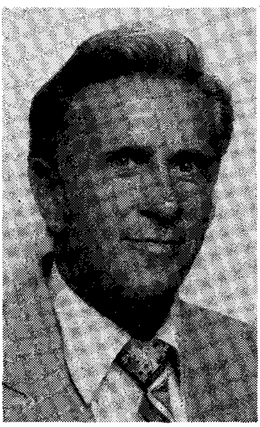
Design-Construction Feature

Multnomah County (Oregon) Maintenance and Operations Facility



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The Division of Maintenance and Operations for Multnomah County (Oregon) will soon take possession of a new facility (see Fig. 1) that will serve as a model of energy efficiency, organizational flexibility, and optimum working conditions. The total cost of the entire project is estimated at $12½ million.

The Division (of Maintenance and Operations) has a staff totaling 215 employees and is responsible for maintaining all county roads, bridges, vehicles, equipment and other county related services. For the past 40 years the Division has been headquartered in a series of buildings located on 40 acres of county-owned property at Rocky Butte, just northeast of the city limits of Portland.

Over the years, additions, remodelings, and new structures have been added piecemeal as the county itself grew, until today many division operations are spread out among five separate buildings. One of the county's six district road crews is also based at Rocky Butte as is part of the Division of Parks and Memorials.

The relocation of the Multnomah County Shops was required by construction of a new interstate freeway. Under the regulations of the Federal Uniform Relocation Act of 1974, the Federal Government was obligated to either pay the county for the property and structures on it or to replace the facility with a new structure incorporating the current state-of-the-art. The county chose the latter option.

Precast and prestressed concrete provided a simple and economical solution for a complex, energy efficient underground facility near Portland, Oregon. Over 600 precast components (comprising columns, floor and roof beams, conventional and giant sized double-tees, hollow-core slabs and wall panels) were used to build this \$12½ million, 185,500 sq ft (17,233 m²), two-story building. This article gives the design-erection highlights of the project.

Out of 200 potential relocation sites, the centrally located "Vance Pit" was selected. The 90 acres of land comprising the Vance Pit property have been used for gravel mining by the county for over 50 years. As areas within the property were mined out, they were used for land fill deposits, either sanitary land fill or rubbish, trash, and less active types of fill.

Thorough geologic, hydrologic, and environmental investigations were undertaken, and concluded in delineating a 15-acre parcel on which the new facility should be built. Eventually as all the gravel pits are mined out, the entire Vance Pit property will be reclaimed for parks and public uses surrounded by residential and light industrial communities.

Figs. 2 and 3 are aerial views of the existing terrain showing the mined areas and the partially completed building in the middle.

Design Features

The basic structure is a 300 x 340 ft (91.44 x 103.62 m) T-shaped, two-story, 44 ft (13.41 m) high box. The lower level is below-grade and the upper level is fully backfilled except at access points and the upper office floor. Fig. 4 shows longitudinal and transverse sections of the two-level structure. The building area comprised some 185,500 sq ft (17,233 m²) of floor area.

The T-shaped structure is mounded with dirt on all sides within 5 ft (1.52 m) of the top of the building. The building required access at several locations to serve its different functions. The facility's most important function is the repair and maintenance of county vehicles on the first floor which is below the natural grade of the site. This access is located on the street side of the building and is the major entrance to this space and the maintenance and operations offices. The ramp's generous width accommodates the loop around the central repair area and allows parking of vehicles scheduled for repair in the center of the access drive.

An entrance through the mound on the building's north face is contained by full-height retaining walls and provides building delivery and service activity. A canopy between the building

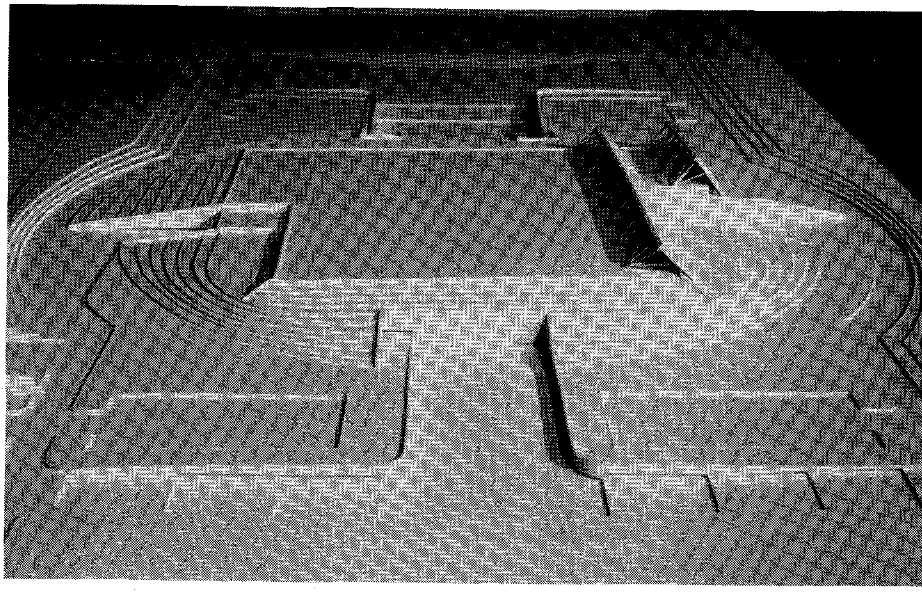

Fig. 1. Building model of Multnomah County (Oregon) maintenance and operations facility. The total cost of this underground structure was $12½ million.

and retaining walls covers the loading dock and the direct service to the storage warehouse. The east facing central ramp, 50 ft (15.25 m) wide, serves the basement. Access is provided from either side of the site to a level area for fleet fueling and wash. The ramp then proceeds perpendicular to the building to the service vehicle storage through berm and enclosed retaining walls.

To economize, the County opted to consolidate three of the six district road crews and house their functions in the building on this level as well as the maintenance crews for the County parks. The activity period of this level is greatest at the beginning and end of the day as crews depart or return from a day's assignment.

The south entry is identical to the north but without cover being provided between the full height retaining walls. Areas served by this entry are the sign shop where all road signs are made, radio repair and service, traffic light installation and maintenance, and a full length vehicle paint booth. This entry also serves as a staging area for maintenance of the solar collectors on either side of it.

Precast Prestressed Concrete Components

Over 600 precast prestressed concrete components (comprising columns, floor and roof beams, conventional and giant sized double-tees, hollow-core slabs and various types of wall panels) were used to build this multimillion dollar facility. The precast work amounted to $2,636,154 (or 21 percent of the total cost of the completed building).

Table 1 summarizes the details of the various types of precast prestressed concrete components that were used in the structure.

