SELECTION CRITERIA FOR ELEVATED RC TANKS CONSTRUCTION

Mohamed Darwish, PhD, PEng[1 2]
Karim Kamel, BSc [2]
Omar Balbaa, BSc [2]
Ahmed El-feel, BSc [2]
Jwanda Elsarag, BSc [2]
Mohamed Tawfeek, BSc [2]
Ahmed El-Embaby, BSc [2]
Ghadir El-Shaer, BSc [2]
Omar Montasser, BSc [2]
Reem Aboali, BSc [2]

Abstract:

Elevated tanks are necessary to supply potable water in most of the countries all over the world. Construction of elevated reinforced concrete tanks involves utilizing unique construction methods due to various characteristics like cost, constructability, resources and time. This paper covers different methods of construction of reinforced concrete elevated tanks by concentrating on different construction methods of every tank component. Moreover, a comparative analysis is provided to show when to use every method of construction according to the conditions available. Two tanks with different sizes and project conditions were studied and examined against the developed selection criteria in order to evaluate the validity of the applied construction methods in each case.

Keywords: Elevated Tanks; Construction Engineering; Slip forms; Climbing Forms; Lift Slab

1 INTRODUCTION.

Elevated water tanks could be constructed of several materials like reinforced concrete, steel, and composite materials. Each type of elevated tanks has its advantages and disadvantages. The main advantages of steel tanks are the high quality assurance and faster construction duration. While the main advantages of the concrete tanks is the low cost of maintenance over time, low cost of construction, not requiring skilled labors, and the multipurpose use the of tank as it can store most liquids. Hence in developing countries, the most common material used to construct elevated tanks is concrete due to lower cost of materials and labor. However, in industrial countries the most common form of elevated tanks is the steel or the composite while the concrete tanks are considered rare.
Reinforced concrete tanks vary depending on the population capacity demand and the sufficient head needed in the system. These tanks are composed of three parts. The first (and uppermost) part is the tank body itself (also called “the vessel”). The second part (the middle) is the tank supporting structure. While the third part is the foundation (whether deep or shallow) this is not within the scope of this paper. The tank body could be spherical, conical, rectangular or cylindrical; however the most common types are the conical and cylindrical designs mainly due to design considerations. On the other hand, there are four types of tank supporting structures. The first type is masonry (sometimes reinforced masonry) walls

[1] Corresponding author, email: mdarwish@aucegypt.edu
[2] The American University in Cairo, Egypt

carrying the tank body, however this type is rarely used as it has limitations in terms of its strength and it could be used for mainly small tanks and rarely for medium tanks. The second alternative is having a steel supporting structure which could support larger tanks than the previously mentioned option however it is beyond the scope of this paper that is only limited to RC tanks. The third alternative is the reinforced concrete frame support (Multi-column supported) that is very similar to the reinforced concrete skeleton of a typical building. The fourth alternative is having an RC cylindrical shaft supporting the tank body, this structural system is the most commonly used now as it has high capability to resist both vertical loads (tank and fluid weights) and lateral loads (mainly earthquakes) (ACI Committee 371, 2008).

On the other hand, the concrete used could be typical reinforced concrete or it could be post-stressed through post-tensioning high strength steel cables. The tank size is the most important factor governing the use of post-stressed concrete. The increase in tank size reflects an increase in the tank capacity which means an increase in the hydrostatic and gravitational loads. Accordingly, post-stressing is not utilized in cases of small tanks. However, moderately sized tanks could be constructed of either typical reinforced concrete or it could be post-stressed reinforced concrete. The post-stressing is mostly utilized in cases of large tanks as using typical reinforced concrete in such cases could be really difficult due to needing very thick walls with very dense reinforcements (ACI Committee 371, 2008).

Concerning elevated RC tanks construction methods, the methods covered within this paper are those concerning the construction of the tank supporting structure, the different methods of tank body construction while covering also the different alternatives concerning the sequence of operations between the two parts of the superstructure and their connection.

