Design-Construction Feature

Precast Prestressed Wall System Used for Water Storage Reservoir

Vern C. Rogne, P.Eng.
Senior Project Engineer
Reid, Crowther & Partners Ltd.
Regina, Saskatchewan
Canada

Douglas L. Harrison, P.Eng.
Senior Structural Engineer
Reid, Crowther & Partners Ltd.
Regina, Saskatchewan

The requirements set forth by the City of Regina for the North West Reservoir specified a desired reservoir capacity of approximately 10 million imperial gallons (45½ million liters)* with a diameter not less than 220 ft (67.1 m) nor more than 230 ft (70.1 m).

A further requirement was that sensitive attention be given to aesthetic treatment and landscaping so that the structure would harmonize with the existing homes and proposed freeway which border the project site. Design was started in April 1978 with a target of placing the reservoir in service before the summer of 1979.

Consideration of these constraints and hydraulics established that a circular structure, with an inside diameter of 225 ft (68.6 m) and a wall height of about 38 ft (11.6 m), would most efficiently satisfy the project requirements.

Since 38 ft (11.6 m) appeared to be the upper practical limit of wall height, the reservoir floor was sloped down to the center to satisfy the hydraulic requirements.

The resulting capacity of the reservoir, including live and dead load storage, is approximately 9,400,000 imperial gallons (41.6 million liters). Figs. 1 and 2 show in plan and cross section, respectively, the general configuration of the reservoir structure.

*Note: 1 U.S. gallon equals 0.827 imperial gallons.

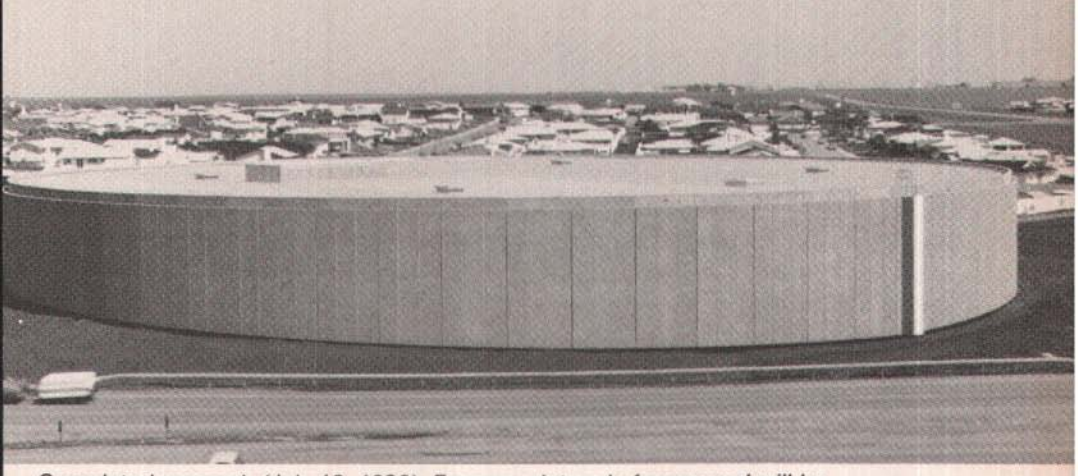
An all precast prestressed concrete system proved to be structurally efficient and economical in building a 10-million gallon water storage reservoir in Regina, Saskatchewan. Nearly 600 precast units (comprising structural wall panels, buttress panels, hollow-core roof members, roof support girders, columns, and architectural cladding panels) were used in the project.

On this basis, four alternate structural systems were assessed:

- Conventionally reinforced, cast-in-place concrete;
- Post-tensioned cast-in-place concrete;
- Wire wound, prestressed concrete; and
- Precast prestressed concrete.

In addition to the above concrete systems, the possibility of using a structural steel tank was investigated and a cursory review of several patented systems was undertaken, but none of those systems proved to be suitable or economical.

A preliminary cost analysis showed that the precast prestressed concrete alternative would produce an apparent cost saving between 5 to 10 percent over the other structural systems.



Completed reservoir (July 10, 1980). Freeway detour in foreground will be abandoned and replaced by attractive landscaping.

Aesthetic Considerations

The challenge of locating a massive industrial structure on a restricted site in a predominantly residential area was identified early in the conceptual design stages. The hydraulics of the waterworks system and a partially completed freeway interchange bordering the site precluded any flexibility in locating the structure and complicated the problem of building the reservoir with minimum impact on the residential community.

