Notes on Post-Tensioned Lift-Slabs

by Harold Omsted*

INTRODUCTION

The first post-tensioned lift-slab building in the Los Angeles City School District was built in 1960. Since then, 28 more such buildings have been added, all of which are two stories high with an exterior balcony around the entire perimeter. Figs. 1 and 2 show the floor plan and cross-section of a typical classroom building. Figs. 3 and 4 are photographs of our Menlo Avenue School (Architect: Roland Russell; Structural Engineer: John A. Martin & Associates).

The concrete for all of the lift-slabs contains expanded clay-shale aggregate produced in rotary kilns, and weighs 110 lbs. per cubic foot; minimum twenty-eight day strength is 4,000 psi. Columns are made of stone aggregate concrete with minimum twenty-eight day strength of 5,000 psi.

Slabs are 8½ in. to 10 in. in thickness, prestressed in two directions with unbonded tendons, and draped to fit the stress pattern. The slabs span 28 ft. in one direction, 32 ft. in the other, and cantilever 8 ft. around the entire perimeter. End anchorages are of the BBR type with buttonheaded wires. The design is based on zero tension in the concrete under any loading condition. Although roof slabs are left exposed, with no roofing of any kind, leaks have never developed through the slabs.

The lift-slab design has proved to be economical, and has produced very satisfactory classroom buildings. A few problems have developed, all of them of a minor nature, and the purpose of this article is to discuss these problems and the procedures we have used to overcome them.

INELASTIC CREEP

The average concrete stress due

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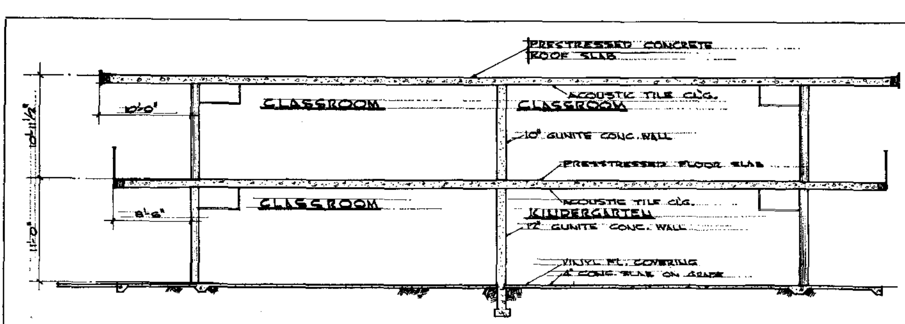

