



AN OPEN LETTER TO ENGINEERS WHO SPECIFY WIRE-AND STRAND-WRAPPED CIRCULAR PRESTRESSED CONCRETE TANKS

Circular prestressed concrete tanks come in two basic types, AWWA D110 Wire- and Strand-Wrapped, and AWWA D115 Tendon Prestressed. Tanks are most often bid as Design-Build projects, and most Engineers are familiar with the various Wire- and Strand-Wrapped tank suppliers. The purpose of this letter is to acquaint interested Engineers with tendon tank technology and show how your tank clients can benefit from this knowledge. This information is being offered to you by Jorgensen & Close Associates, Inc. (J&CA), consulting engineers, on behalf of several tendon suppliers, precast-prestressed tank suppliers and general contractors around the U.S. that offer design-build alternatives to Wire- and Strand-Wrapped tanks.

It is the obligation of the consulting engineer to obtain the best value for their client. One good way to do this, when the project calls for a tank of 500,000 gallons or more, is to increase competition by allowing a tendon tank alternate to the wrapped tank commonly specified in the performance specifications for the project. This can be done with a simple one sentence addition to the tank performance specification saying essentially "Alternate bids based on AWWA Standard D115 and other applicable portions of these Plans and Specifications are encouraged and are acceptable to the Owner." Alternatively, a fully developed Performance Specification based on the sample performance specifications available free upon request from J&CA or any one of various tendon tank suppliers in the US can be put out as an Addendum.

J&CA has designed over 150 post-tensioned tanks all across the country over the last 30 years, using all types of construction (wire-wrapped and internal tendon, precast and cast-in-place, circular and rectangular). We have come to the conclusion, however, that internal tendon tanks, no matter what shape or construction method, are almost always the best choice because of their superior watertightness, long-term durability and low cost. The following sections of this letter outline the differences between wire-wrapped and tendon tanks, the advantages of including a tendon tank alternate in the bidding and suggest ways of incorporating a tendon tank option into your project.

DIFFERENCES BETWEEN WIRE-WRAPPED AND TENDON TANKS

The fundamental difference between a wire-wrapped and tendon tank is, of course, in the way the circumferential prestressing is applied to the tank wall. In wire-wrapped tanks the 3/8 inch diameter prestressing strands or 1/4 inch diameter prestressing wires are applied one at a time in a continuous helix. This will be referred to as "wire-wrapping" in this letter. When larger tanks or dome rings are wrapped, several layers of strands or wires must be separated from one another by layers of shotcrete. When the wire-wrapping is completed several layers of shotcrete must be

applied to the entire wall surface in order to build up the shotcrete covercoat necessary for corrosion protection of the wires or strands.

In tendon tanks, several 1/2-inch or 0.6-inch diameter 7-wire strands are inserted into waterproof plastic ducts previously cast into the wall. These strands are stressed simultaneously by means of hydraulic rams. After the strands are tensioned, cement grout is injected into the ducts to displace any air and help provide the last of three layers of corrosion protection.

For wire-wrapped tanks, because of the thinness of the shotcrete layers and the susceptibility of the exposed wires to corrosion prior to covering them, this operation cannot proceed in freezing weather situations, which can delay a project for months in some parts of the United States. Since the tank wall can easily be tented and heated, tendon tank construction can proceed year-round, regardless of the climactic conditions.

It takes a month or more to apply the circumferential prestressing and build up the shotcrete covercoat in a typical wire-wrapped tank. The stressing process requires very cumbersome specialized equipment that cannot be used for other than circular prestressed concrete tanks. This makes it expensive compared to internal tendon tanks. Tendon tanks use the same stressing equipment as commonly used for major bridges, nuclear containment vessels, dams and buildings. Placing, stressing and grouting the tendons in a tank generally takes half the time of the equivalent processes in a wire-wrapped tank.

There are differences in the corrosion protection of the all important circumferential prestressing between wire-wrapped and internal tendon tanks as well. In wire-wrapped tanks the corrosion protection of the wires is provided by a thin shotcrete covercoat. Shotcrete, like any other portland cement material, is subject to drying shrinkage. This shrinkage is restrained by its bonding to the previously placed shotcrete and wires. Therefore, shrinkage cracks develop throughout the layers of shotcrete. Since the shotcrete is applied prior to filling the tank with water, and the shotcrete covercoat is not circumferentially prestressed, it has to go into tension as the tank is filled. The combination of shrinkage and axial tensile stresses in the shotcrete cover results in numerous vertical and "craze" cracks that completely penetrate the protective layer of shotcrete.

Carbon dioxide in the air slowly degrades the corrosion protection ability of shotcrete and concrete (carbonation). Therefore, as is well known, corrosion protection increases with increased cover thickness. Contrast the thin, one inch, final cover over wire- and strand-wrapping with the three or four inches over internal tendons.

