

COST OF MICHIGAN FRUIT STORAGE BUILDINGS AS AFFECTED BY SIZE AND TYPE OF CONSTRUCTION

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THE FRUIT GROWER, or storage operator, planning a new refrigerated storage is interested in the relative costs and attributes of different types of construction. This report is the result of a study (Pflug, 1958) designed to provide some of the answers to this question, and also the question of clear-span vs posts and the economics of storage size. The relative cost of different types of foundation, wall and ceiling or roof construction for several common sizes of storage rooms will be presented and discussed.

Computation of Costs

These engineering cost estimates were made by determining the cost of each unit of the storage building. The final building cost is the sum of the unit cost values. The unit cost consists of material costs plus the product of the labor rate and the hours of labor per unit. The labor rate and materials cost used in this study were the actual prices and rates in effect in the Kent County (Michigan) area during the third and fourth quarter of 1957. The hours of labor per unit were obtained from Means (1957, '58).

The estimates in this report do not include provision for overhead or profit. To estimate the cost of a contracted storage these labor and materials costs must be increased by 26.5 percent to cover overhead and profit.

Table 1 lists the cost figures used for the more common material and labor.

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TABLE 1—Costs used in estimating refrigerated fruit storage building

	Unit	Amount
Labor		
Carpenter.....	per hour	\$3.25
Carpenter helper.....	per hour	2.00
Common labor.....	per hour	2.00
Mason.....	per hour	3.40
Mason helper.....	per hour	2.00
Materials		
Block, light weight 4 x 8 x 16".....	100	\$23.00
Block, light weight 8 x 8 x 16".....	100	27.00
Block, light weight 12 x 8 x 16".....	100	33.00
Concrete, transit mix.....	cu. yd.	15.00
Excavating and back-filling.....	cu. yd.	1.00
Insulation, board form.....	100 bd. ft.	12.00
Insulation, fill type.....	100 cu. ft.	14.00
Lumber, structural grade.....	1000 bd. ft.	160.00
Roof, flat 20 year pitch and gravel.....	100 sq. ft.	22.00
Steel, concrete reinforcing.....	per ton, in place	250.00
Steel, WF beams.....	per ton, erected	400.00
Tile, vitrified, salt glazed 4 x 5 x 12".....	100	19.00

Foundation and Floor Cost

Table 2 lists estimated costs (in dollars per 100 lineal feet of foundation) for excavating and back filling, footings, and foundation wall. The estimated cost for both poured (monolithic) and concrete blocks filled with concrete has been included. Monolithic concrete is approximately two times the cost of a concrete block wall filled with concrete, even when form lumber can be re-used. The difference in cost is in the large amount of labor necessary to make, erect and remove the forms for the poured concrete foundation wall.

Table 3 lists the cost per 100 sq. ft. for constructing nominal 4- and 6-inch concrete floors. In standard practice, when a 4-inch floor is specified, a 2 x 4 (1½ x 3½) is set edgewise and used to level the concrete fill, and a 2 x 6 (1½ x 5½) is used for a nominal 6-inch floor.

No floor insulation cost has been included since it is standard practice in Michigan to omit floor insulation and use only perimeter insulation. The cost of perimeter insulation 2 inches thick and 24 inches high is 40¢ per foot of foundation wall. All storage buildings should have a smooth, level floor for mechanical or hand fork-truck operation.

TABLE 2—Estimated cost of footing and foundation wall for fruit storage building

Construction operation	Cost (\$ per 100 lineal feet)
Excavating and back filling.....	\$44.50
Footing 12" x 24", 2½ inch reinforcing rods.....	292.50
Foundation wall (12 inch wide, 48 inch high, for shorter walls reduce estimate by percent reductions in height.)	
Monolithic concrete.....	904.00
Monolithic concrete form lumber reused.....	728.00
Concrete block wall, 12 inch blocks filled with concrete.....	392.50
Foundation wall (16 inch wide, 48 inch high, for shorter walls reduce estimate by percent reduction in height.)	
Monolithic concrete.....	997.00
Monolithic concrete form lumber reused.....	821.00
Concrete block wall, 8 inch blocks filled with concrete.....	542.50