All the building components were designed according to the Uniform Building Code (1979) and the ACI Building Code (ACI 318-77). Where possible, the *PCI Design Handbook* (Second Edition) and other PCI Rec-

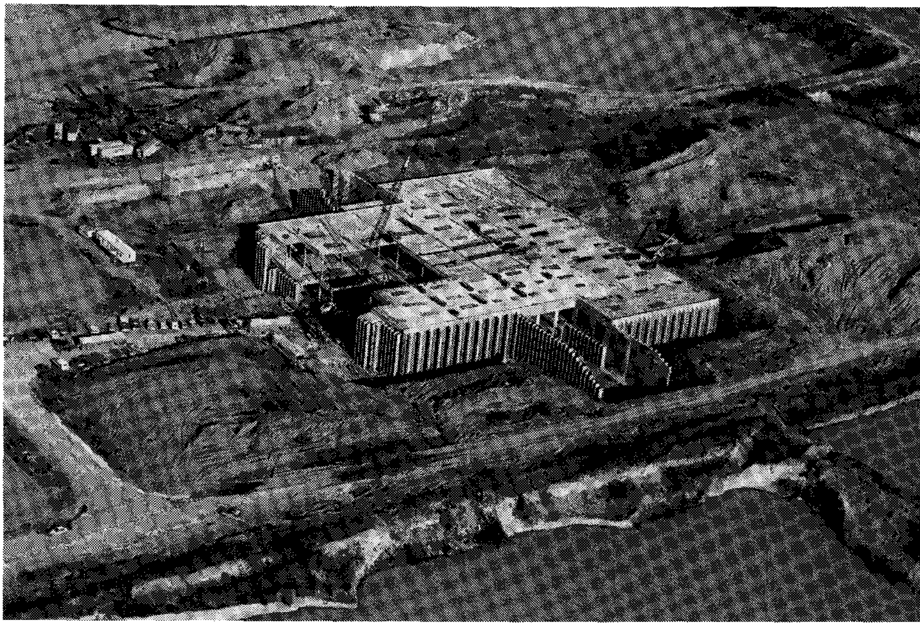

Fig. 2. Aerial view (looking from the south) of partially completed structure showing excavation (backfill) surrounded by mined terrain.

Fig. 3. Aerial view (looking from the north) of partially completed structure showing excavation (backfill) amidst mined terrain.

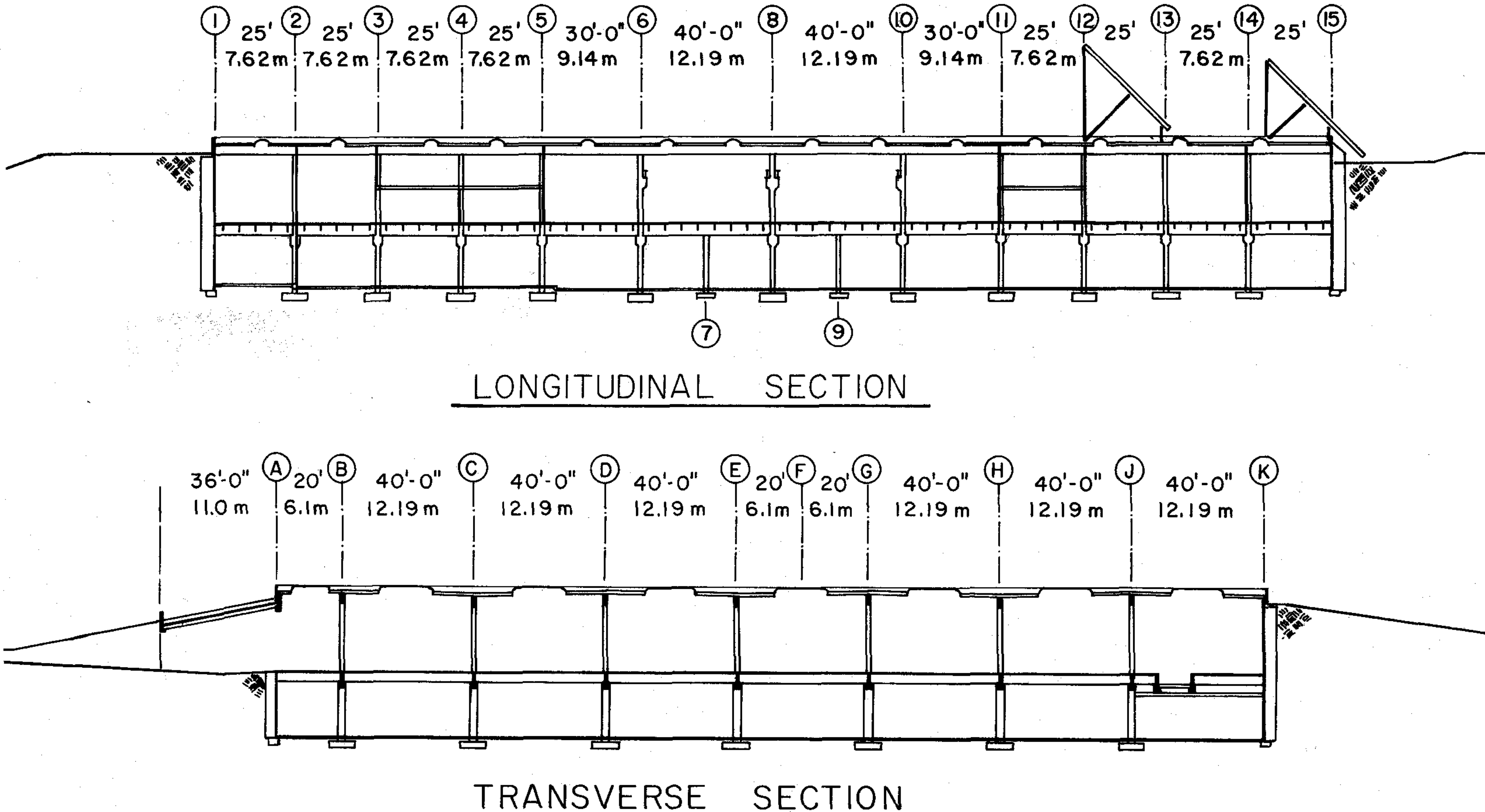

Fig. 4. Longitudinal and transverse sections of two-level underground facility.

