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THE CONSTRUCTION SUPERVISION OF YOUR FIRST CATEGORY III DAM - ASPECTS ALL YOUNG ENGINEERS SHOULD KNOW - THE NECKARTAL DAM, NAMIBIA

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ABSTRACT

Young engineers are well equipped with knowledge regarding the design, engineering, and construction of Category III dams, but require in-field experience to develop both their project and program management skills for such an undertaking. The figures and statistics of these large scale projects can be overwhelming and it can often take months for young engineers to find their feet during the construction phase of such a project. Upon completion, the Neckartal Dam will be the largest dam in Namibia, with nearly three times the volume of the Hardap Dam, currently the largest reservoir in the country. The multi-billion Namibian Dollar, Category III Neckartal dam will contribute significantly to the sustainable economic development of the //Kharas Region, southern Namibia. The dam will provide water for crop cultivation covering approximately 5 000 hectares of irrigated farmland and provide employment for several hundred people in the process. For the author (a young engineer), it was a dream come true to be part of the construction of such a monumental structure. Projects of this magnitude may influence the direction of one's career, cause lifestyle changes and challenge the perspective and vision of an engineer's life. This paper shares lessons learned in overcoming project and individual challenges faced by a young engineer and provides a message to supervisors as to what may be expected from the younger generation.

1. PROJECT BACKGROUND

The approximate location for the site of the Neckartal Dam was earmarked in 1906 by early German colonialists. Since then, numerous preliminary designs were prepared for the dam until the final design was undertaken by Knight Piésold Consulting in 2010 as a curved gravity dam. Site establishment and excavation of the foundation started in 2012 with the first roller compacted concrete (RCC) placed during October 2015.

Construction of the Neckartal Dam has advanced remarkably over the past two years. When completed, this massive multi-billion Namibian Dollar structure, situated in the Fish River, will be the largest dam in Namibia. The construction of the 76 m-high Neckartal Dam is being constructed by the Italian construction giant Salini Impregilo SpA, while construction supervision is undertaken by Knight Piésold Consulting. Both firms are internationally renowned and, combined, have over a century's experience in the construction, design and supervision of large dams and hydropower infrastructure. Construction is being undertaken 24 hours a day, 7 days a week, employing more than 2 000 personnel daily on site. The dam will contribute to the sustainable economic development of the //Kharas Region, southern Namibia and will yield water for irrigated farms and crop cultivation covering up to about 1 960 hectares during Phase 1. During Phase 2, irrigable land may be extended to 5 000 hectares, employing several hundred people in the process.

2. INTRODUCTION

The construction of a Category III dam always poses challenges and the Neckartal Dam is no exception. Situated in the barren south, a desert region of Namibia, the construction process is exposed to extremely hot summer days continuing for most of the year with near freezing winter nights. This emphasizes the need for appropriate construction planning of the nearly 1 million m³ RCC structure. Up to date, the recorded annual rainfall on site during construction was less than 30 mm. The site is approximately 70 km from the nearest small town, Keetmanshoop, with site access along a tedious 35 km gravel road. All the construction material and equipment, except aggregate and crusher dust (locally mined on site), needs to be delivered from Windhoek (the capital of Namibia) or from South Africa, both more than 600 km away.

At the time of publication, the Neckartal Dam will still be under construction and will be approximately 80% complete. The author of this paper is a young engineer working daily on site during the construction phase of the dam. He has experienced challenges, faced on a daily basis, during the construction of the dam wall. Constant interaction with his senior engineers working on the project were needed to gain their input and understanding, and reflecting the understanding of the older generation engineer, for the construction of such a large structure.

In this paper, the author shares lessons learned in overcoming specific project and individual challenges faced during the construction of a Category III dam and hopes to provide some insight to supervisors as to what may be expected from the younger engineering generation.

