Precast Units Support Major Solar-Heated Building

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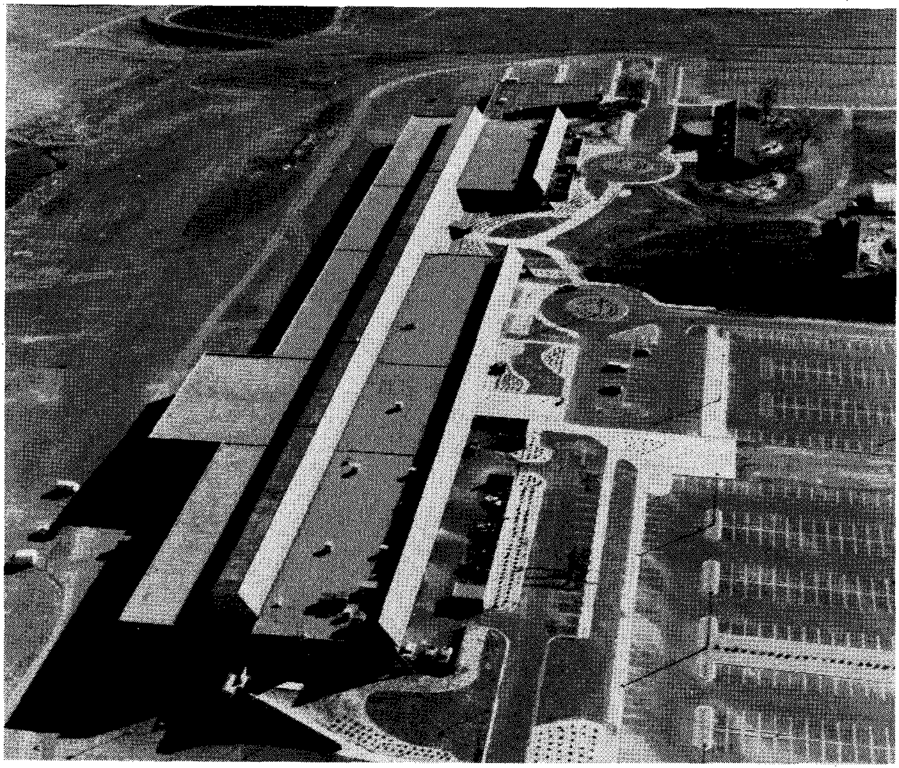
About 1000 precast components (mostly prestressed) were used to frame the North Campus of Denver's Community College—a structure which reportedly is the largest solar-heated building of its type in the world.

Precast double tees, wall panels, columns, and prestressed rectangular beams were used very effectively to frame the North Campus of Denver's Community College.

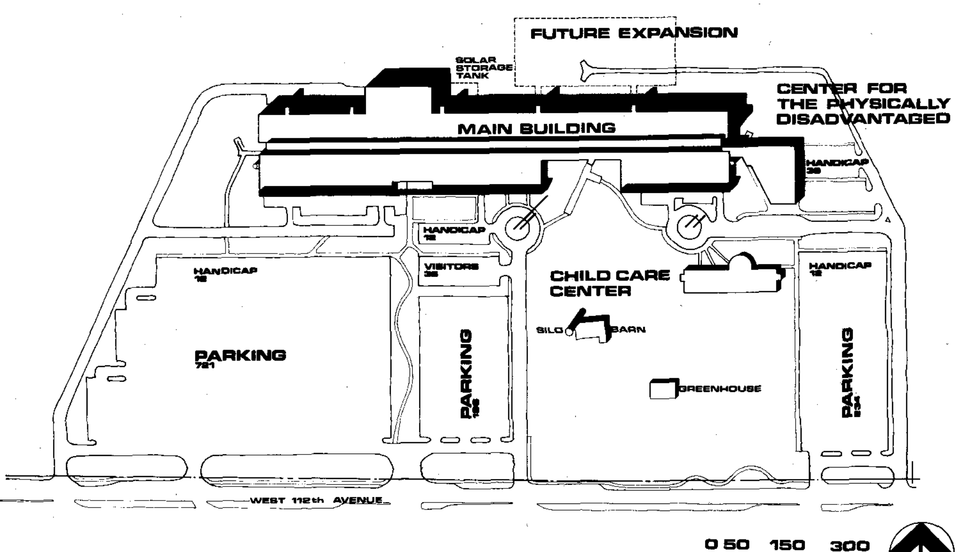
The community college is an occupational-vocational school combined with a 2-year general studies college program. The college is a complex mix of laboratories and classrooms, to serve a wide range of scholastic and technical disciplines.