TABLE 1. SUMMARY OF PRECAST CONCRETE COMPONENTS

Columns		
Two-Story Columns (lower 24x16 in.; upper 16x16 in.)	94 pcs	3817 lin. ft
One-Story Columns (16x16 in.)	19 pcs	300 lin. ft
Total:	113 pcs	4117 lin. ft
Roof Beams		
16IT32 and 16IT28	36 pcs	887 lin. ft
16RB36	41 pcs	1329 lin. ft
18LB36, 18LB42, 18LB65, 18LB72	19 pcs	567 lin. ft
Total:	96 pcs	2783 lin. ft
Floor Beams		
12IT42	81 pcs	1913 lin. ft
12x16 in. Soffitt Beam	15 pcs	398 lin. ft
18LB42, 18LB52, 18LB68	9 pcs	238 lin. ft
Total:	105 pcs	2549 lin. ft
12x48 in. Dycore Plank		89483 sq ft
10TT32 Double-Tee Floor Slab		91099 sq ft
Super Double-Tee Wall Panels (Prestressed)	149 pcs	45310 sq ft
Super Double-Tee Retaining Wall Panels (Reinforced)	67 pcs	28769 sq ft
Miscellaneous 6 and 8 in. Flat Wall Panels		9401 sq ft
Coping (Flat) Panels		1603 sq ft

Note: 1 ft = 0.305 m; 1 sq ft = 0.093 m².

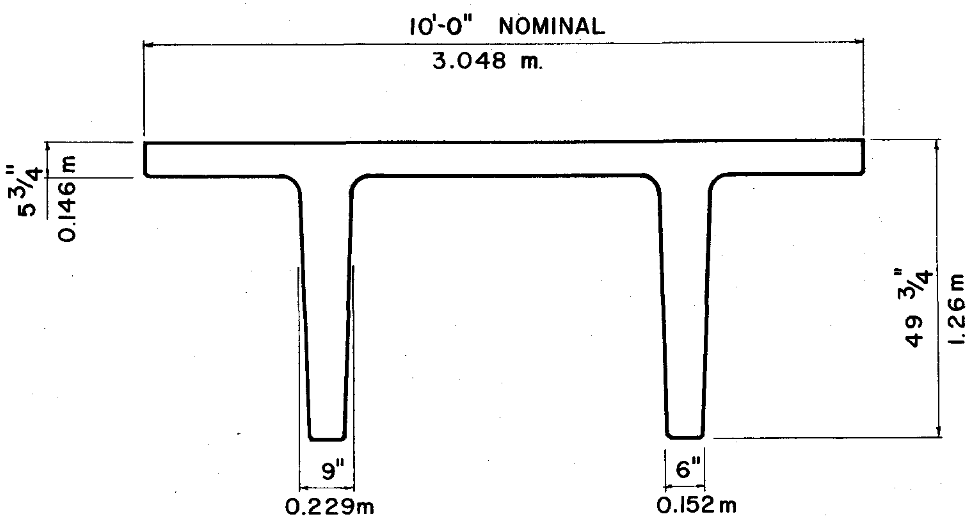

Fig. 5. Cross-sectional dimensions of "super double-tee."

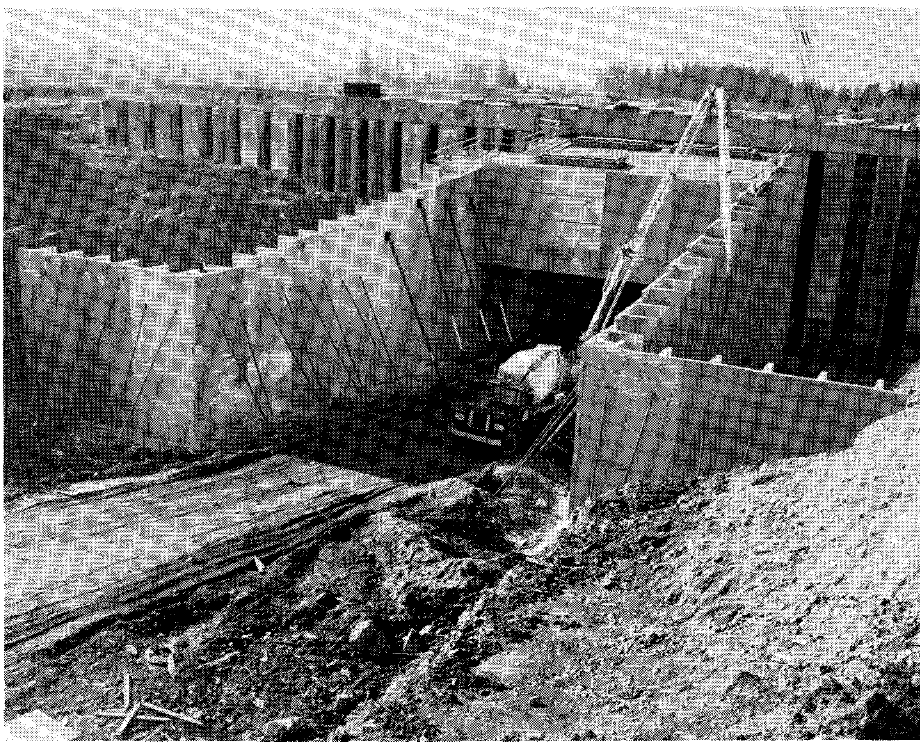

Fig. 6. West entry showing precast concrete retaining walls [up to 35 ft (10.67 m)].

ommended Practices were used together with an in-house computer system.

The wall panels are 10 ft. (3.05 m) wide by 49¾ in. (1.26 m) deep "super double-tees" made of 5000 psi (34 MPa) normal weight concrete. This "super double-tee" (see Fig. 5 for cross-sectional dimensions) was originally developed for a special conveyor structure in the early seventies and has had many unique uses since then: for example, as tall cantilevered columns; long span roofs; and 80-ft (24.38 m) spans for HS 20-44 loads for the Copper River (Alaska) delta bridges.

The two-story 44-ft (13.41 m) high wall panels were designed for 42 lb per cu ft (672.84 kg/m^3) equivalent fluid pressure, according to the soils consultant's specifications. Since the basement floor, first floor, and roof acted as a support, the panels had to be designed for continuity, both for positive and negative moments. They were also analyzed for erection loads, without backfill.

The stems of the tees were located at the backfill face of the panel. Inside the building the T-flange received a stipple finish.

A slight eccentric prestress was designed into the members compensating for the larger negative moment at the first floor support. The 5¾ in. (0.146 m) thick flange and the reinforcement were designed for the specified pressure, using welded wire fabric at both faces and added trussed reinforcement as required.