3. PROJECT SPECIFIC LESSONS LEARNED

3.1 General project specifications

Project specifications are developed to guide both the engineer and the contractor in their decision making process on site, while enforcing a certain degree of work quality and responsibility to a project. As a young engineer, knowing the project specifications, allow you to make quick and correct decisions while under pressure. The design engineer should ensure that the specifications are consistent and project specific with no contradictions or open-ended statements present, to prevent the Contractor from misinterpreting important items (contra proferentem). Contractors tend to take advantage of the limited experience of young engineers by requesting urgent decisions on site, mostly when an experienced supervisor is unavailable. Young engineers should be very familiar with the project specifications since adhering to these specifications will prevent miscommunication throughout a project.

One of the major short comings in the engineering field as a whole is the lack of communication between experienced site engineers (who usually end up staying in construction) and the design office. This leads to unrealistic specifications given by the design engineer and misinterpretations on the construction site. To overcome this problem, it is recommended to familiarize oneself with the project specifications at the beginning of a project and to markdown all worked items as the project progresses. Make specific notes to items where more clarification and detail is required and give the necessary feedback to the design engineer in order to incorporate these comments into future projects.

3.2 Assumptions and preparing official communication to the contractor (Oldham, n.d.)

Assumptions are a perilous practice and should be avoided at all cost. Nevertheless, it is common to make an assumption when preparing official correspondence to the Contractor when providing work instructions. Instructions that are given to the Contractor should always be clear, accurate and should account for any assumptions that the Contractor may make. Below is a list of common mistakes made when interpreting assumptions and site instructions along with practical examples experienced on site:

1) The assumption is bad because there is no evidence:

It is a mistake to say that the assumption fails because there is no evidence. Lack of evidence is part of the definition of an assumption. (An assumption is an assertion that the author does not try to prove – evidence is proof).

Example: When the height of the dam was about 30 m, the rubber and polyvinylchloride (PVC) waterstops twisted during the placement of RCC due to the method used (sloping method – see section 3.3). Instruction was given to correct the alignment of the waterstops while the RCC was still fresh. Upon returning to review the corrective action, the work had continued and the waterstop was aligned from the current elevation. No proof existed that the waterstop had been misaligned at a lower elevation or that the necessary correction had been made. The assumption must be that the work had been done as instructed. However, with further investigation, it was proven that this was not the case. The area had to be opened after the concrete had set to prove that the alignment of the waterstop was not in accordance to the original instruction given.

2) The assumption is good because there is evidence

This is the opposite of the first assumption as mentioned above. If an assumption is an assertion that the Contractor does not try to prove, then there cannot be any evidence for it. The crux must be to identify an assertion that is not supported by evidence, and then decide whether it could be supported, based on what is known or can be seen about the subject. In most cases, you cannot base the acceptance of the assertion on verbal communication but have to investigate the aspects where the evidence is unknown.

Example: The casting of second stage concrete around the sealing frames of the bellmouth intakes on the upstream side of the Intake Tower is not an easy task. Work space is limited and the placement of non-shrink concrete, without the formation of air voids, around all the embedded items is awkward and tricky. During the casting of the first sealing frame for the DN3000 intake, an air void formed without the Contractor's knowledge during concrete placement. This was only revealed once the formwork was removed. Instruction was given to do the necessary repair work as per the project's specification and to prove to the Engineer that the area was correctly prepared before repair work could commence. With the ever-exiting language barrier present, upon return to the area where the repair work had to be undertaken, the work was already done. The evidence of the repair work was there, but it was unknown if the preparation work had been executed according to the project's specification. The area where this repair work had to be done was awkward; it would have caused more damage to the area to remove the repaired concrete to prove to the Engineer that work was done in accordance with the project's specifications than to accept the work as is. In hindsight, it would have been better to take the time and wait while the work was corrected, rather than depend on a called inspection.

3) The assumption is bad because the evidence is weak:

If the contractor has poor evidence for an assertion, by giving irrelevant or unrepresentative proof, then the assertion is not an assumption. The contractor simply failed to provide sufficient evidence for the assertion.