2 SUPPORTING SYSTEM CONSTRUCTION METHODS.

2.1 Conventional Formwork

Although it is not the most common option, conventional formwork is still used in some cases during constructing the tank supporting structure. It is used mostly in case of constructing a reinforced concrete multi-column skeleton that will latterly carry the elevated tank. It is used in such cases because the jump forms (with its different types) and slip forms will not save time and/or cost in these types of structures. However, conventional formworks could waste time and cost if used to construct RC shafts (Peurifoy, Schexneydar, & Shapira, 2006) (Gregory, 1996).

2.2 Jump (Climbing) Formwork

Jump forms, described also as climbing forms, are used for constructing vertical concrete elements such as high rise buildings, core shafts, water tower shafts, shear walls and bridge pylons. The system of form-working basically passes through assembling and fixing the formwork and the working platform, steel fixing and concreting. This system can be adjusted to suit different construction geometries depending on the project being a shaft or shear walls for example and it requires special concrete characteristics, equipment, and labor as discussed later (Gregory, 1996).

2.2.1 Types of Jump Forms

There are three types of jump forms; the three types have exactly the same function and method but with little deviations in the set up and the equipment used. The first is the normal jump/climbing form in which the formwork units are dismantled (as shown in Figure 1), lifted upwards by a crane, and assembled at the next level of construction where reinforcement and concrete pouring takes place and the process is repeated for several levels (Gregory, 1996) (Peurifoy & Oberlender, 2011).

The second type is the guided-climbing jump formwork where the form is also lifted by the crane but the units of the formwork remain fixed to and guided by the structure. This type is faster than the normal jump formwork and commonly used (Peurifoy & Oberlender, 2011).

The third type is the Self-climbing jump formwork where unlike the two other types, the formwork units in this type are lifted by means of hydraulic jacks rather than using a crane. The formwork does not need dismantling and reassembling as it climbs on the hydraulic jacks to the next level of construction which makes this type faster and safer but yet more expensive than the normal and guided jump forms.

Sometimes, two formwork units at different levels are being anchored to the jacking system and lifted upwards at the same time which makes the construction of two successive levels at the same time possible. Some newer versions of these forms are designed in a specific manner in order to maintain that the climbing process is continuous instead of intermittent, and is usually only interrupted for a very short time, in order to fix the mounting mechanisms to new anchoring points (Peurifoy & Oberlender, 2011).

Figure 1: Lifting a jump form (photo taken and authorized for reuse by **(Destil, 2008)**)

2.2.2 Method Sequence and Components

The work sequence starts by the forms assembly and fixation on the ground as well as the working platform for the workers being fixed to the formwork. Then the whole units of the formwork are carried by a crane and fixed to the positions where the concrete will be poured "cast-in" position. Except for the normal climbing formwork type, the formwork and access platform are anchored to the structure element below by what is called "climbing brackets" for the formwork to climb on to. The formwork is anchored using bolts to these brackets. Steel reinforcements are then prepared and placed in their positions. The concrete is poured with secondary activities like vibration proper compaction to avoid segregation take place. The concrete is left to cure and harden enough so that it could carry the formwork at the above level of construction. Surface finishing of the poured concrete is done. For the first two types of jump forms, a crane is used to carry the combined formwork and working platforms to the next level and the cycle begins again while for the self-climbing a system of hydraulic jacks is used instead of the crane, which taking less time. In addition to producing a fare faced concrete surface, these forms do the job in significantly less time compared to the conventional formwork, however, slower than slip form system. On the other hand, and due to its sequence of operations, using such forms will still create joints between the different concrete lifts and it may require crane for inter-lift movement in case the first two types of the jump forms are used (Peurifoy & Oberlender, 2011).

2.3 Slipforms

The slipform is similar to the jump forms in the usage and application and the major advantages, but this type of formwork is faster than the jump formwork as the concrete is being continuously poured into the formwork panels until the whole operation is finished. Thus it needs continuous supply of reinforcement bars. The system of form-working basically passes through assembling and fixing the formwork and the working platform, continuous steel assembly and concreting and finally dismantling and removing the formwork by a crane. So, mainly the crane time is needed for supplying the materials up at the level of construction and during the formwork removal unlike the normal/guided climbing formwork. Another major difference between slipform and jump form is that the slipform does not wait for the poured concrete to harden and support the formwork above it, but the slipform supports itself on the hydraulic jacks. The jacking system is composed of a number of jacks that are held to jacking tubes, which are long steel tubes placed within the steel reinforcement of the structure. All the hydraulic jacks should be operated at the same rate so that the formwork is leveled during lifting (Peurifoy & Oberlender, 2011) (Camellerie, 1996).