This solar-heated campus consists of two buildings connected with a two-story covered walkway. The main building, measuring approximately 980 ft (299 m) long by 170 ft (51.9 m) wide, varies from a single-story structure on the south to a three-story structure on the north. The connecting building is basically a single-story structure housing special areas for the physically disadvantaged.

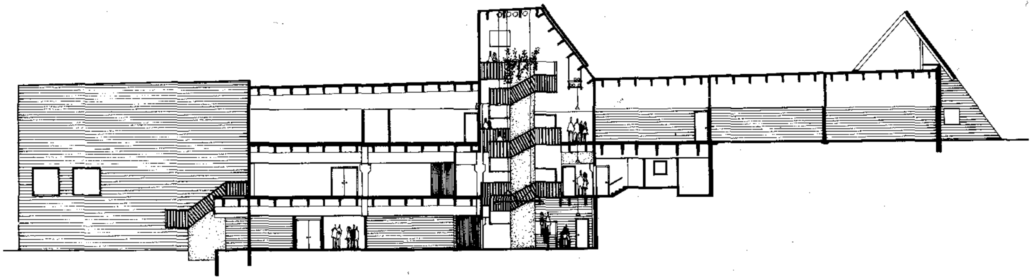
The two structures are connected by a walkway which continues full length of the main building, providing access to all departments. The structure for both



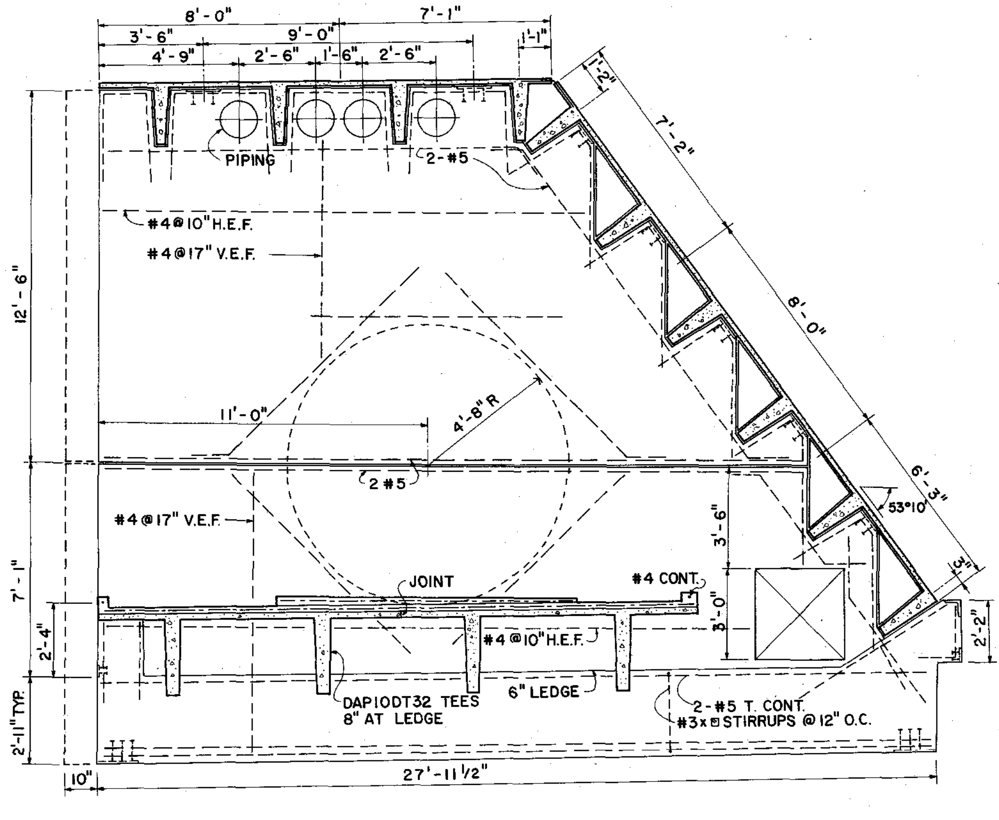
Aerial view of North Campus of Denver's Community College; 980-ft (300 m) central "spine" supports solar panels; second bank is at right.