Example: Minor delamination of the external coating of one of the DN3000 reducing pipe segments was visible after installation. The independent third party inspectorate that inspects all welding, coatings, linings and onsite repair work of the mechanical works, informed the Engineer of their observations. The Engineer requested that the quality control plan (QCP) for the specific item be re-submitted. The QCP for a similar pipe segment was received, with the assumption that it would have been through the same QCP process as the other pipes. However, this was not acceptable and the pipe segment had to be repaired, cleaned, shot-blasted and re-sprayed on site to the same standard as in the factory. As the shot-blasting started, further delamination of the coating was identified, supporting the Engineer's decision not to accept the submitted QCP. Unfortunately, such site repairs add more time to the installation process, delaying the construction progress. Many items are delivered to site on a daily basis, and it is easy to confuse documentation of similar items. Be vigilant to identify all items according to their serial or identification number.

4) To disagree because one cannot know if it's true or not:

If one cannot know, there is no basis for agreeing or disagreeing. However, even if one cannot know for sure, it is the engineer's responsibility to make an educated guess. The engineer must make that guess and explain thoroughly with substantial reasons. If one cannot say whether an assumption is true or not, one can at least say whether it is reasonable. In other words, can you see how someone might think this, even if you yourself cannot say for sure whether it is true?

Example: DN3000 flange adaptors were delivered to site and needed to be installed to serve as dismantling joints at the DN3000 butterfly valves. The installation of the flange adaptors was a difficult process. The mechanical contractor gave notice that the out-of-roundness of the DN3000 pipe, due to its own weight, took up all the available tolerance left during manufacturing of the flange adaptor. Measuring the DN3000 pipe's out-of-roundness or that of the DN3000 flange adaptor is a tall order on site. However, an experienced engineer devised the plan that the circumference of the pipe and the sleeve of the flange adaptor could be measured easily; then, the internal and external diameters can be theoretically calculated by subtracting the material thickness. In this procedure, the external diameter of the pipe was calculated to be 3 023 mm, while the flange adaptor's sleeve had an internal diameter of 3 032 mm. This showed that an oversized pipe was delivered to site and that the available tolerance was only 4.5 mm to the outside diameter of the pipe, reduced from 6 mm. This proved that, not only the out-of-roundness of the pipe, but also the oversized pipe diameter were to be blamed for the difficult installation procedure.

3.3 Shortcuts –the longest distance between two points

“Too often the shortcut, the line of least resistance, is responsible for evanescent and unsatisfactory success.” - Louis Binstock

In other words, taking a shortcut will only result in success for a short duration of time. In the arena of construction, both contractors and engineers are often guilty of taking shortcuts, whether it is not following the prescribed construction procedure or trying to expedite construction at an area not fully prepared (Morrow, 2011). However, each time a shortcut is taken, you may put the project at risk of not being completed on time or within the budget. A contractor will always push to take the path of least resistance and may realize the financial implications associate with it sometimes too late. Some of the examples faced on site were described below.

One third through **the placement of RCC**, the Contractor proposed to start using the sloping method for RCC placement. The procedure, described in Fulton’s 9th edition (Forbes, 2017; Shaw & Perrie, 2009), was adapted to place RCC in 2.4 m high blocks at 300 mm thick layers on a slope, in a direction parallel to the axis of the dam, from one abutment to the other between the formed upstream and downstream faces, as shown in **Figure 1** below.