Fig. 1—Typical Section

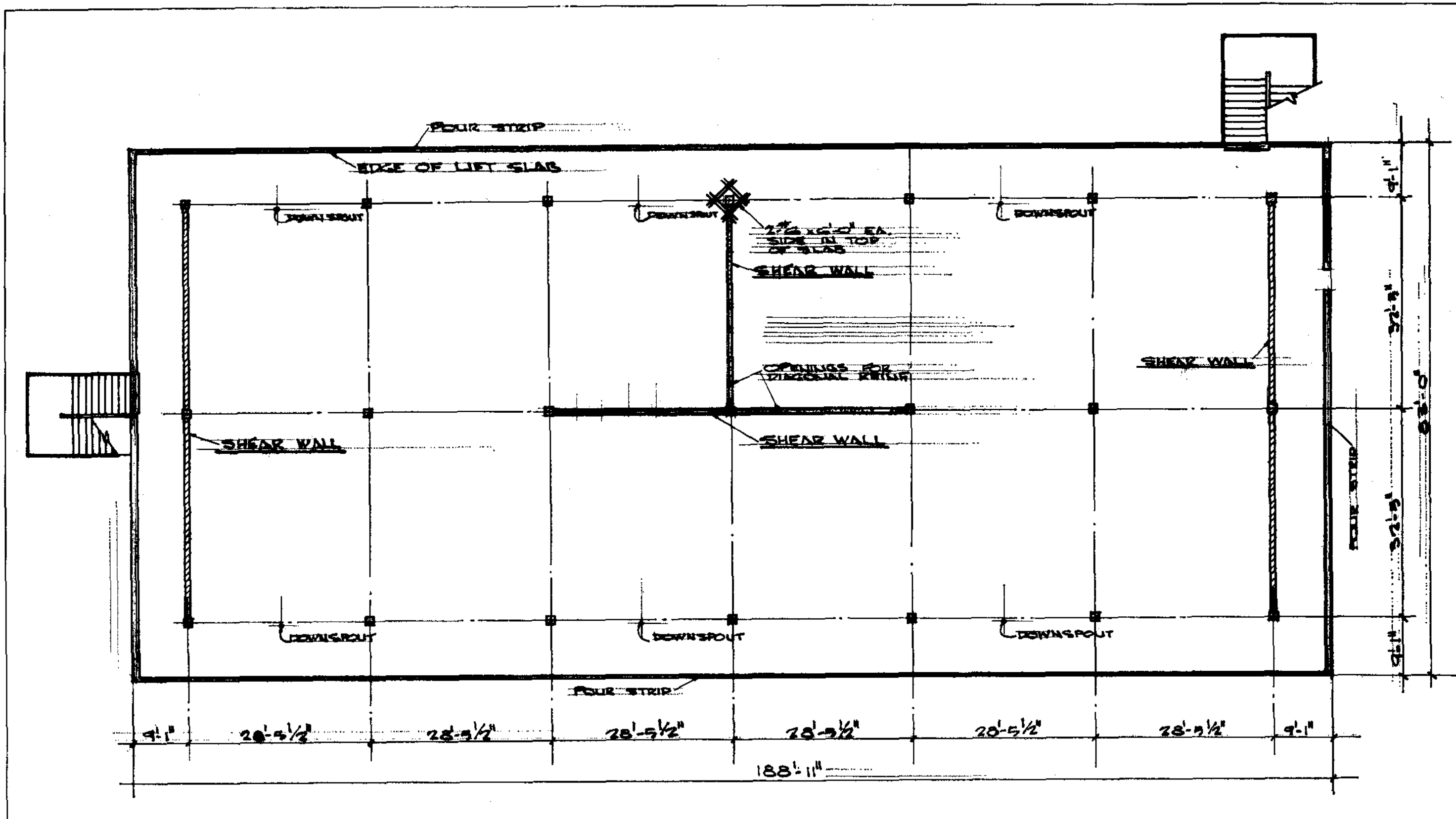

Fig. 2—Typical Second Floor Plan

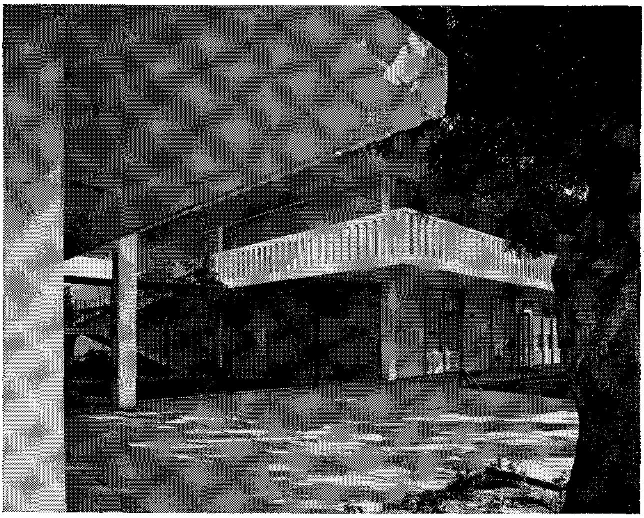

Fig. 3—Menlo Avenue School

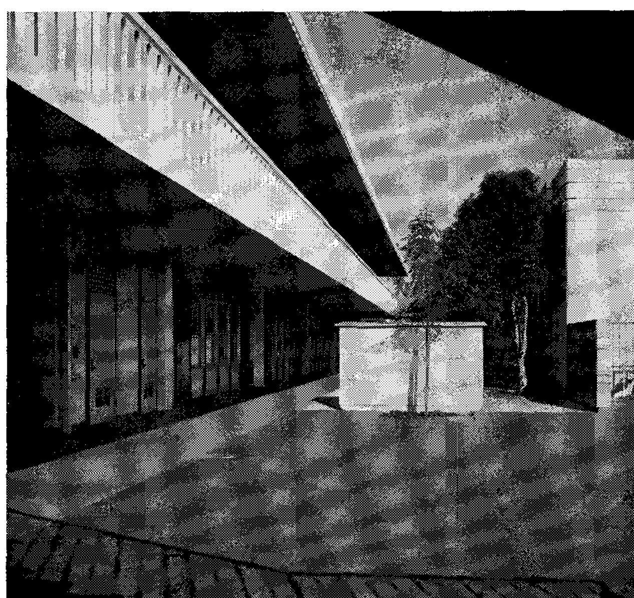

Fig. 4—Menlo Avenue School

to prestressing is around 300 psi. An effort was made to determine slab shortening due to creep by installing brass plugs in the top of lift-slabs in one building transversely as well as longitudinally. Measurements were taken with a "Lovar" tape before and after the slab had been prestressed and after it had been lifted, and then at appropriate intervals for several months. No satisfactory method was devised to measure the temperature of the concrete itself, and we found that temperature expansion and contraction of the concrete was sufficiently great to obscure any shortening due to creep. It was concluded that inelastic creep probably is low enough to be generally ignored when stresses are in the range of only 300 psi. Drying shrinkage and elastic deformation are, of course, easily determined and must be taken into account.

While we believe inelastic creep to be very low in our prestressed lift-slabs, we still observe certain basic rules in order to eliminate any possible harmful consequences. Longitudinal shear walls of cast-in-place concrete or gunite, which are not prestressed and do not creep, are placed as close as possible to the center of the building, and are made as short as possible. Where partitions or suspended ceilings abut end walls, which may be pulled slightly out of plumb due to shortening of the lift-slabs, we provide a joint to accommodate slight movements of the end wall.

A free-standing stairway, serving the second floor of a projecting balcony, must be structurally separated from the lift-slab; the joint being covered with a suitable device to allow for relative movements.

SHRINKAGE CRACKS

In some instances shrinkage cracks did develop before prestressing was applied. These cracks were never wide, and always closed when prestressing was applied. In one instance, a heavy rain occurred shortly after a roof slab had been lifted. A few drops of moisture did appear on the soffit of the slab along the track of the crack. However, when a second heavy rainfall occurred two or three weeks later, the crack had apparently "healed" itself, and no moisture penetrated the slab.

On all recent jobs we have applied a partial prestress when the concrete had achieved a minimum strength of 1500 psi, or not less than 36 hours after the slabs had been cast. The partial prestress amounts to approximately 25% of the final anchoring stress. This procedure, which has only been used on roof slabs, has virtually eliminated the formation of any shrinkage cracks.

CURING

Best results have been achieved with water curing. On roof slabs, up-turned edges have permitted us to pond water to a depth of 2 in. over the entire area. On floor slabs we apply a fog spray immediately behind the last finishing operation, followed by double application of a curing compound which also serves as a bond-breaking agent. The complete absence of crazing and cracking in slabs cured by ponding has clearly demonstrated the superior value of this method of curing.

