ARTICLE 39-50
FEBRUARY 1957

AN EXPERIMENTAL TILT-UP CONCRETE BUILDING FOR THE CONTROLLED-ATMOSPHERE STORAGE OF APPLES

By I. J. PFLUG, M. W. BRANDT and D. H. DEWEY
DEPARTMENTS OF AGRICULTURAL ENGINEERING AND HORTICULTURE

SEVERAL NEW CONSTUCTION IDEAS offer possibilities of reducing the original and maintenance costs of CA (controlled-atmosphere) storage buildings. These ideas are being investigated in an 800-bushel storage constructed in 1956 at the Horticultural Farm on the Michigan State University campus.

The experimental building was constructed by the tilt-up method whereby the wall sections were fabricated of reinforced monolythic concrete in a horizontal position and then erected vertically to form the building. This method introduced several new ways to provide the gastight structure that ordinarily would have been obtained by lining the inside walls, ceiling, and floor of the storage room with sheet metal. A plan of the storage structure is shown in Fig. 1, with a cross section of the wall illustrated in Fig. 2.

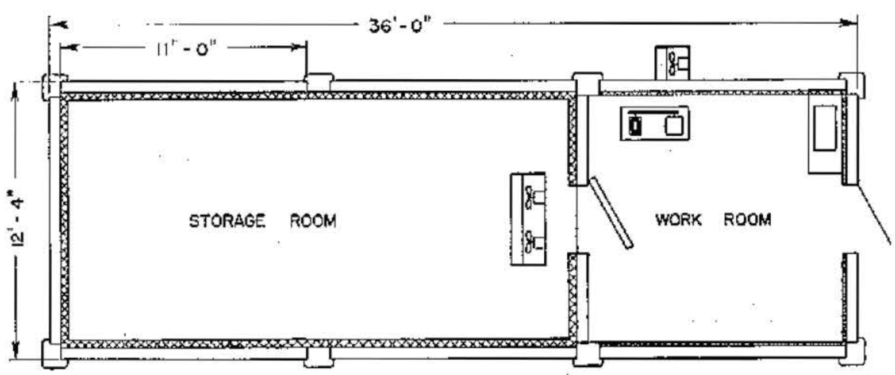


Fig. 1. Plan of experimental tilt-up storage building.

Reprinted from the QUARTERLY BULLETIN of the Michigan Agricultural Experiment Station, Michigan State University, East Lansing. Vol. 39, No. 3, pages 505 to 510. February 1957