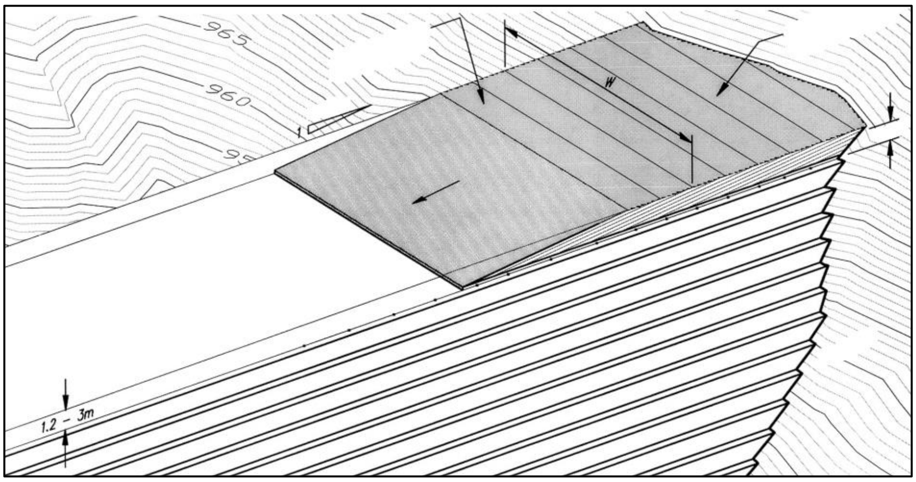

Figure 1. RCC placement with the sloping method (Shaw & Perrie, 2009)

The idea was that the 2.4 m lift could be built up as a continuous process across the entire length of the dam wall without the need for transverse forms, thereby increasing the rate of production. However, excessive bleeding of the RCC and pumping occurred at the toe of the RCC. The effect of feathered edges further aggravated the failure to this approach. Both the rubber and PVC waterstops had a tendency to be easily misaligned by this procedure. Waterstops were pushed out of line by the placed sloping material, causing delayed production when the fresh material needed to be removed. The waterstops had to be re-aligned and the area backfilled with concrete by hand, thereby reducing the structural integrity of the RCC lift. Some of the other aspects that are disadvantageous for the sloped layer include (Forbes, 2003):

- *Limiting downstream formwork options by requiring either high steps (equal to the selected lift height) or a precast concrete block/steel plate step construction system with some associated minor complications in progressive block placing;*
- *Increasing the rate of rise against the formwork, requiring additional formwork anchorages that may result in “kicking” of the formwork;*
- *Aggregate at the toe of the slope could be easily crushed under the roller potentially creating seepage paths;*
- *The potential requirement to remove feathered edges of RCC that occurred where the sloped layer ends at the top of the lift; and*

- *Complicating the finishing of the downstream step horizontal lift surface (grout enriched RCC or conventional internally vibrated concrete).*

A second shortcut that was proposed was **the placement of RCC in 400 mm lifts**, instead of the recommended 300 mm. The placement of RCC in 400 mm lifts would increase the rate of volume placement, since less horizontal lifts would be required. However, the placement rate of the successive layers would be reduced because of the greater volume of RCC required per layer. The time for compaction would also increase, as the number of roller passes would need to be increased in order to obtain the satisfactory compaction rate. In hot weather, rolling should begin within five minutes of spreading and, except for joints, be completed within 30 minutes from the start of mixing (Shaw & Perrie, 2009). In the dry, hot climate of Namibia, the fresh RCC material tends to cure much quicker than the rate at which the new layer may be placed on top of it, resulting in a weak bond between layers. Even with the advantages of set retardation used to improve inter-layer bonds and reduce cold joints, particularly during hot weather, this was not possible. The low water content of the RCC often compromised the effectiveness of the admixture. Increased retardation elicited increased bleeding of the RCC due to inevitable vehicle movement on the layer.