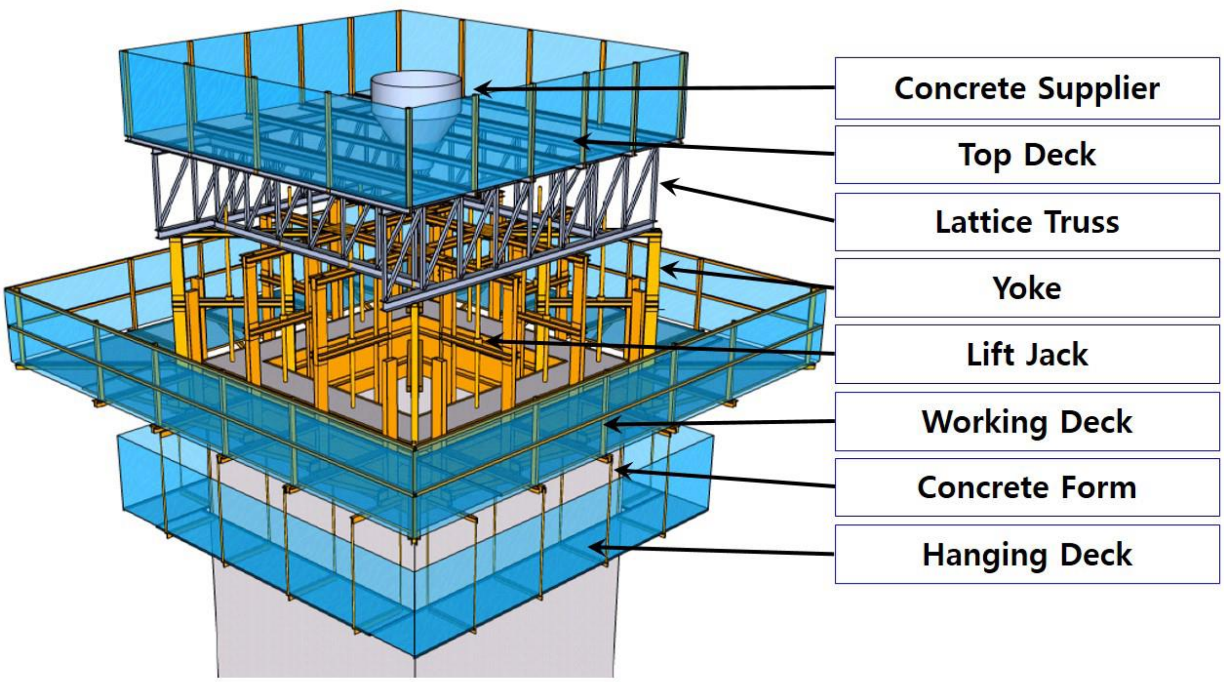


Figure 2: Slipform system (Figure drawn and authorized for reuse by (Kim, Kim, Chin, & Yoon, 2013))