Sometimes, the circumferential wires are galvanized, as a second layer of corrosion protection. However, this creates extra expense and is not considered to be the best solution, based on long-term durability considerations, by many. For example, this practice is not recommended by the Hot-Dip Galvanizer's Association as it may lead to concentrations of corrosion potential at cracks or holidays in the zinc coating, which would lead to stress corrosion.

Internal tendons, on the other hand, naturally have "triple corrosion protection." The first layer is provided by three or four inches of two-way prestressed concrete cover. The prestressing

prevents tension cracking altogether in the circumferential direction, and from reaching the circumferential prestressing (the outer most layer of prestressing) from any vertical bending moments.

The second layer of corrosion protection is provided by waterproof corrugated plastic ducts that contain the prestressing strands. These ducts come in twenty foot lengths that are connected by waterproof methods. This way, a waterproof and, therefore, corrosion protective barrier is maintained around the prestressing strands.

The third layer of corrosion protection is provided by rich cement grout that is injected into the ducts after the post-tensioning operation is completed. The helical lay of the strands along with the corrugations have been proven to fully encapsulate all facets of the strands with the protective grout.

The shotcrete cover coat on wire-wrapped tanks is applied as a separate layer after the circumferential prestressing is applied. This layer can "separate" from the core wall. Periodic field observations including "sounding" the exterior surface should be performed to check for areas of shotcrete covercoat separation. Shotcrete covercoat separation seems to occur without warning, leaving void spaces where water can collect. This makes the underlying circumferential prestressing wires highly susceptible to corrosion. Such periodic maintenance cannot occur, of course, if the tank is to be buried or partially buried.

This is not a problem on internal tendon tanks, as the entire wall, both inside and outside the tendons, is cast monolithically.

Contact J&CA for a reprint of the paper titled: "Corrosion of Circular Prestressed Concrete Water Tanks" for a more complete discussion of the differences in corrosion protection of wire-wrapped and tendon tanks. This paper was given at the ASCE Structures Congress XV in Portland, Oregon, in the spring of 1997 and was published in Volume I of the Proceedings of that Conference.

There are differences in the design philosophies and requirements of the various standards writing committees for wire-wrapped and tendon tanks. For example, wire-wrapped tanks are only required to have residual circumferential compression of 50 psi if below ground, per AWWA D110-04. Tendon tanks on the other hand are required to have 100 psi residual compression below grade, per AWWA D115-06. Also the seismic design criteria for wire-wrapped tanks are not as conservative as for tendon tanks.

Not only are the walls of wire-wrapped and tendon tanks different, so are the floors and roofs. The "membrane" (non-structural) slab-on-grade floors of wire-wrapped tanks are only four inches thick (unless the consultant specifically requires more) and are reinforced with conventional reinforcement. The wrapped tank industry has had to write special exceptions for themselves because there is not enough room in these thin slabs to provide for the normal code required concrete cover. Normally, reinforcing bars are required to have three inches of cover when cast against earth and one-and-one-half inches of cover when exposed to water. This

would require a nearly six inch thick floor slab in order to meet these generally accepted cover requirements.

The floors of wire-wrapped tanks are also typically placed with numerous construction joints, which are notorious for leakage (because of the difficulty in placing properly consolidated concrete on the undersides of the joints). They also have numerous shrinkage cracks, from restraint of sections of the concrete by previously placed concrete.

Tendon tanks, on the other hand, are normally constructed with monolithically placed, five-inch thick, two-way prestressed concrete floors. There is room in this thickness to provide two inches of cover to the bottom, cast against two layers of 6-mil plastic, and two inches to the top, exposed to water. These are the ACI 350 Code required covers for prestressed concrete. Also, per AWWA D115, these slabs maintain 200 psi residual compression, over and above any loads or slab-subgrade friction. These features result in superior watertightness (four times that required of AWWA D110 tanks) and unmatched long term durability.

Similarly, the roofs of wire-wrapped tanks are conventionally reinforced two-way flat plates or domes. Tendon tanks, however, usually have post-tensioned two-way flat plate roofs. Tendon tanks can have domes, which are more expensive, when clear space is specifically needed. Post-tensioning greatly reduces cracking, both shrinkage and temperature related and structural related, thereby ensuring greater long-term durability. Post-tensioned roofs are also more economical than their thicker, heavily reinforced, conventional counterparts.

ADVANTAGES OF COMPETITIVE BIDDING

The performance specifications most civil engineering firms use to contract for wire-wrapped tanks are provided to them, free of charge, by the wire-wrapping companies. Although slight modifications may be made by these civil engineering firms, primarily in the size parameters, the structural requirements remain virtually unchanged in almost every case. Those structural requirements are designed, by the wire-wrapped tank contractors, to exclude competitive systems, especially tendon tanks. In any given geographical region of the U.S., only one or two wire-wrapping companies offer their services. In some cases these companies have close ties and do not appear to compete very hard with one another. In other cases, whichever one you talk to is very good at writing performance specifications that guarantee only their company will get the job. Therefore, competition is greatly reduced or eliminated when using performance specifications that limit the bidding to Wrapped Tank Contractors.