Cost of Comparative Types of Wall Construction

In estimating the cost of the walls, it was assumed that the wall would be 20 feet high and would start at the top of the foundation (floor level). Costs were calculated on the basis of 100 sq. ft. of wall surface. Where single wall, concrete block construction was used, allowance was made for pilasters, wall reinforcement ties and sealing or painting. In the tile and block cavity wall, wall ties were included in the cost estimate. The cost of the recommended (ACR Data

TABLE 3—Cost of concrete floor in fruit storage building

Type of Construction	Cost (\$/100 sq. ft.)
4 inch concrete floor with 6 x 6 mesh.	27.50
6 inch concrete floor with 6 x 6 mesh.	40.00

Book 1957) insulation for a 32°F. refrigerator of 4 inches of board form insulation, or its equivalent, was included as part of the wall estimate. If a board form insulation was used with single wall construction, provision was made for a surface wearing coat of either plaster or suitable mastic.

The cost of the three common types of walls are presented in Table 4. Cross sections of the 3 walls showing construction are illustrated in Fig. 1. Three values — \$126 per 100 sq. ft. for a lightweight block wall with 4 inches of board form insulation compared to \$154 for a double tile cavity wall with fill insulation and \$119 for a double block wall with fill insulation—do not tell the whole story. The cost of maintaining the building after construction has not been considered and this will be considerably higher for a concrete block type of building than for a glazed tile building.

The cost of tile was estimated at \$190 per thousand (Table 1); this represents a good grade of tile. By reducing the quality of the tile used in the wall, the cost can be reduced; however, one of the advantages of tile construction is its permanence, and this is lost to a certain degree when lower quality materials are used.

The total wall cost, or the wall cost per sq. ft. of storage, decreases as the size of the storage increases and as the geometry of the storage approaches a square. The length of wall is 2 (L+W), the area is L×W. This relationship can be illustrated by 3 examples: A

TABLE 4—Wall cost per 100 square feet for fruit storage building

Type of construction*	Cost (\$ per 100 sq. ft.)
Lightweight type 8 inch concrete block wall with necessary pilasters plus 4 inches of board form insulation protected by an inside plaster or mastic surface plus sealing outside.....	126.00
Double tile cavity wall with 6 inches of fill-type insulation. (5 inch wide tile).....	154.00
Double block cavity wall with 6 inches of fill-type insulation. (4 inch wide blocks).....	119.00

*For normal 20 ft. high walls.