Extensive analysis, following both Timoshenko and Szilard plate theories, was used in the flange design for potential crack control. In some slabs

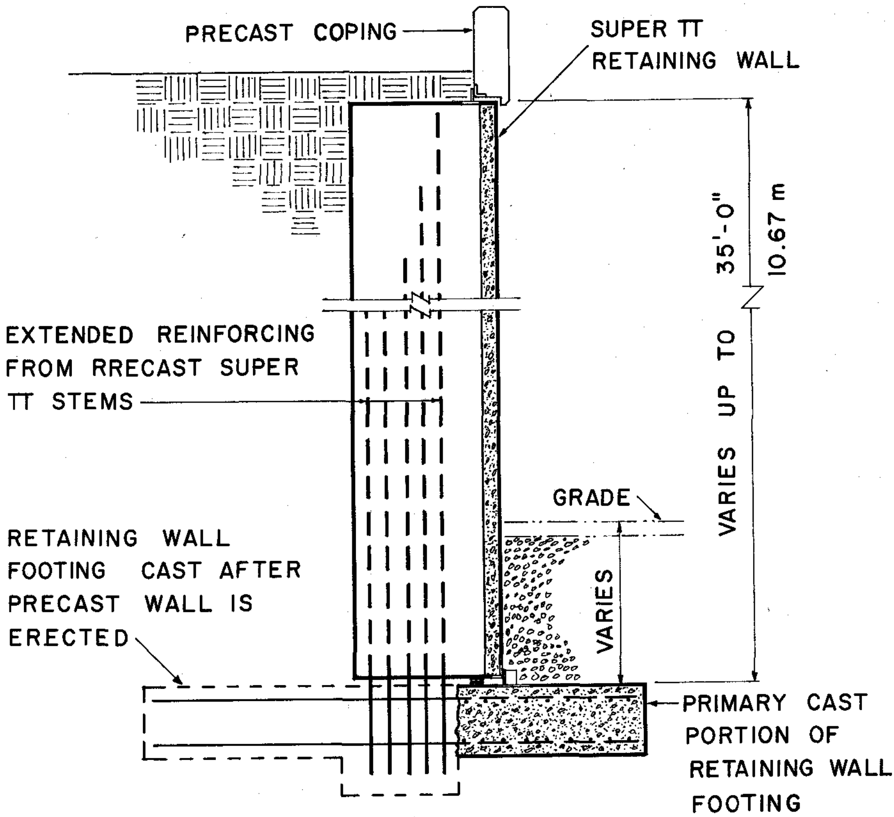

Fig. 7. Precast concrete retaining wall footing connection.

where corbels were required for floor slab or beam seat, they were designed according to the *PCI Design Handbook* (Second Edition).

A simple welded connection was used at the base of the structure for erection only. The shear tie to the basement, first floor and roof slabs are basically embedded inserts in the precast member and threaded rods into cast-in-place concrete. These inserts and flange connectors were designed for diaphragm stresses produced by unbalanced earth pressure introduced by heavier backfill.

In addition to the typical two-story high wall panels, one-story and one and one-half story panels were also used. Fixed base-roof supported prestressed and reinforced wall panels were employed for stair shafts.

Numerous fixed and free-standing retaining wall panels were used for entrance areas (see Fig. 6). The stems of the retaining wall panels were designed with conventional reinforcing steel which proved very economical because of the unique connection of the tall 35-ft (10.67 m) panels into the footing. Fig. 7 shows the elevation detail of the precast retaining wall footing connection.

The toe portion of the footing was cast in place with reinforcing steel protruding at the top and bottom to the heel. The retaining wall (composed of super double-tees) was lowered with extending hooked dowels into the

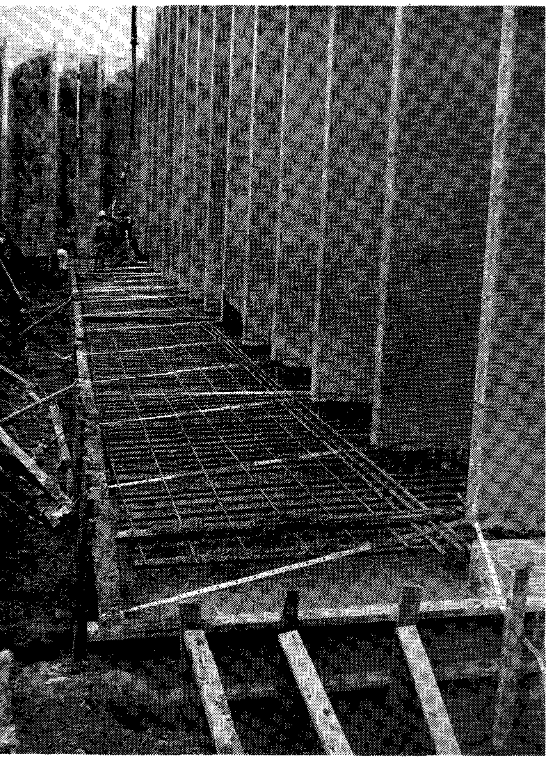

Fig. 8. Precast concrete retaining wall base connection. Note that heel portion of footing was cast in place (see Fig. 7).

reinforcing mat, with the flange portion resting and welded to the toe part of the footing. Later, cast-in-place concrete was placed in the heel portion of the footing (see Fig. 8).

The former gravel pit, subsequently used as a sanitary fill, presented health hazards due to the methane gas generated by the decomposing garbage. The perimeter drain system at the footing elevation also acts as a gas collection system.

This outlet was connected to the underfloor system and, in turn, to a mechanical exhaust device which constantly removes the contaminated air to the atmosphere in order to eliminate the potential of gas pressure build-up or entry into the building. Granular backfill was used 9 ft (2.74 m) from the precast wall panels to allow further ease of gas migration to the atmosphere.

The joints between tees were filled with a backer rod and caulked inside and out. The surface between the stems was then waterproofed on the outside and a fiber glass mesh was placed over the joint with a second coat of waterproofing added. A 1-ft (0.305 m) wide bead board was subsequently installed for protection.

Only on the building's north side where the office area is located are there windows in an exterior wall. The roof, however, is punctured with many skylights. The 4-ft (1.22 m) wide Dycore plank system allowed leaving a single plank out for use as a skylight or roof vent for ventilation or a combination of both.

Skylights were located to serve the prime work spaces on the first floor. The lighting is controlled with three levels of illumination depending on the quality of the light during the day entering the skylights. The precast system also allowed support of the 45-degree, 8000 sq ft (744 m²) solar collector mounted on the roof and attached to the precast wall panels.

The floor slabs are 10 ft (3.05 m) wide by 32 in. (813 mm) deep double-tees with a 2½ in. (64 mm) flange. The basic span is 40 ft (12.19 m). The specified live load is HS20 highway loading or 250 psf (1221 kg/m²). For this type of load and for the floor diaphragm, a 3½-in. (89 mm) heavily reinforced normal weight, concrete topping was used for the whole first floor.

The floor double-tees are simply supported on the inverted tee beam ledges. The bearing pads, precast volume changes, stem details, reinforcing steel requirements and other details were designed according to the *PCI Design Handbook* (Second Edition). Special welded wire fabric was used for flange and web (shear) reinforcement.