Another example of a shortcut was experienced during the **construction of the Intake Tower**. Inherent in the design of the structure, was the recommendation that the Intake Tower be placed on the critical path for construction of the dam wall. It was proposed that the Intake Tower should lead construction of the dam wall by no less than 5 m. However, the Contractor knew that his cash flow existed in the volume of RCC placement and focused from the beginning of construction only on the dam wall itself. This resulted in the formation of steep RCC placement steps required in order to continue with placement (**Figure 2**). The steps became so steep that RCC production had to be reduced to focus on construction of the Intake Tower. In the haste to increase the elevation of the Intake Tower, it was decided to exclude all internal floor slabs and pipework, concentrating on construction of the outer walls only. One of the drawbacks was that the DN1600 horizontal pipework installed in the Intake Tower had to be cut 500 mm upstream of the existing weld to make place for the precast stairs to be installed and enable working space for the casting of the internal floor slabs. Working space was at a premium; working in the narrow internal opening of the Intake Tower required that special attention be given to the lifting of equipment and material to the inside of the Tower. This significantly reduced the rate of construction of the Intake Tower and resulted in additional expenditure.

Figure 2. RCC on 7 steps during the construction of the dam wall

3.4 Working colleagues

A systems engineer with over 30 years of experience once said: *"The underlying technology and science for engineering solutions is evolving so quickly that very few people can keep current, but there will always be people coming forward with new skills, understanding and enthusiasm. The secret is to recognize your duty as a successful young engineer and develop your skills as a manager in an engineering business so you can create the conditions for the next generation of engineers."*

Building an arsenal of professional skills outside the boundaries of engineering programs can significantly increase an engineer's value to any organization. At the top of the list of skills is managing people – especially other engineers (Gurke, 2014). In a multifaceted and diverse project such as the Neckartal Dam Project, it is important to have a good working relationship with internal office colleagues, as well as the external working partners from the contractor's team. One of the most common challenges in international business settings is the language barrier. Language barriers can be quite challenging, but working with people of different cultures and backgrounds is what drives innovation, creativity and success. Do not let language barriers stand in the way of embracing everything that a diverse workplace has to offer. The following approach may be followed to overcome these barriers (Berardo, 2007):

- *Speak slowly and clearly: Even if you are pressured for time, do not rush through the communication;*
- *Ask for clarification: Avoid assuming that you have understood what has been said;*
- *Frequently check for understanding: Check that both you have understood what has been said and that others have fully understood you;*
- *Be careful of jargon: Watch the use of TLAs (Three Letter Abbreviations) and other organizational language that may not be understood by others;*
- *Define the basics of business: In international business contexts terms such as 'success', 'doneness', 'meetings', 'punctuality', etc. may mean different things to different people. Spend some time early in your communication by defining what these mean to you and others. Invest in building a shared vocabulary;*
- *Be specific: Spell out your expectations and deadlines clearly;*
- *Choose your medium of communication effectively (phone or video conference, email, instant message, etc.): Be mindful not to 'overuse' emails. When a message is complex and complicated or there is tension or conflict that needs to be resolved, switch to another medium. Provide information via multiple channels: Follow phone calls with emails that summarize what's been said;*
- *Be patient: Cross-cultural communication takes more time; and*
- *Learn the language: Learning basic phrases shows your commitment to try overcome the language barrier and working together as an effective team worker.*

It is important for a young engineer to build a good working relationship with their mentor. Mentors provide support, encouragement and can boost self-esteem, helping young engineers to make sound decisions during critical times.

3.5 Environmental considerations

The following environmental considerations were made during the Neckartal Dam Project:

1) Temperature

One of the biggest challenges when constructing a dam wall in an arid desert region like Namibia must be the consideration of temperature and wind. During warm weather conditions, the rate of slump loss and the incidence of plastic-shrinkage cracking tend to increase, setting time decreases, water requirement for a given consistence increases, early-age strengths tend to be higher while long-term strengths and non-permeability are significantly lower (Kellerman, 2009).