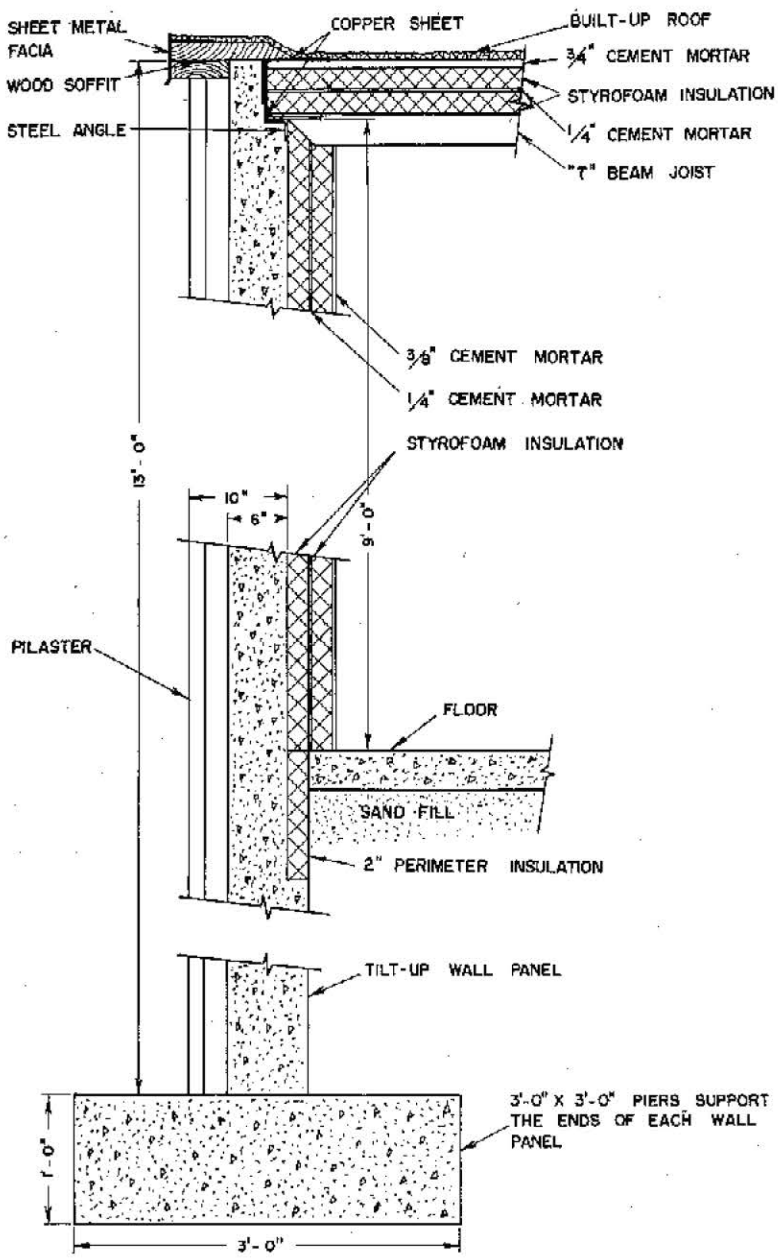


Fig. 2. Cross section of the wall, floor, roof, and foundation pier.

The low permeability of dense concrete was considered a sufficient gas barrier for the wall sections and supporting pilasters, provided they were joined tightly together. Airtight connections were made by incorporating a rubber water-stop strip at all wall section and pilaster junctures. The juncture of the roof to the walls was sealed with copper sheeting. A builtup pitch and gravel roof was used as the gastight seal for the ceiling of the storage.

No special effort was made to seal the floor, since the wall sections were extended into the earth 3 feet below floor level. It was theorized that, although gas would move through the fill below the floor due to pressure variations and through normal diffusion, the path to an outside air supply would be of such length that the oxygen moving into the room would be negligible.

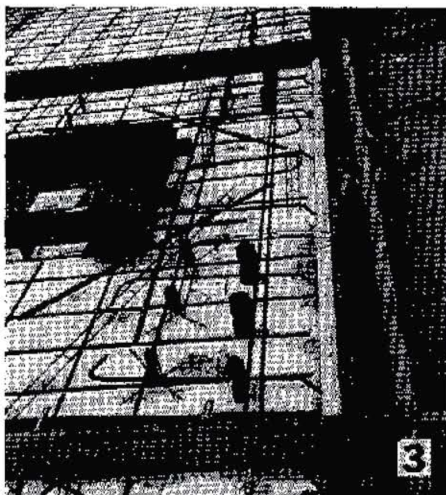
CONSTRUCTION

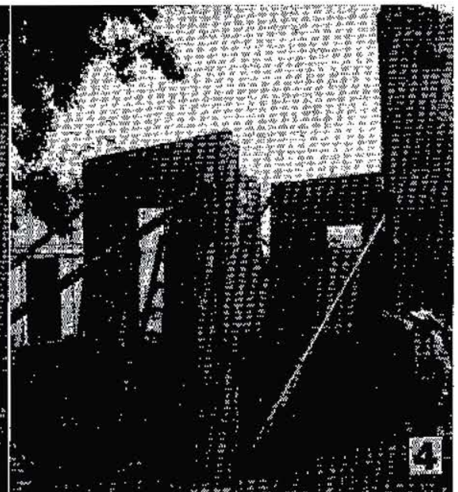
Normally, the floor area of a tilt-up concrete building is larger than the wall area and provides adequate space for pouring the reinforced concrete walls. In this small experimental structure, the wall area is almost three times the floor area; three separate pours would have been needed if the floor was used as the base for the wall slabs. The problem was solved by pouring the slabs on level ground at the side of the storage site. Since the walls were to be insulated, it was decided to incorporate the base layer of insulation with the walls as they were poured.

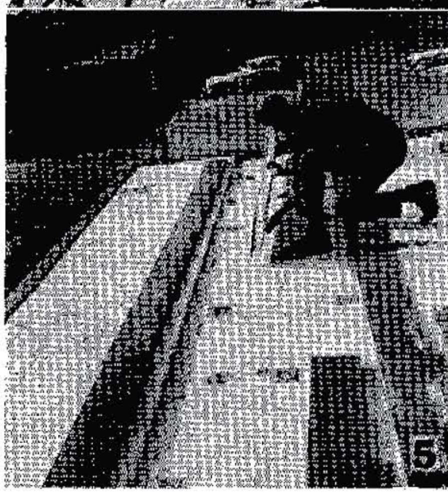
A ground area of 13 by 100 feet was leveled and packed; edge forms were set, and the area within each form was again packed and leveled. Heavy kraft paper was placed on the ground, and a 2-inch layer of board form expanded polystyrene insulation was laid on the paper, except at the door openings where 2-inch wood blocks were used to support the door frame (Fig. 3). The expanded polystyrene is moisture-resistant and adheres well to concrete; therefore, it made an excellent base on which to pour the concrete.

The reinforcing steel, pickup units, anchors, rubber water-stop, and dowl caps were placed within the forms on top of the insulation. The insulation received considerable abuse during placement and the tying of the steel and other components. However, these activities did not result in noticeable damage.