In a sensitive response to this challenge, architectural precast cladding panels incorporating locally occurring aggregates, were selected to complement sculptured land forms and plantings. An added bonus provided by these panels is their resistance to vandalism.

Other factors which influenced selection of this unique structural system were:

1. Watertightness—Prestressing of wall panels in two directions, i.e., vertical pretensioning and horizontal post-tensioning, virtually assures watertightness.

2. Quality Control—Fabrication under plant conditions allows better quality control.

3. Speed of Construction—The project schedule dictated that the reservoir be commissioned prior to the peak summer season, forcing construction operations to continue during typical harsh winter conditions. Plant production of the majority of the structure was the only apparent way to meet the demands of this schedule.

Structural Design

It is believed that the wall panels are the tallest and thinnest panels used for this type of reservoir construction in North America. Accordingly, the major

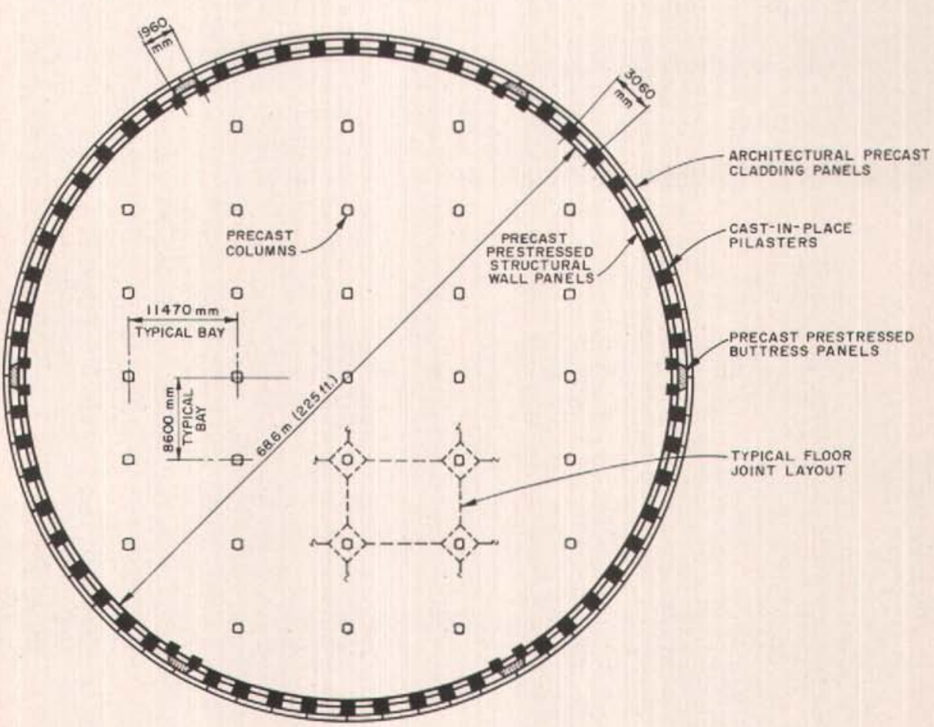


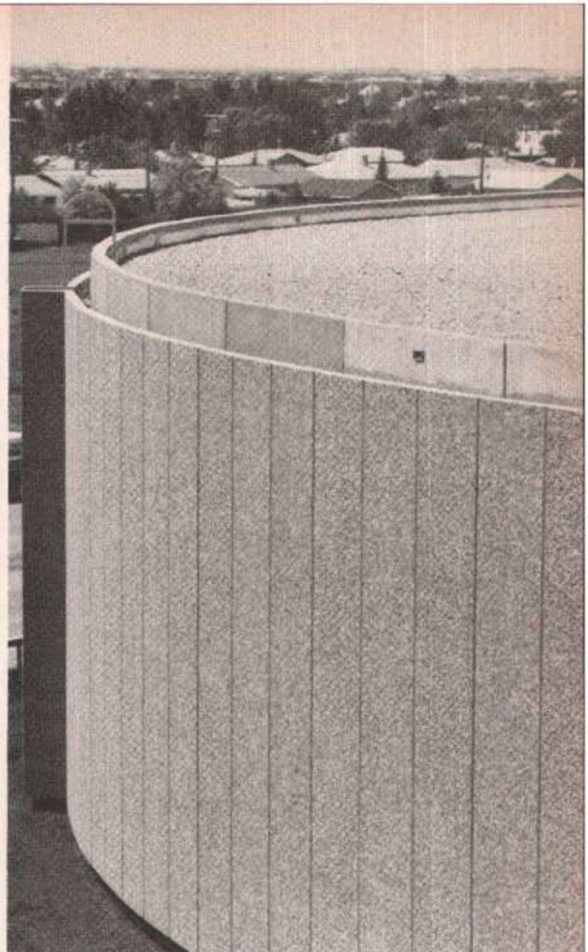
Fig. 1. Plan of reservoir showing principal structural elements.