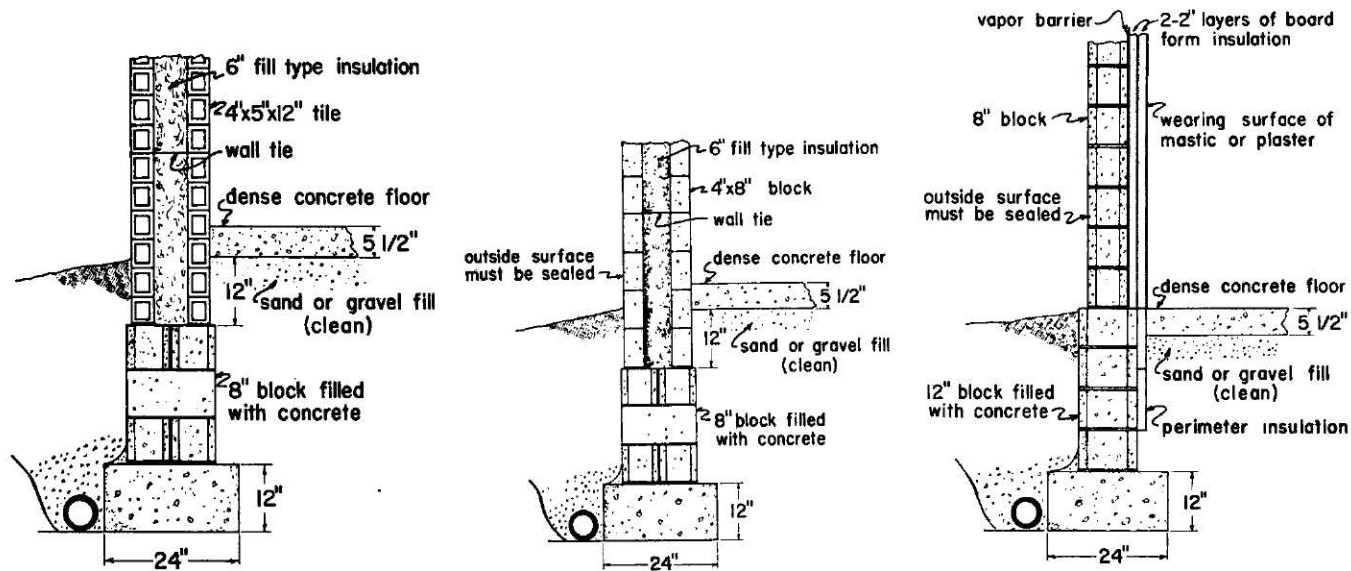


Fig. 1(A). Double tile wall with fill or granular insulation. (B) Double block wall with fill or granular insulation.

20×20 storage has an area of 400 sq. ft., wall length of 80 ft.; a 40 × 40 storage has an area of 1600 sq. ft., a wall length of 160 ft.; a 20 × 80 storage has an area of 1600 sq. ft., but a wall length of 200 ft. Comparing the first two examples, 4 times the storage area has been obtained with only 2 times the length of wall. Comparing the second and third examples, 25 percent more wall is needed for the long, narrow room than for a square storage of equal area.

Roof Construction

The number of combinations of materials and roof designs is almost unlimited. In this project 61 combinations were evaluated for the five storage sizes studied. These were analyzed on a basis of cost per square foot for four general classes of construction: (1) Steel primary members, steel bar joists, metal deck, board form insulation, and built up roof; (2) Steel primary members, steel bar joists, board form insulation roof deck, and built up roof; (3) Steel primary members, wood joists, fill insulation, wood sheathing, and built up roof; and (4) Wood truss, wood joists, fill insulation, wood sheathing, and built up roof. The average cost for the different types of construction will be presented and discussed.

In calculating the cost of the storage structure, the assumption was made that there would be no beam or truss immediately over an outside wall if a flat roof is used; however, for a gable or arch roof it was assumed that a truss would be required over the wall. Therefore, a 40 × 60-foot structure, using a 40-foot flat steel truss on 20-foot centers would require only two trusses, whereas four wood bow-string trusses would be required. This assumption was justified on the basis that when an arch or gable roof is used, it is necessary to provide support for the roof above the side wall height and that this would cost approximately as much as a truss, if a truss were not used.

In this discussion, the term "primary support member" will be used to denote a wall, beam, or truss on which the joists rest. A tile wall supporting bar-joists (a lightweight fabricated steel supporting unit) and metal decking is illustrated in Fig. 2 and a wide flange beam supporting bar-joists and a board form insulation roof deck is shown in Fig. 3. In Table 5 are listed characteristics of primary supporting members; wide flange (W.F.) steel beams, flat steel trusses, and wood bow-string (arch trusses). The joists are the secondary

members which directly support the roof. Steel bar-joists are available in varying lengths and can be used economically up to spans of 40 feet.

Wood-joists are usually limited to a span of 24 feet. Wood-joists are in general more economical in initial cost than steel-joists, and simplify construction since they are usually spaced 16 or 24 inches O.C. where $\frac{3}{4}$ -inch wood sheathing can be used as the roof base. Wood joists have the disadvantage of decaying and supporting combustion.