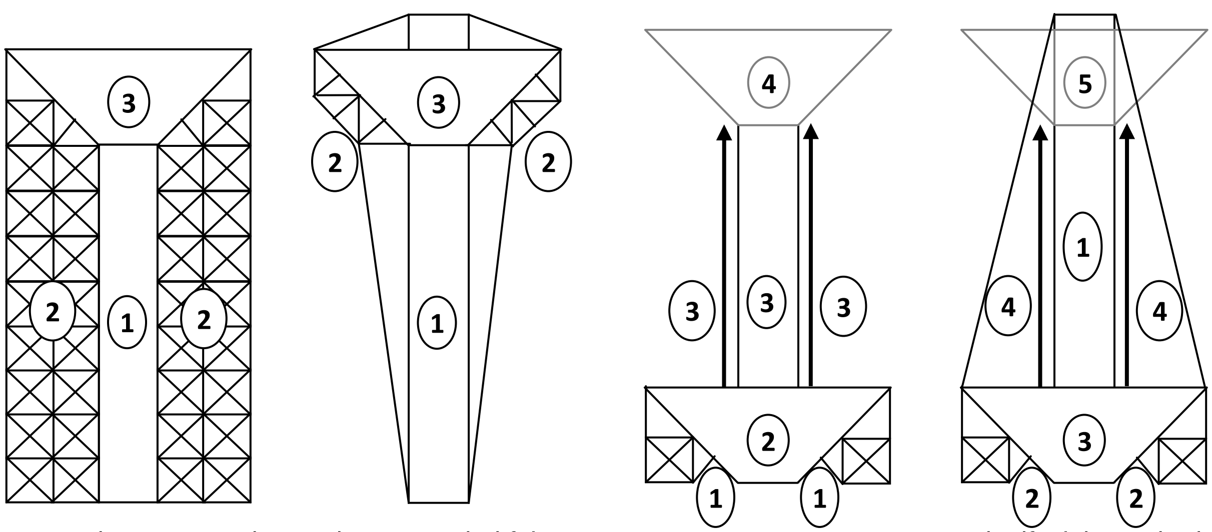
As shown in Figure 2, the slip form system consists of three platforms. The upper platform is mainly for storing and handling materials and acts as a distribution area. The middle platform is the main working area at the top of the poured level of concrete area for reinforcement and concreting activities. While the lower hanging platform is for concrete finishing activities. The construction sequence starts by fixing the jacks and the jack stands are together on the ground by bolts. After that, the jacks and the jack stands are erected vertically on the circumference of the foundation and then connected together by horizontal connection straps; one on the inner and one to the outer legs as shown in. Third, the inner and outer consoles, on which the working platform will be fixed, are anchored to the jack stands. Then the internal and external panels used for the concrete forming are bolted to the connection straps. The slip forms most important components are the hydraulic jack screws and climbing bars. When connected to the main hydraulic unit they ensure that the formwork can be lifted continuously achieving around 2.5 – 4 meters of concrete pour height per day. The jackscrews are connected between the jacks to the connection points. Cavity pipes are then positioned under the jackscrews in order to accurately guide the climbing bars and to provide cavities for the removal of the climbing bars. The large platform elements such as steel mesh floor elements and safety boards are then attached. In addition, handrails are connected through the banister uprights and all assembly points are controlled prior to commencing slip forming. After the formwork has been assembled and operated to around the first level, the lower scaffolding console is then attached. Steel mesh walking platforms are then positioned against the lower console elements. Handrails and kicker boards are then connected. To control the structural rising of the slipform and the accurate operational workings, optical measuring equipment is used. This advanced formwork system performs the job in the shortest construction time due to its continuous mode of operation creating no structural joints and a fare-faced concrete surface with a minimal need of cranes. However, it needs continuous supply of material, highly skilled labor and it involves high capital cost due to its automated equipment setting (Peurifoy & Oberlender, 2011) (Camellerie, 1996).

3 TANK VESSEL CONSTRUCTION METHODS.

The main step in the RC tank vessel construction is the formwork, these formworks will be used for the tank floors and the walls. For the tank walls, either climbing forms or slipforms and both types were described in detail in the previous section. However, the major difference between the two options is the fact that the slipforms will produce joint-free concrete which is much more suitable when constructing the tank walls. The fact that the tank is elevated could raise another complicated issue which is the false work temporarily supporting the tank floor formwork and transferring its load to the ground during the reinforcement placement and concreting activities. This issue is also coupled with another issue concerning the sequence of operations between the tank vessel and its supporting shafts as the different false work options governing the tank body construction will vary depending on which is constructed first, the supporting shaft or the tank body itself.