A six sack-concrete mix with 1-inch maximum stone and a 4-inch slump was poured from ready-mix trucks into the forms. A mechanical







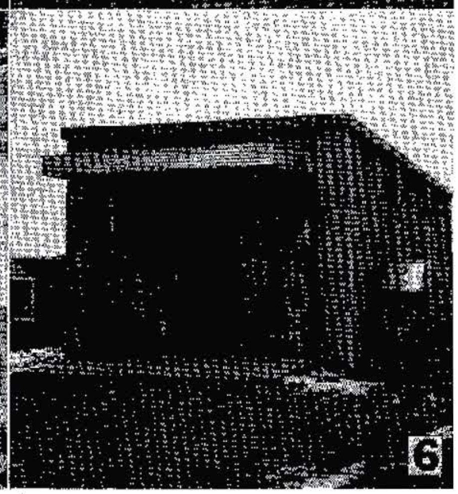


Fig. 3. Wall slab forms showing insulation, door frame, reinforcing steel, pickup anchors, rubber water-stop, and sections of pipe through which electricity and refrigeration will be carried into the storage room.

Fig. 4. Moving wall slabs into position. Two adjustable braces support slab until pilasters are poured.

Fig. 5. The second layer of insulation, coated with a quarter inch of cement mortar, being placed on top of the first layer to complete the ceiling.

Fig. 6. Completed experimental tilt-up concrete controlled-atmosphere storage building.

vibrator was used to work the concrete mix around the steel and agitate it to a dense state. After the slabs were poured, they were floated and steel troweled. The slabs were kept moist for a curing period of 3 weeks to develop maximum strength.

The wall slabs, each weighing about 7 tons, were lifted into place with a 20-ton mobile crane. Before the slabs were placed, eight piers (3 feet square by 1 foot thick) were poured to support the ends of the wall sections and serve as a base for the pilasters. Fig. 4 shows a wall slab as it is moved into place on the piers.

After the nine wall sections were set, the pilasters were poured in place to give lateral support to the walls and to tie the corners. Fabricated Tee bars 2 feet on center were installed to support the roof. Two layers of expanded polystyrene insulation boards, each 2 inches thick with one-fourth of an inch of cement mortar between the two layers, were laid on top of the Tees.

Fig. 5 shows the placement of the second 2-inch insulation layer. The insulation was covered with three-quarters of an inch of mortar and cured for 1 week under moist conditions. The roof was finished with the application of a "20-year" pitch and gravel roof into which the copper flashing seal to the walls was incorporated.

The inside of the storage was finished by insulating the exposed portions of the pilasters with 4 inches of insulation and by adding a second 2-inch layer of insulation to the wall panels. A concrete floor, 4 inches thick and reinforced with 6 by 6 No. 10 wire mesh, was poured on compacted fill. No provisions were made for sealing the floor or for sealing the juncture of the floor to the walls.

The storage was completed by pouring a concrete apron, hanging the doors, and installing refrigeration and other utilities. An outside view of the completed structure is illustrated in Fig. 6.

RESULTS

The experimental tilt-up storage is in an initial stage of testing; therefore, the results must be considered as preliminary. The 823 bushels of apples, refrigerated to 32° F., developed the desired CA atmosphere of 3 percent oxygen in 29 days.

The room has served as a satisfactory CA storage. However, it has been noted that gusty winds of high velocity affect the atmosphere in the storage, causing a rise in the oxygen level of 0.2 to 0.3 percent in a 24-hour period. This wind effect has not been reported for commercial metal-lined rooms.

Possibly, the relatively large area of wall surface in proportion to the room volume in this experimental room may permit wind effects to be observed that would be present but unnoticed in larger rooms. Furthermore, some air may move through the unsealed floor and earth fill whenever high winds create a positive pressure on the windward side and a vacuum on the leeward side of the building.

SUMMARY

An experimental 800-bushel capacity CA storage has been constructed of precast wall slabs with a sandwich-type ceiling supporting a builtup roof. The juncture of the wall slabs was sealed with a rubber water-stop strip. The juncture of the builtup roof and the wall slabs were joined with copper sheeting. These features, together with the earth fill below the floor, make the building sufficiently airtight for the controlled atmosphere storage of apples at 32° F.

Although the operation of this experimental storage has been satisfactory, this type of construction cannot be recommended until it is tested further.

ACKNOWLEDGMENTS

The authors wish to thank the following companies and individuals for their cooperation and assistance in designing and constructing this experimental building:

The Dow Chemical Company, Krieghoff-Lenawee Company, Portland Cement Association, and Udell Refrigeration Company.

J. S. Catey, W. G. Chace, Jr., J. B. Cawood, R. J. Ellsworth, C. E. Hikes, D. R. Huebner, Adam Hulinek, Glenn Shiffer, V. I. Vandenburg, and H. J. Waite.