In planning a refrigerated fruit storage, the problem of posts or clear working area, usually arises. An analysis was made of the cost of the primary roof supporting members of 40, 60 and 80-foot wide storage buildings. (Supporting members 20-foot O.C.) The results indicated that (1) it did not cost any more to span the 40-foot storage with a single truss than to use two 20-foot beams with a post; (2) that the cost of two 30-foot steel trusses plus a post was practically the same as the cost of a 60-foot truss; (3) that the difference in cost of

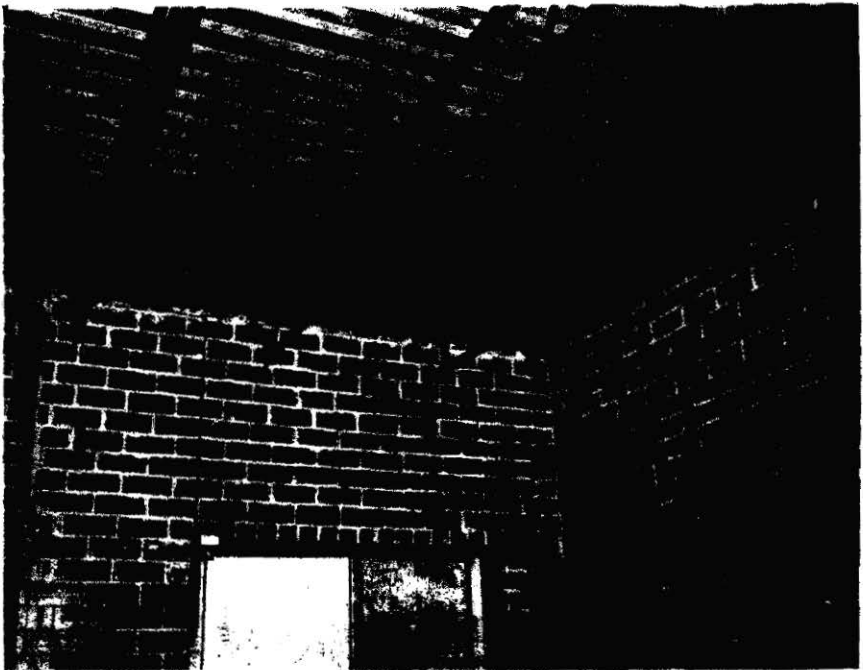


Fig. 2. Tile wall supporting bar-joist and metal roof deck.

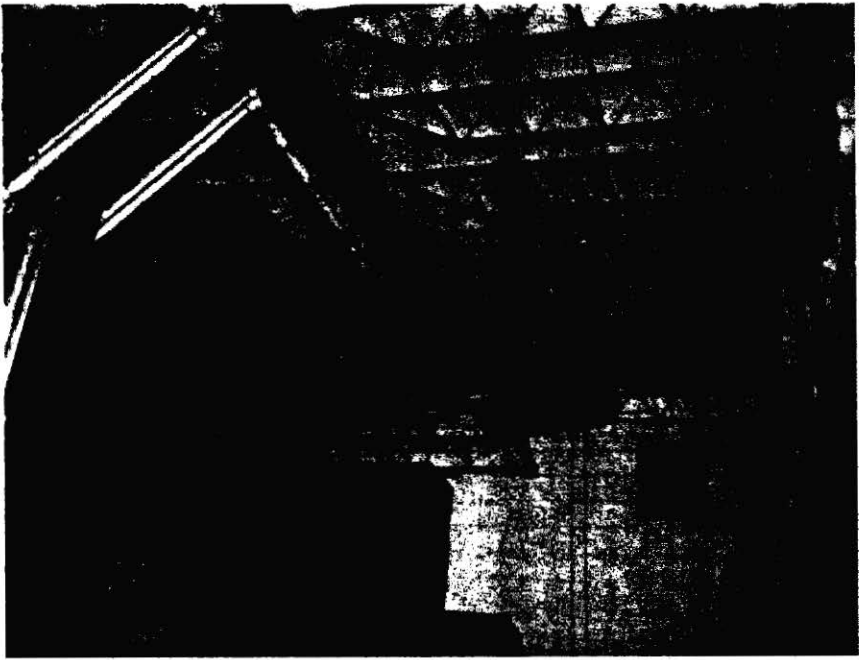


Fig. 3. Wide-flange beam supporting bar-joist and a board form insulation roof deck.

one 80-foot truss over two 40-foot trusses plus a post amounted to 11¢ per sq. foot of roof area. The dollar value or effect of having the longer trusses extend farther below the ceiling has not been evaluated and this is a point that must be given some consideration. The depth of truss is given in Table 5 and it can be observed that the longer trusses have correspondingly greater depth of section.