3.1 Conventional Massive Structured False Work

The method requires erection of a massive structure of conventional false work starting from the ground level till reaching the level of the bottom slab. As shown in Figure 3a, this process is done after the construction of the tank supporting structure is finished. The major advantage of using this alternative is the fact that no high-technology equipment needed is to build the scaffold, hence there is no need for highly skilled labor and any subcontractor could have the technical qualifications do this job with minimal equipment and labor costs. However, the cost of the false work for higher heights is large. It is even more unfavorable due to risky working conditions and the fact that assembling and dismantling such a massive structure is time consuming (Bennett & D'Alessio, 1996).



a. Massive structured false work steps
b. Suspended false work method steps
c. False work lift method steps
d. Lift slab method steps

Figure 3: Summary of the four tank body construction methods.

3.2 Suspended False Work Method

This method shows another approach using false work only. As shown in Figure 3b, the false work is suspended from the top of the supporting shaft and anchored to the ground to prevent the movement of the false work. The formwork rests at the inner edge against the shaft and is then suspended at its outer edge by a large number of suspension rods from the top of the shaft and additionally connected to the foundation using steel members or pre-tensioned guy tendons. This process is done after the construction of the tank supporting shaft is finished. The merits of this system when compared to the previous one is that it saves the time consumed in assembling and dismantling the massive structured false work however, it involves a higher level of sophistication when designing the falsework, its connections to the shaft, the suspension tendons and the steel members or the pre-tensioned guys. This is also considered an additional cost as the cost of these tendons and the pre-tensioned guys is higher than that of the massive structure if used at low heights however it is cost saving for higher heights. The risk issue again comes into the picture as the workers will perform all the formwork, reinforcement and concreting activities at a high elevation and they will need fall-arrest training and equipment (VSL International LTD., 1983).

3.3 False Work Lift (Pushed) Method

This method is based on the idea that the false work is placed close to the ground, then the tank is pushed upwards then the shaft is constructed beneath. After the foundation slab is built, HEA beams are assembled in an upright position together with a jack of lifting stroke. Then, and as shown in Figure 3c, the tank is built and upon completion it is raised by the jacks while the shaft wall is constructed simultaneously. At each step of construction, prefabricated concrete cylinders are placed beneath the jacks. This method is most suitable when the diameter of the shaft is relatively large; however its disadvantage is that stability issues might occur during the lifting process. It solves a huge safety issue of working at a high elevation as most of the activities happen on the ground which also saves the time of the shoring activities. However, this alternative could slow down the supporting shaft construction (VSL International LTD., 1983).

3.4 Liftslab Method

This method is similar to the false work lift method in the fact that the tank body construction is done on the ground then lifted. However, and as shown in Figure 3d, the tank body is constructed and lifted after the supporting shaft is fully constructed. Within this method, surrounding the shaft at the ground level, the tank bottom slab and walls are constructed. Then the constructed tank is attached with cables to the hydraulic jacks that are attached on the top of the shaft. Throughout the lifting process, all jacks should be modified to function on the same speed in order to keep the firmness of the structure and avoid any critical deformations. After the tank being lifted into its final position, a ring beam should then be constructed beneath the connection between the tank bottom slab and the shaft. This ring beam needs to fully cover the connection between the shaft and the tank and must be well connected to each of the two. This system involves high use of heavy rigging systems involving jacks and cables that could constitute a high equipment cost. Hence, it is not cost-effective if used at low heights as for such cases assembling massive false work would be more cost saving. It is for sure the fastest method as it involves constructing the tank without slowing down the shaft construction as in the false work lift method and it is less risky than the first two methods involving working at elevated heights (VSL International LTD., 1983). Another drawback of such method is the fact that the joint between the tank body and its supporting shaft is a point of weakness from a structural perspective and it needs to be analyzed dynamically within its design phase to guarantee that the shaft, tank body and the connection between them are stiff enough to withstand gravity and lateral loads (Masih & Hambertsumian, 1999) (Zallen & Grossf, 2002).