All final continuity and diaphragm action were achieved with the compos-

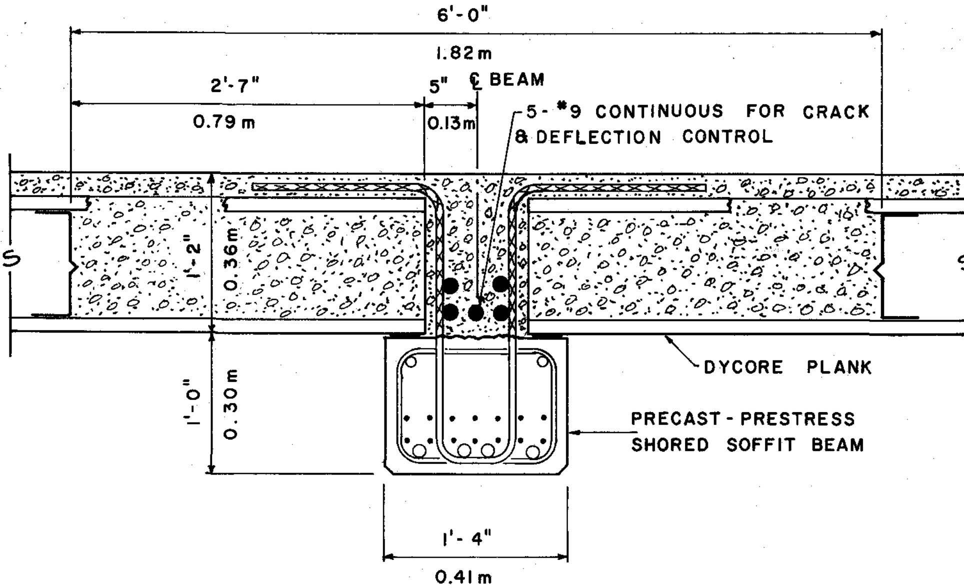

Fig. 9. Cross section of mezzanine connection.

ite design of the cast-in-place topping.

The mezzanine and roof slabs are 48 in. wide by 12 in. deep (1219 x 305 mm) prestressed concrete Dycore slabs. Basic 40-ft (12.19 m) spans were provided for 100 and 40 psf (488 and 195 kg/m²). Designed for 6000-psi (41 MPa) concrete, most of the slabs have a strength over 8000 psi (55 MPa). Fig. 9 shows a typical cross section of the mezzanine.

To take advantage of the energy savings gained from the underground scheme and to fulfill its objectives of energy efficiency, the County was eager to include a solar energy system for the shopping facility, a feature that was an integral part of the design concept employed throughout the development of the project. The County applied for and was awarded a solar energy demonstration grant from the U.S. Department of Energy.

Approximately 8000 sq ft (744 m²) of solar collector panels (see Fig. 10) will be placed in two arrays along the south side of the roof. They will provide all of the air conditioning and hot water needs of the facility and about half of its heating. The solar system will be backed by an oil-fired boiler and supplemented with radiant gas heating during the winter. As the building and the surrounding ground equalize temperatures, extreme shifts in temperature will be reduced by the insulating properties of the earth and heating and cooling requirements will lessen.

The columns are two-story high precast and conventionally reinforced members. The lower level dimension is 24 x 16 in. (0.61 x 0.406 m) and the upper level is 16 x 16 in. (0.406 x 0.406 m). The first floor beams are supported by corbels cast integrally with the columns. The roof beams are seated on top of the columns.

In the two central bays (three rows of columns) additional corbels were provided for overhead cranes running on steel beams between columns. The average main reinforcing steel in the columns was about 2½ percent; however, some columns, because of high moments and slenderness ratios, received 6 percent of reinforcing steel.

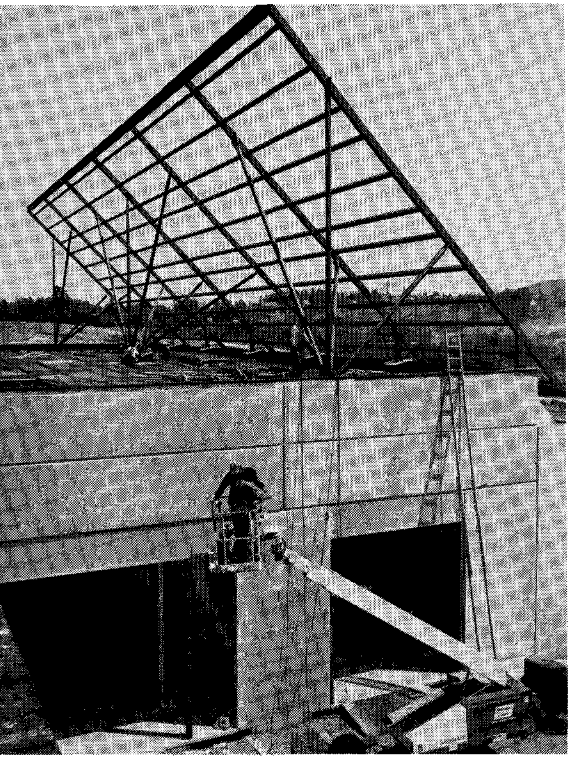

Fig. 10. Installation of solar collector frame on roof.

All column design is based on 5000-psi (34 MPa) strength concrete. Note that a welded connection to the footing was provided for erection only. Again, the cast-in-place slabs provided stability, transferring the lateral forces to the exterior walls.

The floor and roof beams are prestressed concrete inverted tees, L beams and rectangular beams. The basic spans are 25 and 30 ft (7.62 and 9.14 m). All beams are seated on "Alert T/F" bearing pads.

For headroom provision, the beams under the second floor level had to be shallow soffit beams. These beams were heavily prestressed, shored to 1 in. (25 mm) camber and acted composite with the concrete end-filled Dycore slabs.