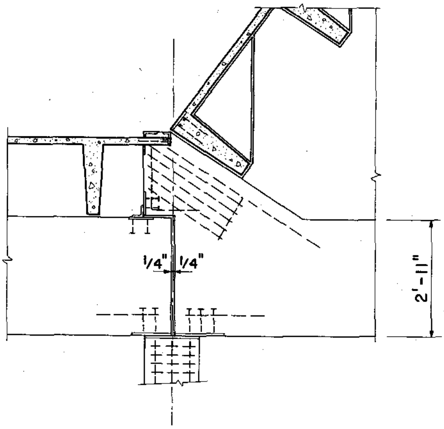
Site plan of Denver's Community College North Campus.



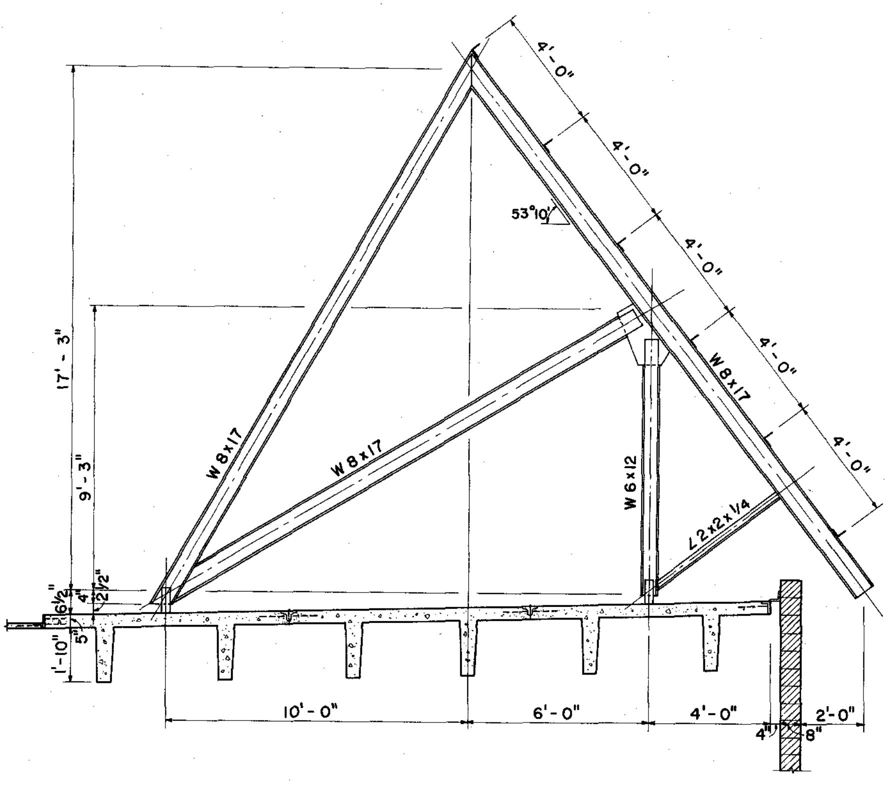
cross section



TYPICAL MONITOR WALL PANEL NEAR HORIZONTAL AND SLOPED DOUBLE TEES
NOTE THAT DOTTED CIRCLE SHOWS LOCATION OF 9-FT-4-IN. DIAMETER HOLE THROUGH 16-IN. WALL PANELS