4 CONSTRUCTION METHODS SELECTION CRITERIA.

Based on the discussion of the different supporting system construction methods presented in section 2, a selection criteria could be developed to aid the decision making process concerning the supporting system construction methods. The project size, time frame, resources (whether material, labor or equipment), cost and site conditions are the main factors governing the method choice. From a project schedule perspective the slipform technique is the fastest (especially for large-scale projects) followed by the self-climbing forms, guided jump forms and normal jump forms respectively, while the conventional formwork are the most time consuming. However, this speed could be on the account of something else as the level of skill required for the labor working on non-conventional forms is much higher than that of the conventional forms, as on the increase of sophistication of the method and its associated equipment, the required level of labor skill increases and consequently the cost will be higher. Hence, the more advanced/sophisticated methods are more suitable for larger scale projects where repetitive systems are applied and saving time would mean directly and indirectly saving money. From a site layout perspective, the more advanced techniques (slipforms and self-climbing forms) save more space as the need for external equipment is only for the purposes of material supply, which means that if a concrete pump with a suitable boom size is available there will be no need for a permanent crane on site. A summary of the selection criteria could be found in Table **1**.

Table 1: Selection criteria for supporting system construction methods.

Construction Method	Conventional Formwork	Normal Jump Forms	Guided Jump Forms	Self-Climbing Forms	Slipforms
Cost	Cost-saving for small heights	Cost-saving for medium – large heights			Only Cost saving for large heights
Safety	Least safe	Better safety due to more advanced components			
Surface Finish	Normal	Fare-faced concrete			
Formwork Adjustability	Adjustable	Adjustable	Adjustable	Adjustable	Non-Adjustable
Need for Crane	Always Needed	Always Needed	Always Needed	Only during concrete supply	
Site Congestion	Most Congested	Less Congested		Least Congested	
Labor	Semi-skilled	Skilled	Skilled	Skilled	Highly skilled
Time	Slowest	Medium speed	Medium-High speed	High speed	Fastest
Formwork Durability	Least Durable	Durable	Durable	Durable	Durable
Needed Concrete Characteristics	Typical conventional concrete	Preference when fast setting is possible			The rate of pouring should be equal to that of setting

Also, based on the discussion of the different tank body construction methods presented in section 3, a selection criteria could be developed to aid the decision making process concerning the tank body system construction methods. The project size, time frame, resources (whether material, labor or equipment), cost, level of risk and design considerations are the main factors governing the method choice. From a project schedule perspective the liftslab technique is the fastest (especially for large-scale projects) followed by the false work lift method and the suspended falsework method respectively, while the conventional method is the most time consuming. However, this speed could be on the account of something else as the level of skill required for the labor working on non-conventional methods is much higher than that of the conventional methods, as on the increase of sophistication of the method and its associated equipment, the required level of labor skill increases and consequently the cost will be higher. Hence, the more advanced/sophisticated methods are more suitable for larger scale projects where the additional equipment and labor cost is less than the additional cost that would have been faced if the project duration would have significantly increased in case of using conventional methods in a large project. From risk and design perspectives, the more advanced techniques (Falsework lift method and liftslab method) need special attention before, during and after construction due to the sensitivity of the connections between the tank body and the supporting shaft in these cases. A summary of the selection criteria could be found in Table 2.

Table 2: Selection criteria for tank body construction methods.

Construction Method	Conventional Massive False Work	Suspended False Work Method	False Work Lift Method	Liftslab Method
Cost	Cost-saving for limited heights	Cost-saving for medium heights	Cost-saving for medium and large heights	Cost-saving for medium and large heights
Risk	High probability of worker fall-off		Special precautions required during lifting	
Accessibility limitation	Not limited	Limited	Not limited	Not limited
Equipment	Simple	Simple	Requires special equipment	Requires special equipment
Labor	Semi-skilled	Semi-skilled	Skilled	Skilled
Time	Slowest	Medium	Medium	Fastest
Design Considerations	None	None	Special design considerations should be taken into account	
Quality Control	Moderate	Moderate	Better Quality	Better Quality