Programming the work sequences in such a way that casting of conventional vibrated concrete (CVC) occurs during the lowest temperature time of the day was needed. Even with the recommendations to control the concrete temperatures proposed by Kellerman (2009) (discussed below), casting of CVC was only permitted at night between 18h00 and 06h00 during the summer months. For large volumes of concrete pours, thermo couplings were installed to record the temperature increase due to hydration and were also used to determine when the sequential concrete pours could be executed. Some of the other important considerations undertaken to control the concrete temperature included:

- *Aggregates were kept as cool as possible. Stockpiles were shaded from direct sunlight using nets at the batching plant. However, high wind speeds often resulted in these nets being torn during the windy seasons (July and August);*
- *Cement silos were painted white to keep the contents as cool as possible;*
- *Mixing water was stored out of direct sunlight and crushed ice was used as part of the mixing water to make it as cold as possible;*
- *The batching and mixing plant was kept shaded as far as possible and painted white. Also, the plant was designed to minimise raw material handling times;*
- *Transport time was kept to a minimum. When transporting the RCC over long distances, the concrete trucks were covered with a damp hessian cloth;*

- *Retarders were used to minimise the water content of the mix, permitting a lower cement content and to produce a higher initial slump for the same water content;*
- *Aggregates for the mix design were selected to minimise the water content and thus the cement content. Some of the cement was also replaced with fly ash; and*
- *Casting was done at night to avoid direct sunlight.*

2) Geology

Weathered rock posed a real challenge on site and was aggravated by fluctuating temperatures and exposure to water during the cleaning process. The project specifications required that concrete had to be casted within 24 hours of final excavation cleaning to avoid the exposed rock degrading further. Geology played an integral role in determining the depth of excavation for the shear-key and the dam abutments. Treatment of the exposed rock surface after removal of unsuitable overlying materials depended on the type of rock and the irregularities present. The configuration of exposed hard rock surfaces is controlled largely by foliation, joints, faults, shear zones and excavation methods. Depending on discontinuity orientations, these features sometimes result in vertical surfaces, benches, deep depressions and overhangs. Over-excavation was required in some zones of the weathered rock. During excavation, all loose and weathered material was removed by handwork, barring, picking, brooming, water jetting and/or air jetting. Accumulated water from the washing operations was removed by strategically placed sump pumps. Unsuitable material in cavities and along discontinuities was removed before any RCC or CVC could be placed and dental concrete (sometimes referred to as rock reconstruction) was used to fill all the narrow faults and shears.

Removing portions of the foundation exhibiting less favourable deformation moduli and replacing it with dental concrete was necessary. The rock surface was thoroughly cleaned as described above and moistened prior to concrete placement to obtain a good bond between the concrete and the rock foundation surface. Leaving overhangs after the excavation of rock was avoided as far as possible. Where negative inclined surfaces existed, the concrete was placed so that the head of the concrete was higher than the upper surface of the rock. Rock reconstruction was cured with water and operations over the formation were not permitted until the concrete strength and temperatures were within the acceptable range as defined in the technical specifications – typically after 3 to 4 days.

The excavation on the left bank, in the area of the Intake Tower and Turbine Room, required vertical or near vertical cuts and therefore temporary excavation support measures. Any unstable rock faces were anchored with a temporary steel draped, weighted mesh. A more permanent solution for keeping any of the unstable rock faces secure and away from the structure is still under review.

3) Water supply

The Neckartal Dam is constructed in a non-perennial river, posing serious challenges with regards to water supply. The dam was not ready for impoundment during the 2016/2017 wet season, losing the opportunity to capture the precious water with a flood peak of nearly 1 000 m^3/s passing through the terrain. Currently, water can only be supplied from farmers' boreholes downstream of the dam. Boreholes, however, only provide a limited discharge and are slowly being reduced by the progression of the water-rich curtain grouting. An alternative water supply was identified at an existing smaller dam, approximately 70 km away. Water tankers or a temporary, above-ground pipeline were both unrealistic and uneconomical options for supplying this water which would cause time constraints that could not be accommodated in the construction programme.