HAUNCH REQUIRED FOR DIAPHRAGM
TRANSFER ANGLES ON SOUTH END
OF WALL PANELS



TYPICAL SOLAR COLLECTOR SUPPORT FRAME ON TOP OF
22+5 TEES ALONG SOUTH SIDE OF BUILDING
NOTE THAT THESE FRAMES ARE 9-FT ON CENTER

SUMMARY OF PRECAST COMPONENTS

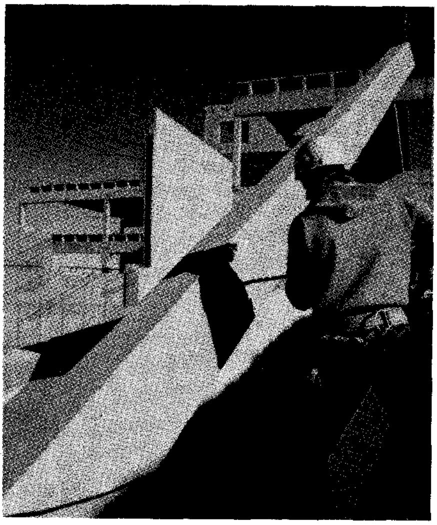
- **683 Precast Prestressed Double Tees:**
  Typical roof tees were 8 ft x 22 + 2 in. (2.4 m x 559 + 51 mm), spanning 56 ft (17.1 m). Exceptions: gymnasium and library had tees spanning 70 ft (21.3 m).
  Typical floor tees were 8 x 22 + 2 in. (2.4 m x 559 + 51 mm), spanning 56 ft (17.1 m); minimum 2-in. (51 mm) composite topping. Exception: library floor tees were 7 ft x 22 + 2 in. (2.1 m x 559 + 51 mm) spanning 70 ft (21.3 m).
  Mechanical floors had two 10-ft x 30 + 2-in. (3.1 m x 762 + 51 mm) tees, spanning 56 ft (17.1 m) between monitor wall panels; minimum 2-in. (51 mm) composite topping.
- **40 Precast Wall Panels:**
  Typical monitor wall panels were 10 in. (254 mm) thick with a 6-in. (152 mm) ledge to pick up the mechanical floor tees.
  Wall panels between the mechanical floors were 16 in. (406 mm) thick, with 9-ft 4-in. (2.8 m) diameter holes through their centers to lessen their weight, allow passage of light, and improve their appearance. (Openings in mechanical floor tees are for mechanical ducts only.)
- **172 Rectangular Precast Prestressed Beams:**
  All beams span 28 ft (8.5 m).
  Roof beams were 16 x 35 in. (406 x 889 mm).
  Floor beams were 16 x 36 in. (406 x 914 mm), 16 x 38 in. (406 x 965 mm), and 16 x 44 in. (406 x 1118 mm).
- **135 Precast Columns:**
  Mild steel reinforced columns varied in cross section from 12 x 12 in. (305 x 305 mm) to 16 x 22 in. (406 x 561 mm) and in length from 12½ to 38 ft (3.8 to 11.6 m).

buildings is a combination of cast-in-place concrete, precast concrete and concrete block.

Running the length of the 980-ft (299 m) building is a striking 28-ft (8.5 m) wide central spine. Its roof, of tilted double tees set into notched precast panels, is angled at 53 deg from the horizontal to support the north bank of solar collectors. The roof area houses eight fan rooms, as well as supplying clerestory light and dramatic vertical space to the student mall below.

The structure of this portion of the building, like the rest of the building, consists of 8-ft x 22 + 2-in. (2.4 m x 559 + 51 mm) deep precast double tees spanning the long direction of the building. These tees are supported at the ends on 10-in. (254 mm) thick precast wall panels which were cast with slots for each tee stem to provide bearing and lateral stability. The slots for the tees on the sloping surface were cast with the uphill side vertical instead of sloped to allow for ease in erection.