DIURNAL MOVEMENTS OF ROOF SLABS

We have found that daily cycles of temperature variations cause measureable movements of the roof slabs. When the sun strikes the top surface in the morning, a temperature gradient begins to develop through the slab. The top portion heats up and expands; the bottom portion lags behind. As a consequence, the cantilever deflects downward, and the interior sections arch upwards. At sunset, the temperature gradient begins to even out, and sometime during the night the slab returns to its initial position. On a hot summer day the total movement from night to day measured at the end of an 8-ft. canti-

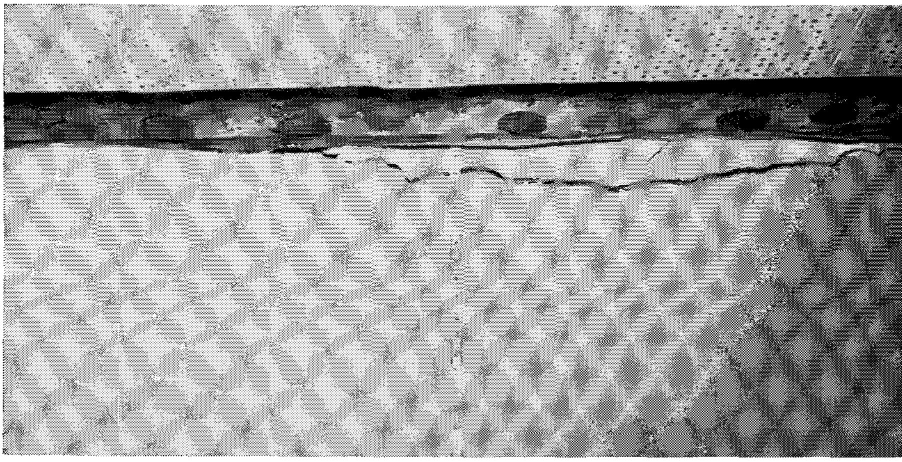

Fig. 5—Damage to shear wall due to insufficient anchorage to roof slab.

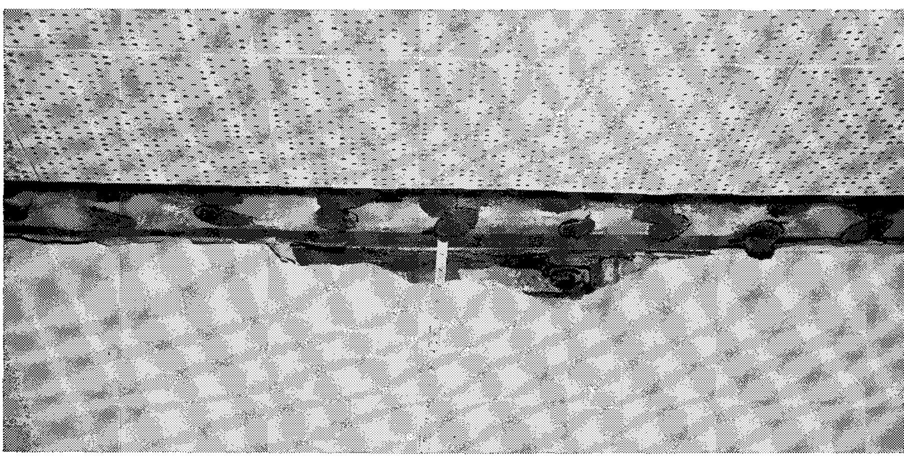

Fig. 6—Shear connection consisting of short steel angle bolted to insert in lift slab could not develop any uplift force.

lever may be as much as ¾ in., and the upward arching of the interior portions may be one-half of this amount.

The second floor slab is largely shaded from the sun and, while similar movements probably take place, they are too small to be observed.

It is important that these movements of a roof slab be duly considered in the design. Non-bearing partitions extending to the soffit of the roof slab must be connected to the slab in such a way that movements of the order of ⅜ in. can be accommodated. The variable crack at the top of the partition should be concealed by an appropriate molding secured to the slab. Interior shear walls, which develop seismic shear from the roof slab, must be connected to the same with a detail which is capable of developing tension as well as shear.