portion of the structural design was devoted to analyzing the prestressed, post-tensioned, precast concrete wall panels. The walls were analyzed using the theory of Timoshenko,[1] the PCA design aid *Circular Tanks Without Prestressing,*[2] and CTA's Technical Bulletin 77-B1.[3]

A preliminary design was performed to obtain an estimate of wall thickness required. The typical wall panel and buttress panel sizes were then determined considering the geometric constraints, the precast concrete plant crane capacity, the quality control requirements, and the erection problems. The cast-in-place concrete pilasters were sized with minimum dimensions that would still allow practical placement of the concrete and maintain quality control. The pilasters are heavily reinforced to control shrinkage cracks.

Fig. 3 illustrates the essential features of the structural wall panels and describes the function of the critical top and bottom joints. The basic configuration of the buttress panels and the cast-in-place pilasters are shown in Fig. 4.

The wall panels were prestressed vertically in order to resist the applied vertical bending due to the water pressure and due to the earth backfill pressure. It was found during the design that the vertical prestressing requirements were



Closeup of architectural precast cladding panels (July 10, 1980). Sixty-six 6-in. (152 mm) thick panels were used in the reservoir comprising a total wall area of about 15,240 sq ft (1416 m²).

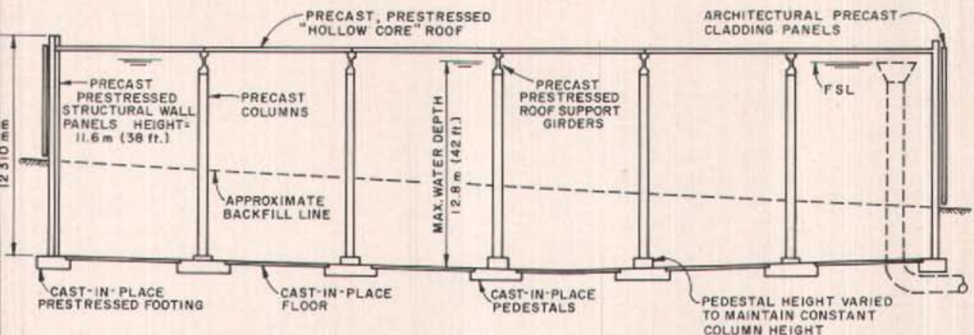
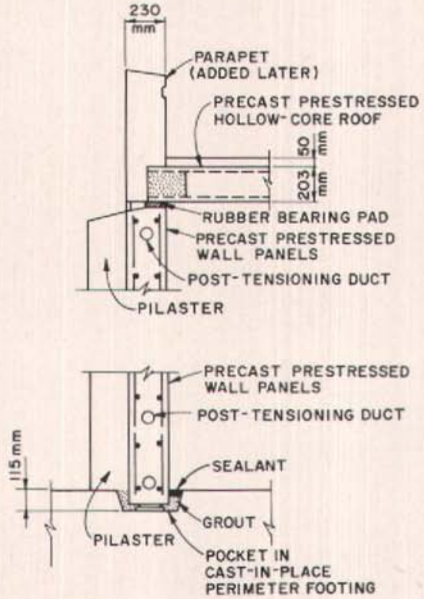


Fig. 2. Cross section of reservoir showing structural components.



Note 1: The top joint separates the wall from the roof to allow movement due to post-tensioning, temperature changes, and lateral water pressure.

Note 2: The grouted joint at the base of the wall panels provides a structural hinge. The sealant provides watertightness.

Fig. 3. Joint details of precast prestressed wall panels.

the major criteria in determining the required concrete compressive strength.

