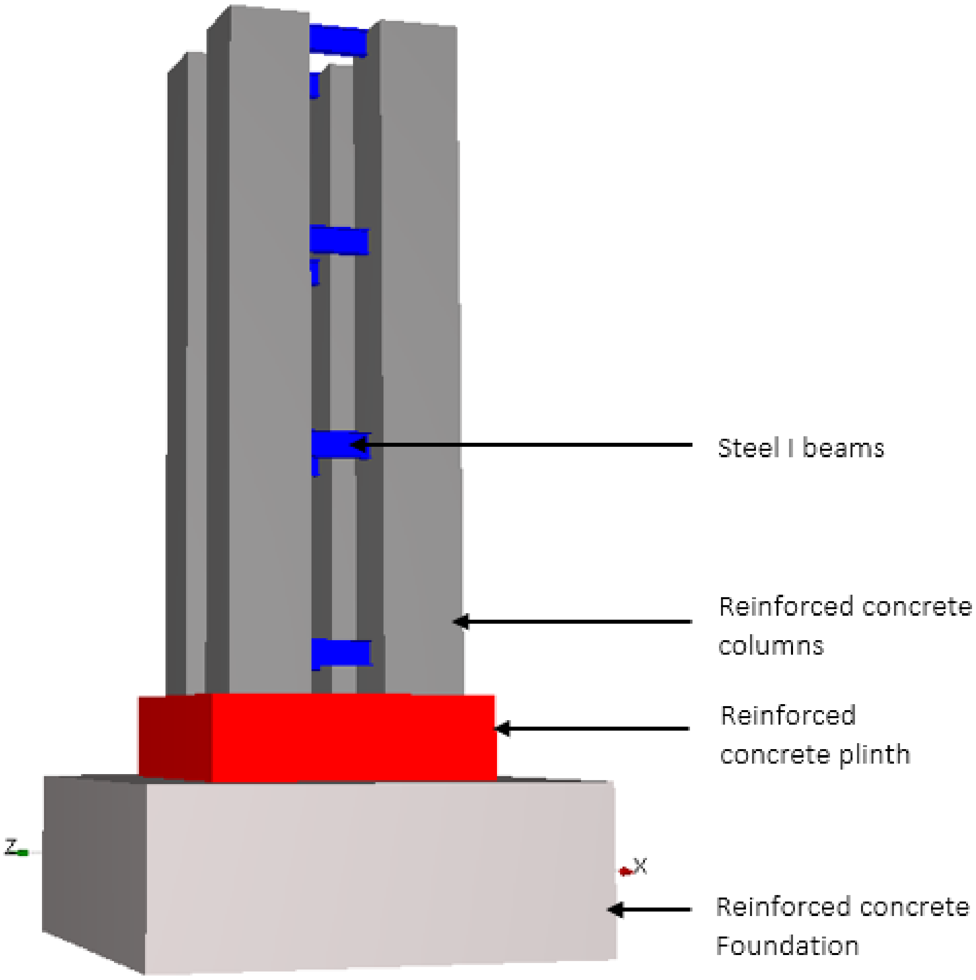

Figure 3-3: Tower Crane Base Model

4. DESIGN LIMITATIONS

The structural capacity of the crane bases is limited to a flood event that will produce a water column of 1.5m high measure at the bottom of the current concrete spillway. Alternative foundation solutions will have to be incorporated for water columns higher than the limitation height.

5. CONCLUSION

The placement of the tower crane bases in the stilling basin at the bottom of the Tzaneen dam spillway provides an intriguing engineering challenge. The magnitude of the forces induced onto the structure is much larger than the normal crane base forces.

With good investigation and consideration of all possible solutions the report outlines the engineering design of the CTT 181 and CTT 202 tower crane bases. With the slight variability in the provided crane loading table, the larger force induced onto the base structure is that of the dynamic water pressure.

The safety factor obtained from the global stability design was as follow:

Water height acting on Base	FoS Sliding	FoS Overturning
1.5m	1.33	2.08
2m	1.01	1.79

The tower crane bases were design for a flood event that produces a water column of 1.5m high impacting at a velocity of 32 m/s. The sliding FoS of 1.3 was deemed acceptable due to the temporary nature of the work. It must be noted that if a flood event occurs that induces a water column higher than 1.5m at the bottom of the base the base can be at higher risk to slide and over turn. If the risk is not acceptable to the client further resisting measurements will have to be incorporated for higher flood events.

We trust that we have interpreted your requirements correctly. Please contact the under signed should you require any further information or clarification.

Yours faithfully,

Ulrich Drotsky Pr.Eng (Director)
For **TEP Consulting Engineers (Pty) Ltd**