On one of our lift-slab schools this was neglected. The connection detail between slab and a transverse shear wall efficiently transmitted any shear, but was incapable of resisting the upward arching of the roof slab. The top of the wall cracked off and extensive repairs must be made. Figs. 5 and 6 illustrate damage to this wall. In order to prevent the arching at this shear wall, it was necessary to develop an uplift force of 3,800 lbs. on each of the shear connectors which are spaced 4'-0" on centers. While this force is easily manageable through a proper design detail, it must not be neglected.

JOINTS BETWEEN BUILDINGS

A few Los Angeles school buildings using lift-slab construction are composed of two classrooom buildings built end-to-end, with the cantilevered ends of the roof slabs supporting a cast-in-place filler strip. Stairs to the second floor occupy the space beneath the roof overhang. Expansion and contraction are provided for along one edge of the cast-in-place filler strip, and the joint was originally filled with an epoxy-thiokol compound. This joint filler proved inadequate to accommodate the fairly large movements mostly due to changes in temperature; and leaks through the joint developed with every rain. After several attempts to improve the joint failed, curbs were provided on each side of the joint and metal flashing installed across the gap. Where two relatively long buildings are separated by such a joint, this simple detail is positive and economical and should always be used in preference to a plastic joint sealer.

JOINTS AT EDGE STRIPS

End anchorages are covered with a cast-in-place edge strip, approximately 12 in. wide, secured to the edge of the lift-slab by mild steel dowels. It is extremely important that no water reach the end anchorages, and this joint must, therefore, be made absolutely watertight. Because the relative movements between each side of this joint are minimal, it is easy to develop a satisfactory joint filler using a thiokol compound. However, the recess

Fig. 7—Steel stud partition having metal lath and plaster between Rooms 20 and 21 was completely bare of plaster around top of steel door frame which was warped.

Fig. 8—Checking depth of spall of lightweight concrete at ceiling of Room 21. Maximum depth of spall was 1¾ in. over a spot one ft. square; average depth was ¾ in. over west end.

Fig. 9—Ceiling at west end of Room 21. One 3-ft. length of tendon having a 1⅛-in. cover of lightweight concrete was exposed by spalling.

Fig. 10—Clay brick east wall was spalled to a depth of ¾ in. over 2-ft. diameter spot even though the adjacent lightweight concrete ceiling slab did not spall.

must be of the proper proportions and the concrete surfaces meticulously cleaned in order to develop a perfect bond between concrete and the joint filler.

ROOF DRAINAGE

All our lift-slab roof slabs built recently are perfectly level on top, except for a turned-up edge around the perimeter of the overhang. Roof drains are placed on line with the exterior walls, and some ponding of rain water due to unevenness of the finish is accepted without any concern.

Because of the rhythmic up-and-down movements of the cantilevered edge, the roof slab is thickened a minimum of 2 in. at the extreme edge, and tapered back to normal thickness on a line 3 or 4 ft. from the edge. On early jobs, the thickening was only 1 in., which proved to be inadequate. During an occasional rainstorm, the water would overtop the 1 in. "dam" and would cascade over the edge.

FIRE RESISTANCE

Post-tensioned cables are protected with minimum cover of 1½ in. of lightweight aggregate concrete. This proved to be adequate in two recent fires at one of our schools. Both fires were started by arsonists. The first one was hot enough to melt the aluminum frames of the window wall and to fuse copper wires for electric fixtures. The peak temperature was estimated at nearly 2000°F., and the duration of the fire at one hour. Everything combustible within two rooms was virtually consumed. Extensive spalling of the slab soffits occurred in both rooms, and a few of the tendons were actually exposed for a short distance. On one cable the wires were actually exposed for a length of 3 ft., but some of the lubricating compound between the wires was still soft; proving beyond reasonable doubt that the spalling must have occurred when the stream of water from the fireman's nozzle hit the hot ceiling. Lift-off tests on all tendons in the affected area revealed no loss of tension in any cable. Figs. 7 through 10 show fire damage in this building.