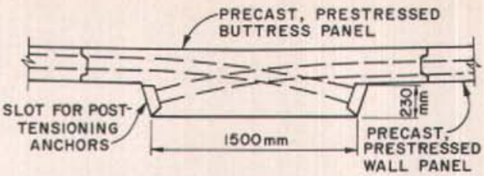
The critical section in the wall panel is at the location of the post-tensioning ducts. The reduced width at the sides of the duct requires a high concrete strength at release in order to accommodate the high prestressing forces. During the design, it was confirmed that a release strength of 4350 psi (30 MPa) and an ultimate strength of 6500 psi (45 MPa) were required.

Once the hoop stresses were calculated, the post-tensioning requirements were easily determined. The practical limitations of bringing the ducts out at the buttress panels had to be studied before the spacing of the ducts could be

PRECAST PRESTRESSED CONCRETE COMPONENTS

Type of Element	Number	Dimensions	
		U.S. Units	Metric Units
Structural Wall Panels	60	9 in. thick x 10 ft wide x 38 ft	0.23 x 3.05 x 11.6 m
Buttress Panels	6	18 in. thick x 6.4 ft wide x 38 ft	0.46 x 1.95 x 11.6 m
Hollow-Core Roof Members	388	8 in. deep x 4 ft wide (Total Area = 39,760 sq ft)	0.20 x 1.22 m (Area = 3694 m^2)
Roof Support Girders	38	3.8 ft deep (Total Length = 1350 ft)	1.17 m deep (Length = 412 m)
Columns	31	20 in. x 20 in. x 33 ft	0.50 x 0.50 x 10.13 m
Architectural Cladding Panels	66	6 in. thick (Total Area = 15,240 sq ft)	0.15 m thick (Area = 1416 m^2)

Note 1: Post-tensioning tendons were anchored at six heavily reinforced buttress wall panels located at equally spaced intervals. Buttress panel anchors permitted post-tensioning from outside the reservoir after all panels were erected and joined together with the cast-in-place pilasters.



Note 2: Pilasters were cast-in-place to form the joints between precast wall panels. Post-tensioning ducts within the walls are spliced at this joint.

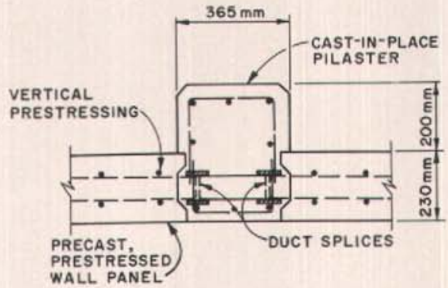


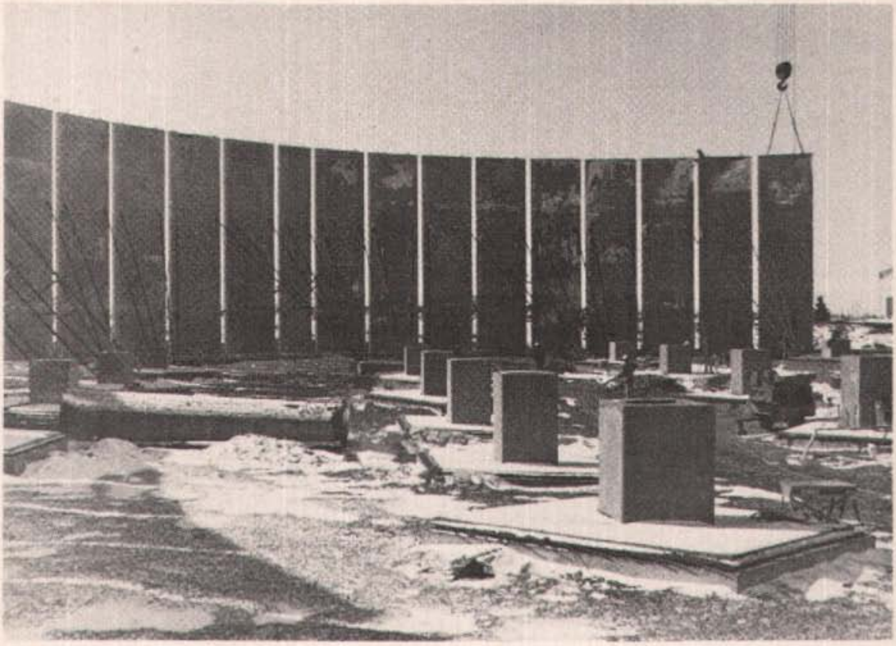
Fig. 4. Details of pilaster and buttress configurations.

finalized. The cast-in-place concrete footing was post-tensioned in order to resist the shear at the base of the wall. The tendons were continuous for one-third of the tank circumference with adjacent tendons taken out at alternate buttresses.