In the final design, it was found that high tensile stresses existed at the joint of the precast to cast-in-place concrete area. For deflection and crack control, additional reinforcement was provided just above the precast beam. [Reference was made to T. Y. Lin's book on *De-*

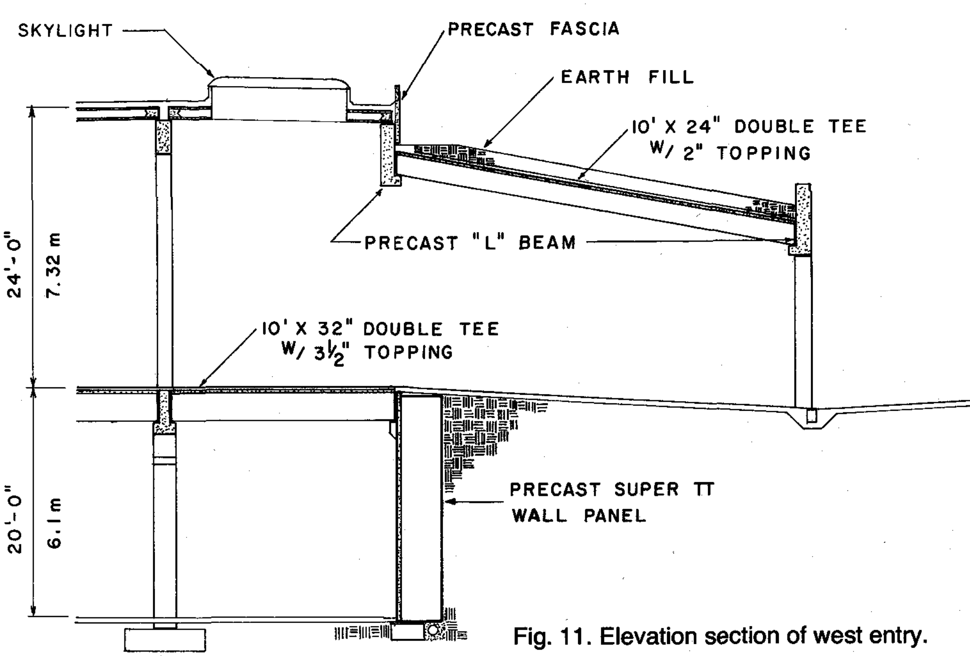

Fig. 11. Elevation section of west entry.

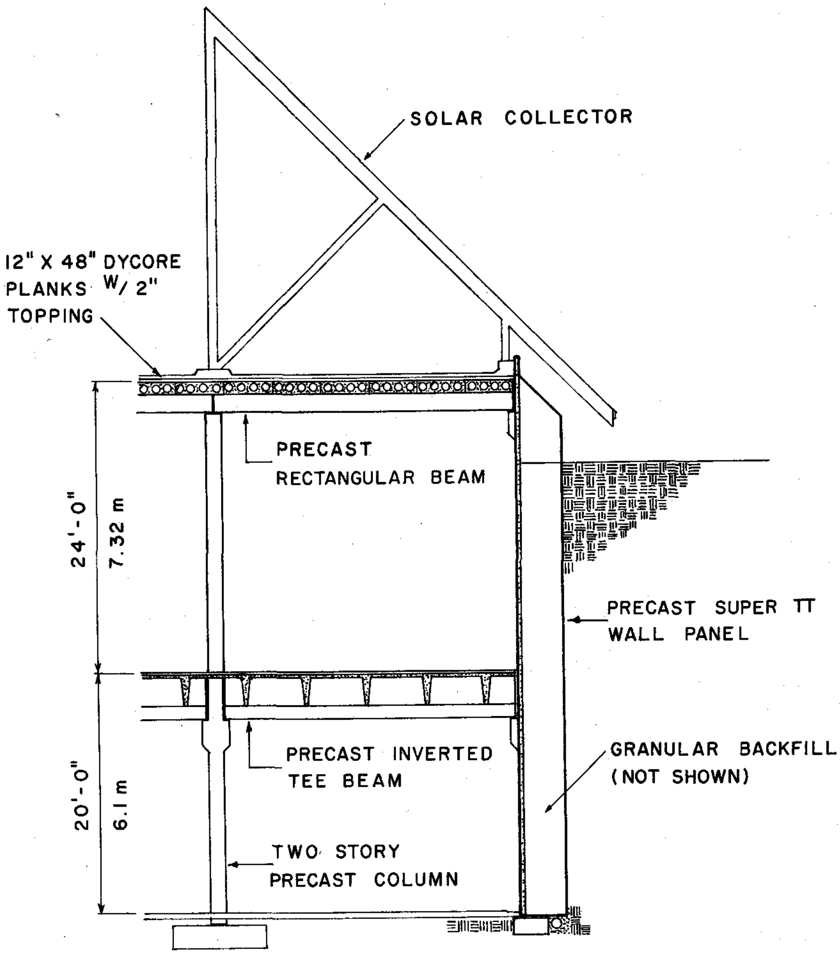

Fig. 12. Elevation section of partial building.

sign of Prestressed Concrete Structures (Second Edition), John Wiley, p. 154.] The basic concrete strength was 5000 psi (34 MPa), see Fig. 9.

Numerous miscellaneous precast, reinforced concrete flat wall panels, small beams, copings, and other devices were attached to the main structure by means of welded connection and/or by threaded rods into inserts and cast-in-place concrete.

Fig. 11 shows an elevation section of the west entry.

Fig. 12 (depicting an elevation section of the partial building) shows the inter-relationship of all the components to each other.

Erection

Morse Bros. Prestress Inc. was the successful bidder for the precast phase of the project, namely, to provide the structural shell of the facility including basic foundation, designed and produced components, and erecting device (subcontracted by Campbell Crane Co.), so that the structure could be

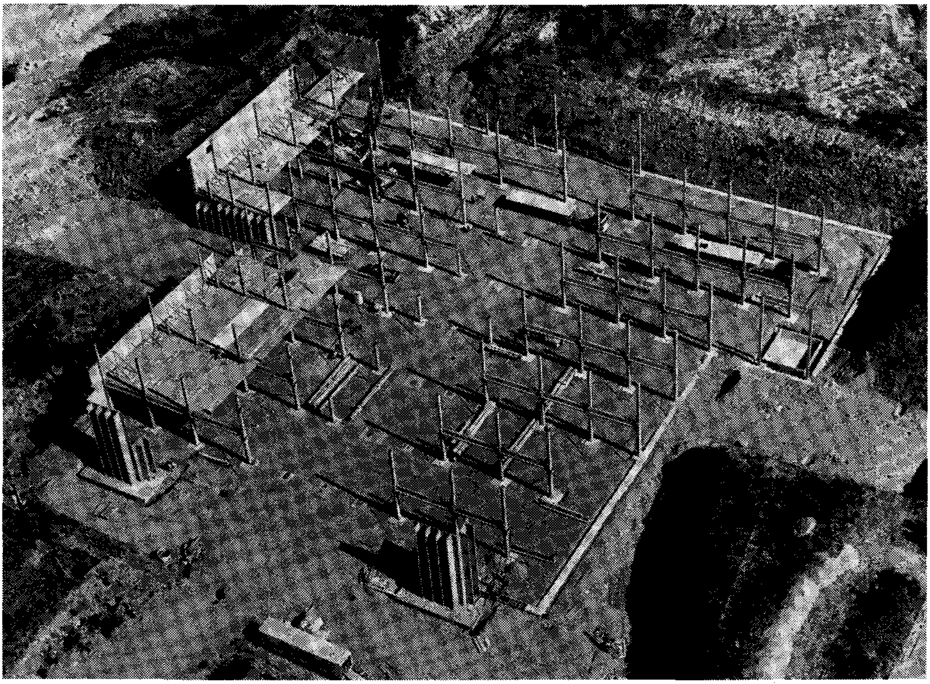

Fig. 13. Beginning of construction showing forest of columns with partially erected floor beams and floor slabs. Note stabilizing corner walls.