5 APPLICATION OF THE SELECTION CRITERIA.

5.1 Frankfort – Kentucky Elevated Water Storage Tank

This elevated water tank was built in Frankfort, Kentucky, USA to provide adequate storage for water demands. This 7570 m^3 conical tank, owned by the Frankfort Electric and Water Plant Board had a total height of 40 m and a diameter of 35 m. The tank is located on Woolbright main road and can be accessed directly from the main road. The foundation system is a matt foundation with a dimension 14 m by 4 m by 1.8 m depth. The concrete shaft carrying the tank has a diameter of 9.75 m with a height of 27.5 m. The transition attached to the top of the shaft is a cylindrical heavy concrete layer connecting the tank body to the shafts and its thickness varies from 0.6 m to 1.2 m. In addition to the transition acting as a support for the vessel shaft, it also acts as a floor for the vessel. The vessel is composed of a cone with a height of 13 m and its main purpose forming the body of the tank and an upper 2 m deep ring beam and its purpose is to resist both outward forces transmitted from the dome above and also to resist the outward pressure from the tank. Finally, the dome spanning a diameter of 35 m and its main role is to act as a covering for the tank (Copley, Ward, & Bannister, 2007).

After constructing the foundations, the concrete shaft was constructed using jump formwork in 1.2 m lifts. The transition section was constructed using conventional formwork and was poured in two separate castings. The suspended formwork for the tank vessel was complicated as it was a system of steel frame formwork without any wall ties, which was possible due to the conical shape of the tank. The formwork of the vessel is consisted of outer and inner forms which were independent of each other. The outer form consisted of vertical beams that were tied together with a tension member. The tension members were added to withstand concrete pressure and form a tight grid to maintain the shape of the outer wall surface. The interior form consisted of vertical beams that were tied together with a compression member. These compression members were added to withstand concrete pressure and form a tight grid to maintain the shape of the inner wall surface. The exterior formwork panels were installed first then the two layers of horizontal and vertical steel reinforcements were placed. After that, the interior formwork panels were installed. Concrete was poured by a separable placing boom which was mounted on the transition section where concrete was pumped from a stationary pump at the base of the tank through pipes. After pouring each concrete lift, a water stop was placed at the interface between every layer then the succeeding climbing formworks were attached to the previous form to maintain the shape of the vessel. The ring beam was casted by the same formwork system as used in the vessel which doesn't need any wall ties. However, the sequence of doing the formwork was reversed where the inner forms were assembled first. After preparing the steel reinforcement, the outer forms were assembled and concrete was poured. Then the dome was constructed using a conventional formwork system (Copley, Ward, & Bannister, 2007).

5.2 Disney Road Elevated Water Storage Tank

This elevated water tank was built in Disney road to provide adequate storage for water demands in the county of Anne Arundel, Maryland, USA. This 7570 m^3 tank, owned by the Anne Arundel county department of public works had a total height of 59.1 m and a bowl diameter of 30.5 m. The storage of the tank is divided into 3 capacities each one is used whenever needed and that was considered in the tank's design. The first (Equalization Storage) volume provides the difference between treatment plant's capacity & hourly demands. The second (Fire Storage) provides water for the fire fighting beyond the capacity of the treatment plant already existing there. These first two sections of the tank have a bowl shape with a depth of 8 m. The third (Emergency Storage) provides water during power outages and system shutdown, since this is one of the major problems facing County in Maryland. This upper section has a cylindrical shape as its walls are perfectly vertical with a height of 6 m (Anne Arundel County Department of Public Works, 2011).
After constructing the foundation, the first 3.9 m (from level -2.0 to level +1.9) of the concrete shaft was constructed using conventional formwork. Then the slipform method was used to construct the remaining 33.1 m (up to level +35.0) of the concrete shaft. Then the inner columns (inside the tank body) were constructed. Then, the construction of the upper slabs containing openings (to lift the tank body) took place. After that the tank body was constructed on the ground. After that, the lift slab technique was utilized where the lifting of the tank body using hydraulic jacks was performed. The ring beam supporting the tank body and connecting it to the shaft was constructed followed by the tank roof slab which was constructed using conventional formworks.