The appearance of competition is sometimes created by bidding a conventionally reinforced tank alternate against the wrapped tank. Conventionally reinforced tanks, however, are generally not cost effective over about 500,000 gallons capacity, in J&CA's experience. Some designers, competing tank builders, and suppliers of tendon systems believe that once the decision is made to use a wire-wrapped circular prestressed concrete tank as the base bid on large tanks, there may not be any real competition unless the performance specifications are "opened up."

Between 1971 and 1981, J&CA designed most of their tank projects with two or three types of walls, each designed to the same structural criteria. Two were wire-wrapped, based on the two competing wire-wrapped tank contractors active in the West, and one was based on internal tendons. It was possible for the tendons to be supplied by any one of two or three competing companies. In all this time, encompassing between 20 and 30 tanks, only one went to one of the wire-wrapped tank contractors, the second tank designed this way. All the others were built as tendon tanks, proving that all things being equal, tendon tanks almost always are the most cost effective.

One project, in the mid-1970s, involved 12 wastewater treatment tanks for the City of Spokane, Washington. This project had been bid based on performance specifications written around one of the two wire-wrapped tank contractors active in the West. After the bids were received the other wire-wrapping company complained to the EPA, who was funding the major portion of the project. They asked for the performance specifications, that effectively limited the bidding to only the first wire-wrapped tank contractor, to be opened up so they could bid on the project. The EPA agreed, the performance specifications were modified somewhat and the tanks were rebid to the overall general contractor who had already been selected. Again the excluded wire-wrapped tank contractor complained that the revised performance specifications were still not sufficiently open for him to fairly bid the project.

At this point the general contractor, who needed to get this conflict resolved, advertised for proposals from any company who could help them with a circular prestressed concrete tank. A Denver based tendon supplier read the ad, contacted J&CA and put together what was ultimately to be the winning design-build proposal for these 12 tanks. It should be noted that our proposal saved 1.8 million dollars out of an original 4 million dollar bid by the first wire-wrapped tank contractor, according to the ENR article about it.

Two separate tank projects in the Northwest were recently bid using this philosophy. In these cases the wire-wrapped tank contractor, who is generally regarded to be the most expensive in the industry (they advertise their quality not their price), bid the circumferential prestressing at less than the tendon supplier's costs. This price was less than half of the amount the same wire-wrapped tank contractor had bid on comparable jobs that did not contain open specifications. Some think this wire-wrapped tank contractor simply bought these jobs in order to dispel the idea that tendon tanks are always more cost competitive. Nevertheless, these jobs certainly turned out to be bargains for their owners.

In 1993, J&CA teamed up with a general contractor and a tendon supplier to put in a design/build bid on three tanks in Worcester, a suburb of Boston. The tanks were being bid based on performance specifications the engineer received from one or the other of the two wire-wrapped tank contractors that operate in the Northeast. It was a closed specification intended to limit the competition to these two wire-wrapped tank contractors. One general contractor familiar with internal tendon tanks, however, put in an alternate bid anyway. That general contractor's bid was about \$170,000 less than one wire-wrapped tank contractor's and about \$940,000 less than the other's, who appeared to be giving only a "complimentary bid."

This scenario has played out many times since the 1970s with almost always the same result;

with a “level playing field” internal tendon tanks almost always prove to be the better value. No matter how the bid turns out, an owner can only be better off with the increased competition. Even if the wire-wrapped tank contractors are the low bidders, the bid will certainly be lower than without the increased competition. If, on the other hand, a tendon tank wins the bid and is selected, the owner will get what many consider a better tank at a lower price.

PROVIDING FOR A TENDON TANK ALTERNATE

Traditionally, the structural design of circular prestressed concrete tanks is provided for by way of performance specifications. Performance specifications for both a wire-wrapped and internal tendon tank need to be incorporated into the specifications to ensure maximum competition. Sample performance specifications for an internal tendon tank based on AWWA D115-06 are available for your use free from J&CA’s website, www.Close-Associates.com.

SUMMARY AND CONCLUSIONS

Consulting engineers, such as J&CA, and owners who have had experience with both types, think internal tendon tanks are superior to wire-wrapped tanks. Internal tendon tanks naturally have much greater long-term durability, are more watertight, and are almost always lower in cost than their wire-wrapped counterparts.

If the performance specifications include both an internal tendon and wrapped tank option as equal alternates, and the wire-wrapped tank is low, your owner would get a wire-wrapped tank at what you have confirmed is a good price. The benefits from this increase in competition can be obtained by adding a tendon tank alternate section to the otherwise unchanged bid documents.

Thank you for the opportunity of presenting these concepts to you. If you have any questions or require additional information, please feel free to contact us.

Sincerely,

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