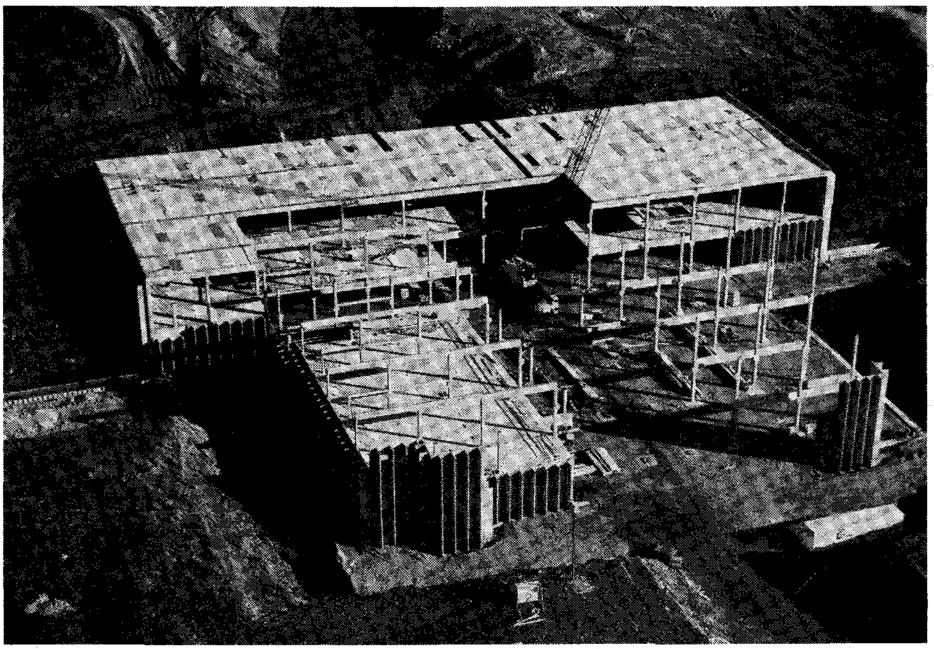

Fig. 14. Overall construction showing various precast prestressed components.

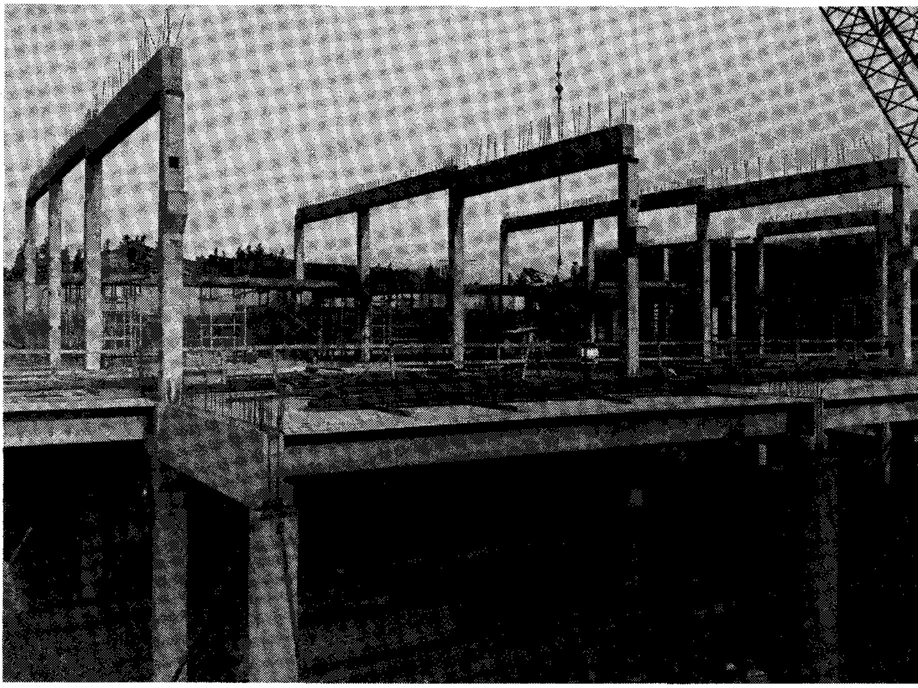

Fig. 15. Typical interior framing system.

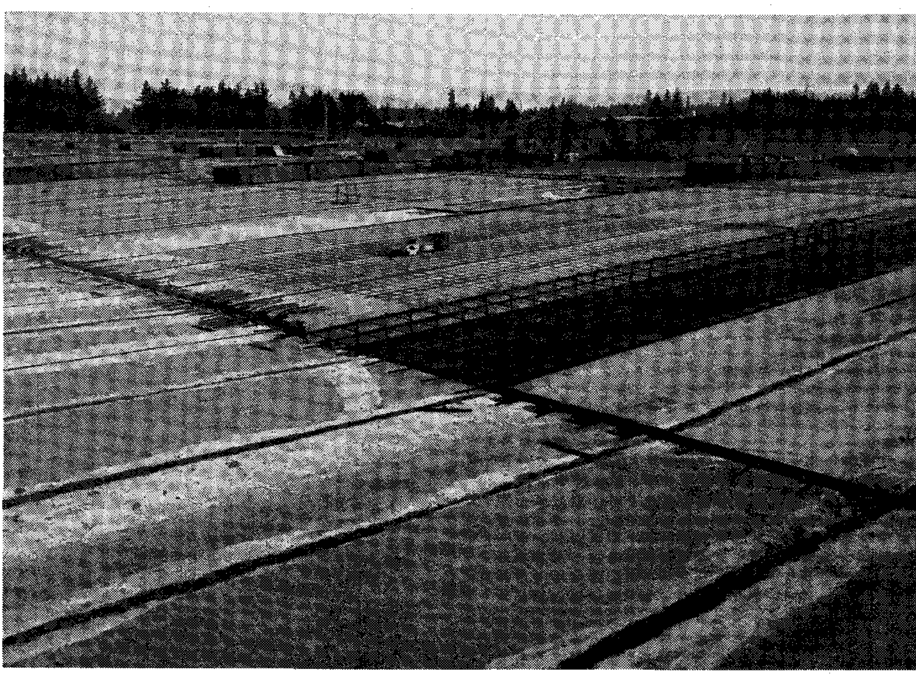

Fig. 16. Dycore roof slabs in place. Note composite beam connections.