A third alternative, involving the release of water from Hardap Dam, some 352 km upstream of the site, was investigated. Planning water releases over such a long distance is problematic. Releasing too much water from Hardap not only poses the probability of flooding both the nearby town downstream (Mariëntal) and the construction site but will have further financial implications to the farmers of the Hardap Irrigation Scheme if their water is substantially depleted before the next wet season. Releasing too little water, on the other hand, would be a waste, since the losses in the current dry river would be so substantial to thwart any of the released water to reach the Neckartal construction site.

It was decided to release water from Hardap Dam in a cascading sequence, releasing between 1 and 2 Mm^3 at a time and recording the distance which the water has travelled. The effects of the first two releases were as follows:

- The first release of 2 Mm^3 covered 125 km in 14 days; and
- The second release of 1.5 Mm^3 covered 180 km in 11 days.

Currently, the site is awaiting the results from the 3rd release of 2 Mm^3 and the hope is to impound at least 0.5 Mm^3 for construction purposes.

3.6 Construction programme

Construction programming is one of the key elements for the successful completion of any project. Even more so with a large project such as the Neckartal Dam Project. A construction programme is normally submitted with the original tendered documentation. Not only does the scheduled outline show how quickly the work will be done, but also how it will be done. The schedule defines the sequence and method in which the materials will be put in place. Thus, the earlier the schedule is put on paper and communicated to the project team, the better (Fournier, 2015).

It is essential that the programmer thoroughly reasons through the placement of the proposed elements while maintaining the integrity of the design. The programmer must understand the proposed scope of work and the details affecting the connection of each component in order to create a proper construction schedule. The schedule should include a maximum level of efficiency and productivity for the Contractor and each subcontractor involved in the placement and assembly of the various components and systems. Updating the programme is required, preferably on a weekly basis, to determine whether there are any problems about to unfold. Unfortunately, this was one of the missing links at Neckartal during the construction process of the Intake Tower, which led to an expensive increase in cost (see section 3.3). Requesting the contractor to provide method statements for all major tasks to be undertaken could prevent such mistakes. Even more critical, is ensuring proper communication of the approved method statements to the construction workers on site. Areas in dam engineering where special attention should be given to the project programme are, but not limited to the following:

- Foundation preparation and curtain grouting. Time related aspects required for site establishment, drilling of holes and washing/cleaning of surfaces;
- The placement of RCC and CVC works. Accounting for the preparation of cold joints and placement of the necessary bedding mortar;
- Construction of Inlet/Outlet works and the interaction with mechanical components such as pipework, cranes, hydropower equipment etc.;
- The construction of the Ogee spillway near the end of the project, still providing safe and accessible access for construction workers; and
- Concrete repairs and coring without interfering with the production of RCC – this is one of the items that is easily overlooked and should be incorporated from the initial casting of all concrete works.

Knowing the actual lead times and the definitive way that materials will be assembled, a good planner can evaluate several possible installation arrangements to arrive at the most productive sequence. This will avoid improvisation imposed by last minute surprises or lack of foresight, and will benefit a project by preventing unnecessary costs and delays. It has been proven by the Construction Industry Institute (CII) that a positive, quantifiable relationship exists between the effort expended during the pre-project planning phase and the ultimate success of a project (Fournier, 2015). There is no substitute for proper planning and hard work. A properly prepared schedule will yield many benefits for all team members.

3.7 Financial implications

The saying “money talks” may not be too far-fetched during construction. Timeous payments from an employer will ensure that the contractor will be able to pay his suppliers, workers and subcontractors to keep production sustainable throughout the project. Unfortunately, throughout Africa, payment issues exist and Neckartal Dam was also exposed to these complications. Late payments by the Employer compelled the Contractor, on more than one occasion, to reduce production; contributing to the delayed completion of the project. Employers need to realize the implications of late payments both towards the Contractor as a breach of contract, but also the secondary effects that go towards sub-contractors and construction workers not being paid.