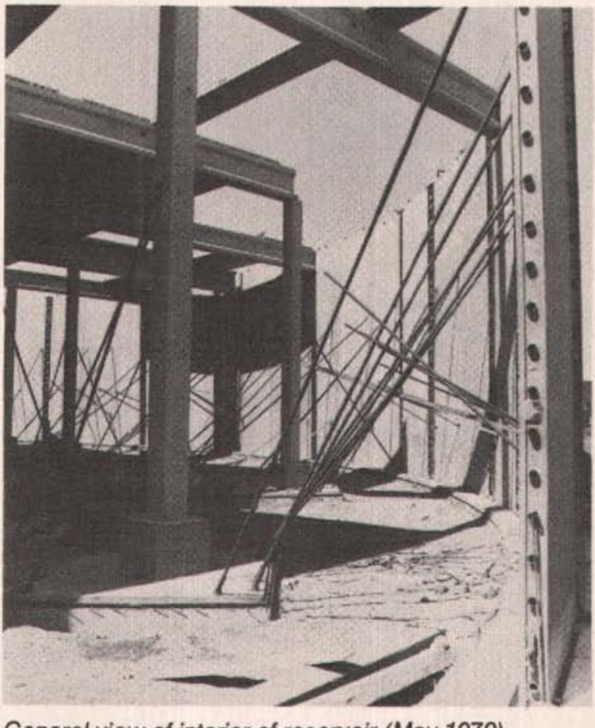
Friction losses and other prestress losses were calculated using procedures similar to that used for bridges. The important design consideration of the roof structure was to ensure that a sliding joint was obtained between the roof deck and the perimeter walls. This allows lateral movement of the walls due to temperature changes, water pressure and backfill pressure.

The precast prestressed concrete roof

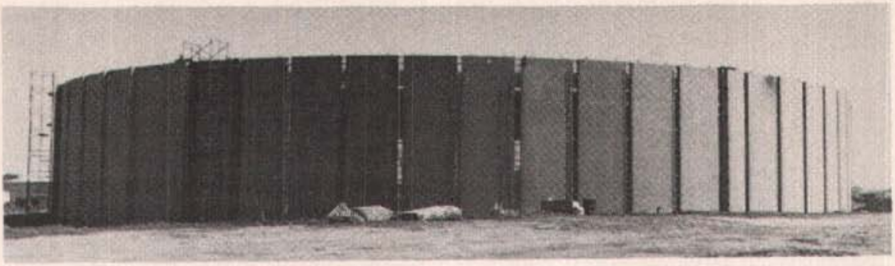
Erection of wall panels in late winter showing column pedestals and perimeter footing (March 1979).



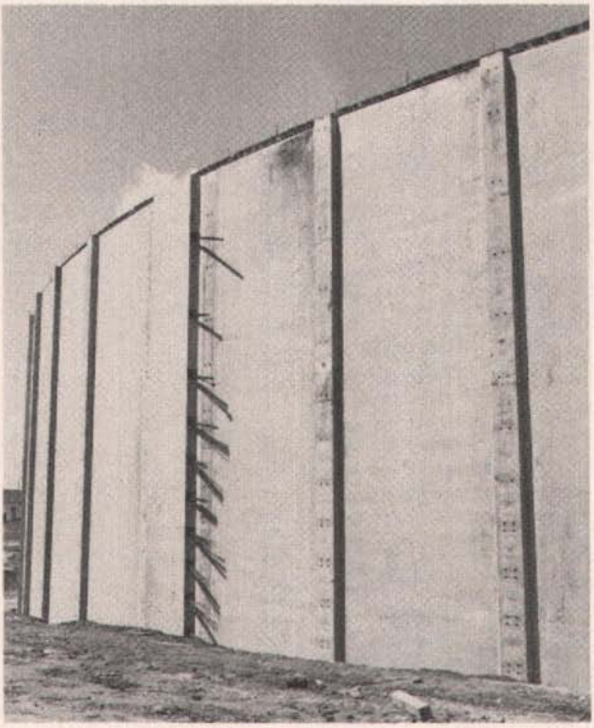
Erection of wall panels (March 1979). Snow has blown on to the panels.