The triangular space thus created was later filled in with two 2-in. (51 mm) thick filler panels (one flush with each face). These panels also served as a support



Slender precast column being prepared for erection. The lengths of the columns varied from 12½ - 38 ft (3.8 - 11.6 m).

for the mechanical floor tees which were carried on a 6-in. (152 mm) ledge at the lower portion of the wall. These panels are spaced on 56-ft (17.1 m) centers.

Since the roof is discontinuous for the full 980 ft (299 m) across this center 28-ft (8.5 m) wide bay, the lateral earthquake and wind load was taken from one roof diaphragm to the other through these panels by anchoring back-to-back angles to the ends of each wall panel and welding them to embedded plates in the roof tees along a line parallel to the length of the wall panel.

This arrangement enabled the diaphragm to carry concentrated loads across the elevated portion of the roof to the other side where the loads were then taken into concrete block shear walls.

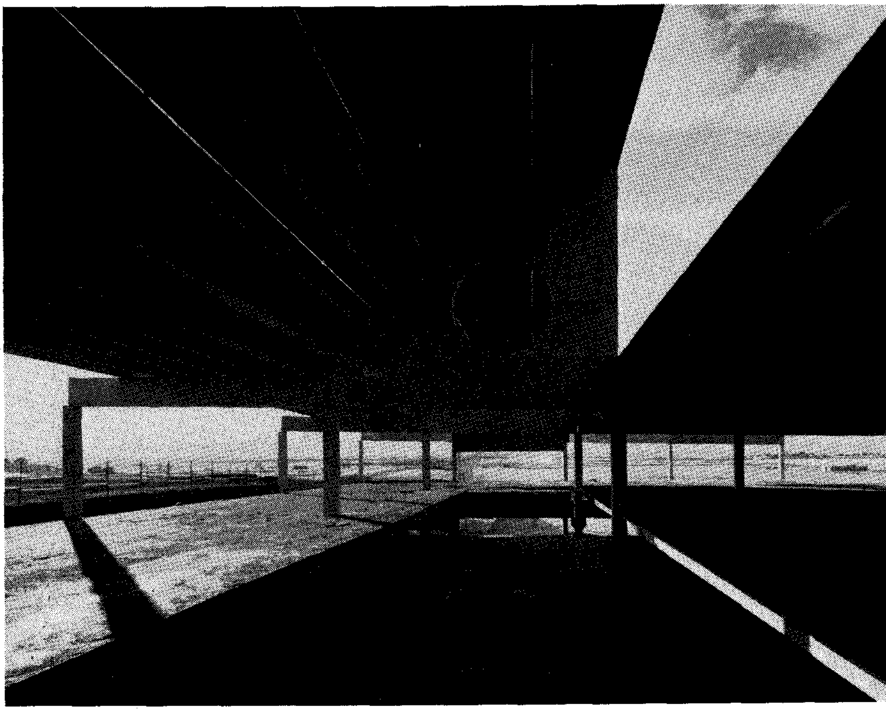
The sloping tees along the center portion of the roof were designed to carry wind loading in the stems and gravity loads including dead loads, snow loads and solar collector loads in the flange. Deflection of tees in both directions needed to be carefully controlled, since the back surface of the collectors clears them by only ¼ in. (6.4 mm).

The south bank of solar collectors was supported on a combination of structural steel frames every 9 ft (2.7 m) and a space truss spanning 84 ft (25.6 m). The frames were, in turn, supported on double tees which were cast with 8 ft x 22 + 5-in. (2.4 m x 559 + 127 mm) thick flanges, to add weight to counteract the uplift forces created by wind loading on the back surface of the collectors, and to add stiffness and depth to help handle the downward forces created by wind loading on the front surface of the collectors.

This support system, consisting of precast concrete tees and steel frames, also had to be studied carefully for combined deflection of both elements, because the glass-surfaced collectors could tolerate only small deflections.