5.3 Construction Method Evaluation

On using the selection criteria developed in section 4 to evaluate the validity of the construction methods utilized in the two projects described in subsections 5.1 and 5.2, one could see that these methods are in compliance with the developed selection criteria. The Frankfort – Kentucky tank was 19 m shorter than the Disney Road tank. Hence, it was expected to see a difference in the concrete shaft construction method as it would have been extremely time consuming to construct a 59 m high shaft using jump forms and the use of slipforms in such a case would be much more efficient and time saving and this reduction in duration would also save costs as the rental costs of the forms and the wages of the labors are both function of time and will both be reduced when saving time. Hence, the additional cost accrued by the use of slipforms is counteracted by the cost savings due to time savings. The significantly higher height of the Disney road tank, together with the tank shape are the major reasons giving preference to the lift slab method over any construction method to construct the tank vessel as the walls of the tank body were vertical (not slanted as the case for the conical Frankfurt – Kentucky tank). This shape made the construction using the suspended formwork much more difficult than constructing it on the ground then lifting it using the lift slab technique. In addition to that, creating a supporting structure to transfer the suspended formwork load from a height of 59 m above the ground would be an extremely time-consuming and cost-consuming process and using a lift slab would save significant time and cost. Hence, and according to what has been applied in the two projects studied, the selection criteria developed in section 4 is sound and applicable.

6 CONCLUSIONS AND RECOMMENDATIONS.

When examining the methods applied in the two cases discussed in section 5 of this paper against the selection criteria developed in section 4, the selection criteria proved that it covered the different aspects governing the selection of the most suitable methods for different elevated reinforced concrete tanks construction cases. However, it is highly recommended when using the selection criteria matrices to take all the factors governing the method selection into account as neglecting some of them could cause real problems.

Acknowledgements

The authors would like to acknowledge the Department of Construction and Architectural Engineering in the American University in Cairo for its continuous support.

References

ACI Committee 371. (2008). *Guide for the Analysis, Design, and Construction of Elevated Concrete and Composite Steel-Concrete Water Storage Tanks.* Farmington Hills: American Concrete Institute.

Anne Arundel County Department of Public Works. (2011, December). *Disney Road Elevated Water Storage Tank.* Retrieved December 4, 2014, from Anne Arundel County Department of Public Works: http://www.aacounty.org/DPW/HighlightedCapProject.pdf

Bennett, C. P., & D'Alessio, M. S. (1996). Falsework/Shoring. In R. Ratay, *Handbook of Temporary Structures in Construction* (2nd ed., pp. 16.1-16.54). New York, NY, USA: McGraw-Hill.

Camellerie, J. F. (1996). Slipforming. In R. T. Ratay, *Handbook of Temporary Structures in Construction* (2nd ed., pp. 18.1-18.36). New York, NY, USA: McGraw-Hill.

Copley, J. D., Ward, J. S., & Bannister, H. (2007, June 22). *2.0-Million Gallon Prestressed Concrete Elevated Tank Frankfurt, Kentucky.* Retrieved December 4, 2014, from Bentley.com: ftp://ftp2.bentley.com/dist/collateral/Web/Building/Frankfort_Paper_1.pdf

Destil, F. (2008, April 22). *Cassaforma rampante Destil.* Retrieved November 27, 2014, from wikipidea: http://commons.wikimedia.org/wiki/File:Cassaforma_rampante_Destil.jpg

Gregory, K. (1996). Concrete Formwork. In R. T. Ratay, *Handbook of Temporary Structures in Construction* (2nd ed., pp. 7.1-7.42). New York, NY, USA: McGraw-Hill.

Kim, H. S., Kim, Y. J., Chin, W. J., & Yoon, H. (2013, August). Development of Highly Efficient Construction Technologies for Super Long Span Bridge. *Engineering, 5*, 629-636.

Masih, R., & Hambertsumian, V. (1999, February). Dynamic Liad Effect on Lift Slab Structures. *JOURNAL OF PERFORMANCE OF CONSTRUCTED FACILITIES*, 34-38.

Peurifoy, R. L., & Oberlender, G. D. (2011). *Formwork for Concrete Structures.* New York: McGraw-Hill.

Peurifoy, R. L., Schexneydar, C. J., & Shapira, A. (2006). *Construction Planning Equipment and Methods.* New York: McGraw-Hill.

VSL International LTD. (1983). *Concrete Storage Structures - Use of the VSL Special Construction Methods.* Bern, Switzerland: VSL International LTD.

Zallen, R. M., & Grossf, B. (2002, November). Effective Length of Lift-Slab Columns. *JOURNAL OF PERFORMANCE OF CONSTRUCTED FACILITIES*, 141-148.