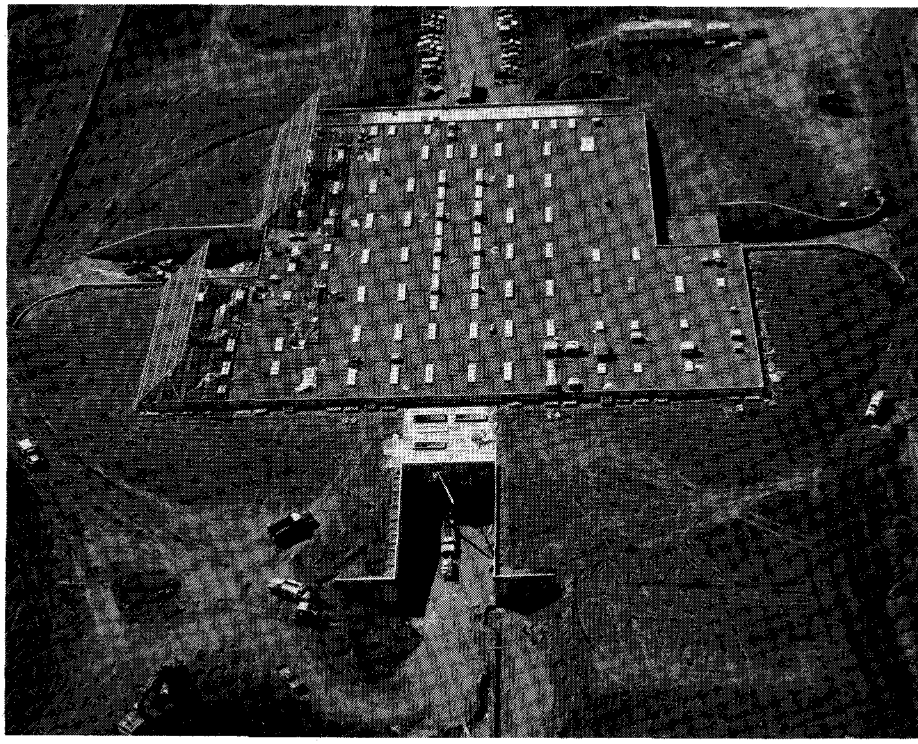

Fig. 17. Backfilled structure looking at east entry. Approximately 8000 sq ft (744 m²) of solar collector panels will be used on roof.

ready to receive cast-in-place concrete by the next phase contractor.

Since the stability of the final structure is dependent on the cast-in-place floors, toppings and backfill, substantial analysis and bracing systems had to be developed to provide a safe structure until final requirements were met.

In brief, the columns were erected and braced in both directions at the lower level only. The tops of floor beams were welded at the ends to the columns. The floor tees received two welded flange connectors. At each side of each column these floor slabs were then tied across at the top of the beams providing a complete tie in any given bay.

The exterior bays at the wall were welded to the wall tees. The system provided a simple welded floor diaphragm with braced columns. The upper columns were wire-braced to each other.

The exterior wall was braced to the floor slabs. Precast roof beams were welded to columns. The roof slabs had only gravity connections to walls and beams.

Of special interest, instead of heavy concrete deadmans, 6 ft (1.83 m) steel "H" pile sections were driven into the ground to provide uplift and compression resistance for column bracing.

A special lifting and turning frame was used for the vertical erection of 62,000 lb (28,123 kg) wall panels.

Figs. 13 through 18 show pictorially the various stages of erection of the structure.

The building is scheduled for completion this fall.

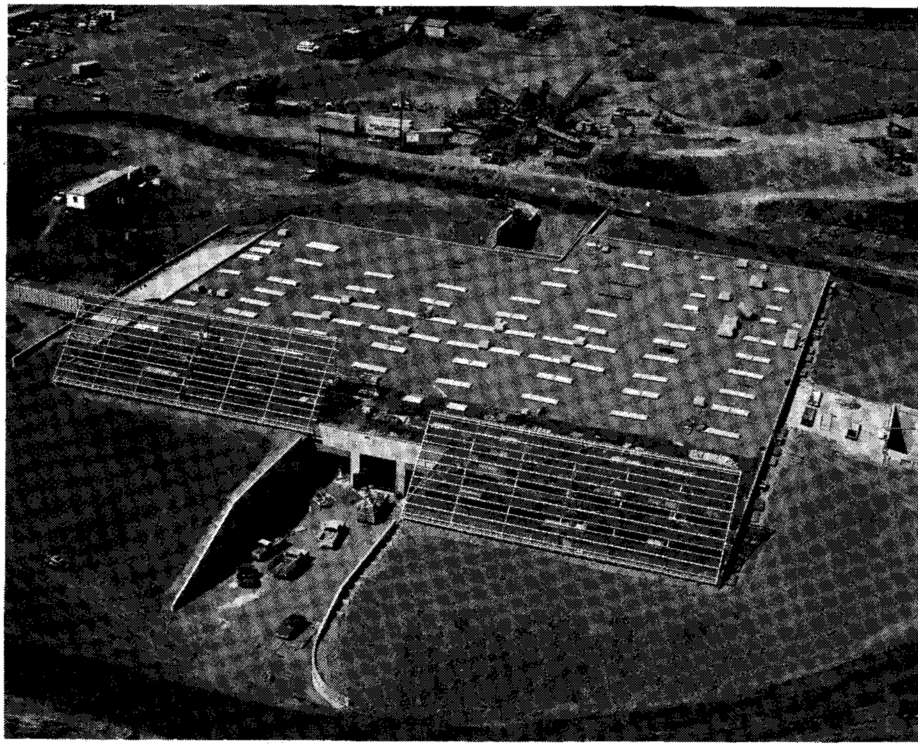

Fig. 18. Backfilled completed structure looking from south face. Contrast this picture with earlier photographs (Figs. 2 and 3) of mined terrain.

Concluding Remarks

The selection of basic, repeating precast prestressed concrete components produced a simple structure which would have been a conventional building had it been built above ground.

However, by placing the components underground, the architects solved a complex problem aesthetically, structurally, with energy efficiency and created an economical, large facility for heavy loads with unique building requirements. The resulting structure reflects these design features.

The total cost of the building, including all site work and equipment (solar system), was about $12½ million which is equal to $67.39 per sq ft of floor area.

The cost of the erected precast prestressed concrete was $2,636,154 which is 21 percent of the total cost of the completed building or $14.21 per sq ft of floor area.

* * *

Credits

Owner: Multnomah County, Oregon.

Architect: Zimmer Gunsul Frasca Partnership, Portland, Oregon.

Structural Engineer: kpff Consulting Engineers, Portland, Oregon.

Phase II Contractor and Component Producer: Morse Bros. Prestress, Inc., Clackamas, Oregon.