The roof structure is separated into five sections with expansion joints at approximately 200-ft (61 m) centers to handle thermal movements. However, the steel collector support frames, which are connected to each other with continuous steel angles, have expansion joints every 56 ft (17.1 m) since they are exposed and thus experience a greater temperature change than the concrete

Precast double tee being moved prior to tilting on roof.



Interior shot of building showing inclined double tees, monitor wall panel with opening, rectangular beams and columns (all components are precast).

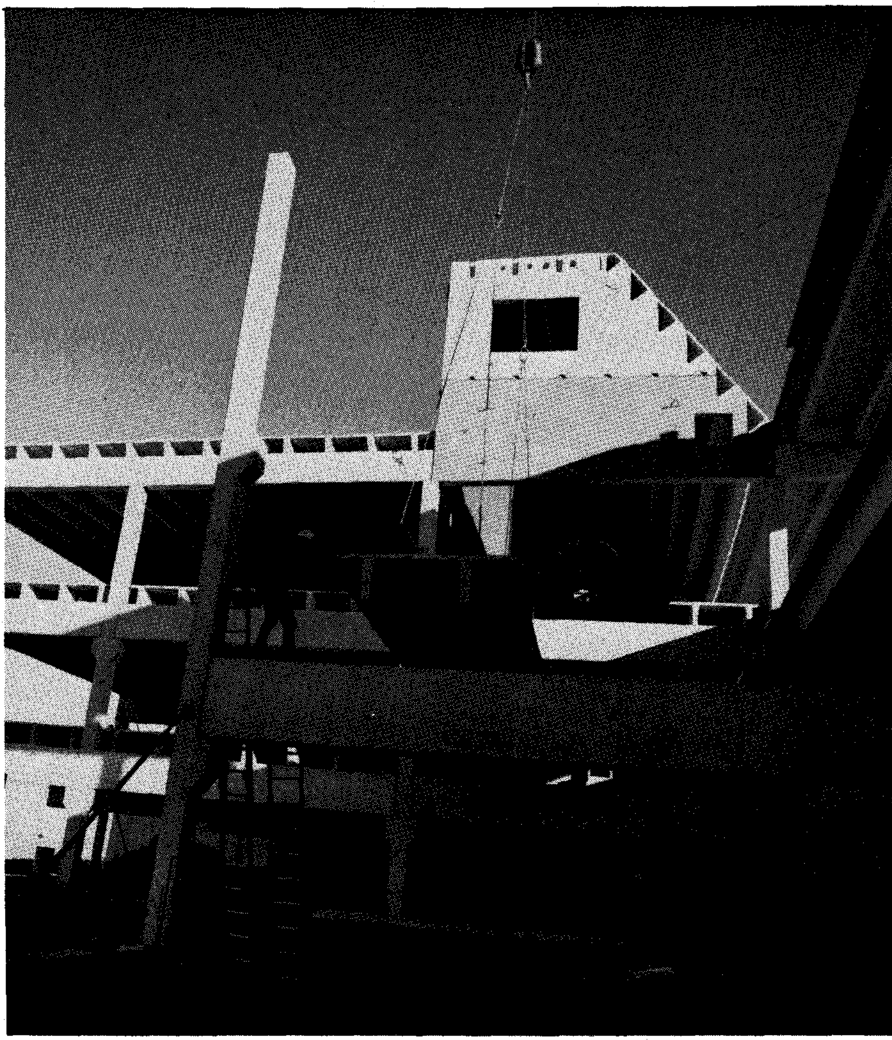
tees do. Almost the entire structure is exposed to view, which made designing and detailing of connections a very important part of the project.

In addition to the ability of the precast prestressed system to accommodate the complex solar-oriented requirements, this structural system was ideal for an "exposed-systems aesthetic:" the solar heating system components are exposed throughout and brightly painted as the major visual focus of the project. By exposing structural and mechanical systems, both initial and life cycle costs were minimized; and the exposed systems serve as an educational aid in the college's solar technology curriculum.