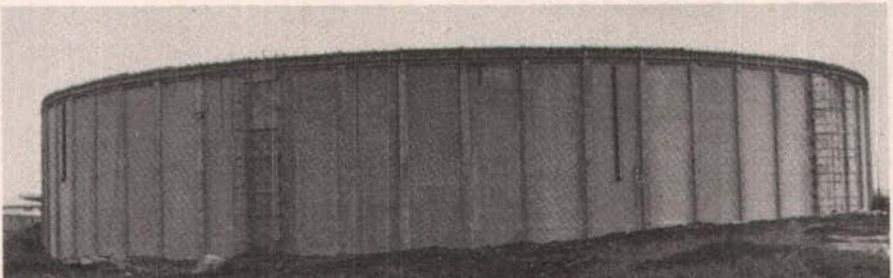
General view of interior of reservoir (May 1979).



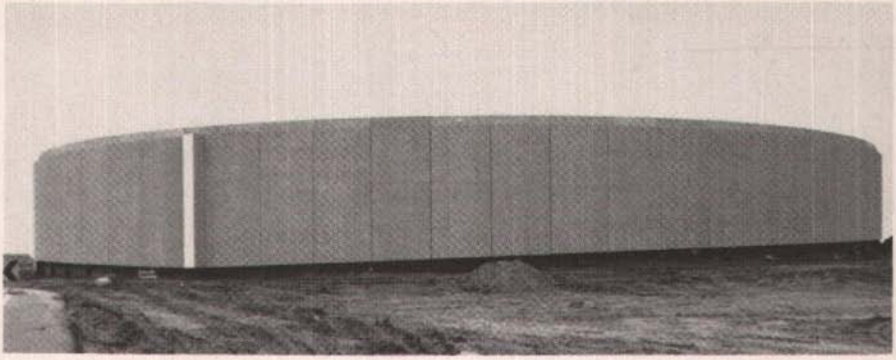
General view of reservoir with wall panels installed (May 1979).



Pilasters and abutments are complete; post-tensioning tendons have been installed (June 1979).



Parapet forms in place (July 1979).



General view of reservoir (November 1979).

deck, precast prestressed roof beams and precast concrete columns were designed in accordance with standard practice. The bases for the precast columns were varied in height to allow the length of the precast columns to remain constant.

Cost

The total cost of the reservoir project (which included rerouting of frontage roads, extensive piping, landscaping plus other items) amounted to about 2.3 million Canadian dollars. The structural portion of the project cost about 17 Canadian cents per gallon of water.

A short construction strike, adverse winter conditions and an exceptionally late spring delayed construction operations, but the reservoir was ready for use by July, 1979. Since then the reservoir has been functioning satisfactorily.

Concluding Remarks

The early performance of the North West Reservoir has justified the selection of the PSP (precast, segmental, post-tensioned system). Prestressing of the wall panels in two directions virtually assures watertightness of the walls, if special attention is paid to pilaster construction and the wall-to-footing joint.

In addition to the satisfactory serviceability of the reservoir structure, the project has provided a net gain for the residents of the area, in that a neighborhood park, with eye-pleasing architectural precast panels providing a backdrop to the landscape and a buffer to the interchange, will be created for year-round recreation.

Credits

Prime Consultant and Design Engineer: Reid, Crowther & Partners Limited, Regina, Saskatchewan.

Consulting Architect: Wiens & Associates Ltd., Regina, Saskatchewan.

General Contractor: PCL Construction Ltd., Regina, Saskatchewan.

Precast Concrete Manufacturer: Con-Force Products Limited, Regina, Saskatchewan.

Owner: City of Regina, Saskatchewan.

References

1. Timoshenko, S., and Woinowsky-Kreiger, S., *Theory of Plates and Shells,* Second Edition, McGraw-Hill Book Co., New York, N.Y., 1959.
2. *Circular Tanks Without Prestressing (IS072),* Portland Cement Association, Skokie, Illinois.
3. *Precast Segmental Post-Tensioned (PSP) Concrete Tanks for Water and Other Liquids,* Technical Bulletin 77-B1, Concrete Technology Associates, Tacoma, Washington, December 1977.

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