The flipside of the coin is also true. Contractors tendered and agreed to provide a product to a specified standard and needs to adhere to that agreement. Not adhering to tendered specified products requires a re-assessment of the value of the product delivered to a reduced rate. An example of that is the DN3000 flange adaptors delivered to site (discussed previously). These flange adaptors could not function as intended by the design engineer, causing unacceptable damage to the pipework during installation. The tendered value of the flange adaptor, according to the bill of qualities (BOQ), had to be reduced to compensate for the acceptable solution.

Withholding payment from a contractor within the contractual limits is, in many cases, the engineer's only defence in enforcing product quality. This is not only true for the construction regime, but also for the environmental aspect. Incorporating an exponential penalty for environmental discrepancies might be the only way to force a contractor to adhere to the project specified processes. One such an example experienced on site was the continual pollution of a river downstream of the dam as a result of sludge dams that overtopped repeatedly. Unfortunately, no significant penalties were included in the original Contract and the Contractor continued polluting the river stream without direct consequences to be enforced. This was luckily reduced when threatened with the local law enforcement agency.

3.8 Other miscellaneous aspects to consider

More miscellaneous project specific aspects to consider by a young engineer include the following:

- Define the coordinate projection that is used for the project. Ensure that only one local coordinate system is used rather than projected coordinate systems. The difference between different coordinate systems can be significant, as was noticed on the Neckartal Dam site; it may be up to 80 mm in the length of the dam wall;
- Know the project specifications and study the construction drawings. Ensure that there are no conflicts between the project specifications and the construction drawings;
- When using any new product on site, do a trial on a smaller section (off site) and determine how the product performs under the specific conditions and with the available labour using the product. Many products function well in the laboratory where they are used in a controlled environment by highly skilled personnel. This may be difficult to replicate on a construction site;
- The using of continues perforated formwork (CPF) is highly recommended for the casting of inclined areas. This includes the construction of a formed Ogee spillway;
- The Contractor will always push for production regardless of quality control. Quality control is the engineer's responsibility regardless of what the project specification states.

4. INDIVIDUAL ASPECTS TO CONSIDER

Engineers tend to overlook the individual aspects that need to be considered when assessing problems and rather focus on the technical facets. However, these aspects should be included both in planning and execution of any major project to be successfully completed. Some of the individual aspects that a young engineer needs to take note of when working on such a big project are:

- It is not always easy to pick up your belongings and temporally move to a new country. Having a vision of how the decision is made today could potentially influence your career in the long term that will help with the transition;
- On a construction site it is required of you to work under pressure and make decisions on the spot. The good news is that, the more you do it the better you get at it. Be visible, be on site, work hard and participate as far as possible;
- Having no access to internet on site requires one to delve deep into your university knowledge and pay special attention to all aspects on site. If possible, use a notebook to record the necessary information that needs to be studied at a later stage when having access to available resources;
- Production runs 7 days a week, 24 hours a day, all year round. Be prepared to work on weekends and public holidays;
- If possible, adopt a pet for those late night arrivals back home. Having a pet being happy to see you coming home will assist you in keeping a positive morale;
- Do not be afraid to ask questions. Asking questions forces you to consider all the options. It extends your comfort zone and helps you to grow; and

- No one is always right – but be open and willing to learn more from all available resources. Innovation in engineering can often come from unexpected quarters. While the trend towards specialization is not likely to let up, the need for cross-pollination of engineering disciplines is critical. A continual stream of learning for young engineers is required for success (Gurke, 2014).

5. CONCLUSION

Working on a big project such as the Neckartal Dam is a privilege for any young engineer. With this privilege, however, comes the responsibility of making correct decisions under the given circumstances. Young engineers are expected to sift through mounds of information to learn and obtain the best possible answer to their query, while still addressing their daily responsibilities. The author hopes that the information portrayed in this article will be beneficial for both the young engineer as well as the more experienced engineer. The hope is that younger engineers will be assisted in the decision making process when they are found under similar circumstances.

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