From the beginning, the project has been conceived as a model of energy conservation and a major demonstration of solar energy application. Today the building is reportedly the largest solar-heated structure of its type in the world, with 35,000 sq ft (3252 m^2) of solar collectors.

Compounding the problems inherent in designing for solar energy on such a large scale, and providing adequate justification for the necessary additional initial cost, were concurrent problems of poor soil conditions, a very tight budget, the extreme cost escalation of 1974 and concern for making the facility a model of accessibility for the severely handicapped.

The main structure, very compactly organized, is dug into the north slope of the ridge. As counterpoint for very compact design and tight budget, interior space is organized around a main east-west corridor system and allowed to expand vertically in a series of open wells rising to over 50 ft (15.2 m). The precast prestressed system was de-



Overall shot of structure during erection; double tee is being lowered into position.

signed on a 56-ft (17.1 m) column free bay to allow maximum flexibility in the long-term arrangement of interior spaces.

The community college operates an active solar assisted heat pump mechanical system. There are 35,000 gross sq ft (3252 m^2) of liquid-cooled double-glazed non-selective surface collectors, and a concrete thermal storage tank with a capacity of 200,000 gallons (757,000 liters) of water.

The building uses such passive design features as lower stories recessed into grade, minimally glazed exterior walls, heavy thermal mass materials, and placement of all major entrances and overhead doors facing south. Further, all exhaust air passes through heat recovery equipment prior to being expelled, and design rates of lighting and ventilation are reduced.

The college building was completed in September 1977. The 8.5 percent cost increase due to initial cost of the solar heating system has been offset by the 79 percent reduction in fuel consumption. Recent estimates, based on current fuel cost increases, indicate the system should be paying for itself by the mid-eighties.

The total construction time from the time of drilling the caissons to completion of the cast-in-place toppings and masonry walls took about 14 months. The precast concrete units were erected on schedule within a 4-month period.

The total cost of the entire building project (including parking facilities and landscaping, etc.) was about $12 million.

The building facility, which has now been in operation for over 2 years, is today functioning as predicted. Also, the performance of the precast concrete components during this period has been totally satisfactory.

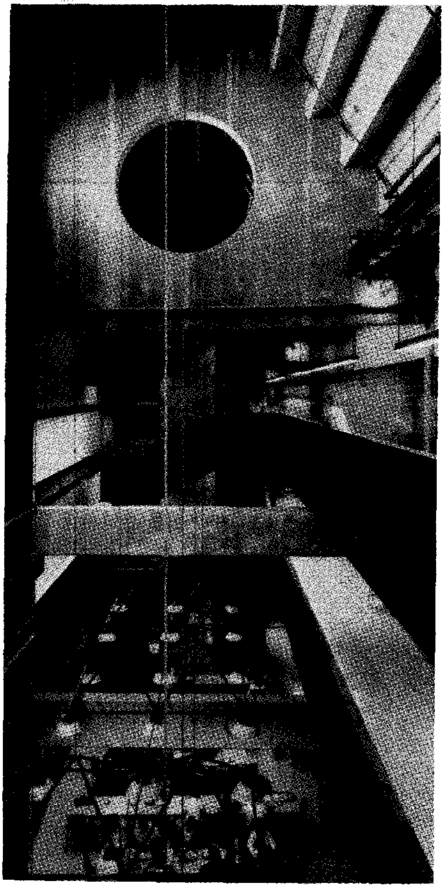
Credits

Architect: John D. Anderson and Associates, Denver, Colo.

Structural and Civil Engineer: KKBNA, Inc., Denver, Colo.

General Contractor: Pinkard Construction Company, Denver, Colo.

Precast Prestressed Concrete: Stanley Structures, Denver, Colo.



Large portholes in precast panels lighten them, both physically and visually. Students lunch at tables below.

Panoramic shot of North Campus solar-heated building silhouetted against mountains near Denver. Solar panels are visible.