The roof of a storage building must be insulated with a minimum of 4 inches of board form insulation or its equivalent. If wood ceiling joists are used, the most economical method of insulating the ceiling of the building is to close the bottom of the joist with corrugated aluminum sheets or moisture resistant asbestos board nailed to the bottom of the joists. Fill or bat type insulation is placed in the space between the joints. The roof is applied over wood-sheathing nailed on top of the joists. If steel bar-joists are used to support the roof, then normally a board form of insulation is used unless a dropped ceiling is installed. The cost of board form insulation will often exceed, by as much as 30¢ per sq. ft., the cost of fill or bat-type in-

sulation. A roof using steel bar-joists, plus 4 inches of board form insulation will usually cost 50 to 70¢ more per sq. ft. than where wood joists and fill or bat-type insulation between the joists is used.

The cost of the roof, ceiling and supporting members was evaluated on the basis of type of construction and size of the storage. The five sizes evaluated were: 40 × 60, 40 × 80, 60 × 80, 60 × 120 and 80 × 120 feet. It was found that the type of construction was the factor that most influenced the cost. The results are summarized in Table 6 where the average costs (per sq. ft.) are listed for the four general types of roof construction. In general, the range of costs for a given type of construction varied plus or minus 5 percent from the average and this variation was greater than the effect of storage size. It was found that where there were several ways of arranging beams and trusses for the same size roof, there was a definite variation in cost. From an economical standpoint, it appears that the time spent in planning the roof construction is very fruitful. Important conclusions drawn regarding roof construction are: (1) There was no noticeable trend of cost per unit area in relation to size. In general, the average and the range were approximately the same regardless of the size of roof area; (2) the wide spread, plus or minus 5 percent

TABLE 5—Cost of primary support based on 20 ft. spacing and 50 lb. per sq. ft. total live load plus dead load in fruit storage construction

Type of member	Size		Span (feet)	Cost (dollars)	Cost (Dollars per sq. ft. of floor area)
	Depth of member, inch	Weight per foot of length			
WF steel beam	12"	27 lb.	20	108	0.27
	16"	45 lb.	30	270	0.45
	18"	64 lb.	40	512	0.64
	24"	84 lb.	50	840	0.84
	30"	108 lb.	60	1296	1.08
	33"	130 lb.	70	1820	1.30
	36"	150 lb.	80	2400	1.50
Steel truss, flat	36"	40 lb.	30	246	0.41
	48"	40 lb.	40	325	0.41
	72"	52 lb.	60	610	0.51
	96"	70 lb.	80	940	0.59
Wood Bowstring truss			40	250	0.31
			60	450	0.38
			80	750	0.47

TABLE 6—Roof cost as a function of type of construction in fruit storage

Construction	Average cost (dollars per square foot)
Steel primary members, steel bar-joists, metal deck, board form insulation, built-up roof.....	2.28
Steel primary members, steel bar-joists, board-form insulation roof deck, built-up roof.....	1.89
Steel primary members, wood-joist, bat, blanket or granular insulation between joists, wood sheathing, built-up roof.....	1.59
Wood Truss, bat, blanket or granular joists, insulation between joists, wood sheathing, built-up roof.....	1.42

of the average between the most expensive and most economical for a given type of construction, indicates that the roof design should be carefully planned; (3) the cost of wood joists and fill type insulation was considerably less than the cost of steel bar-joists and board form insulation, and (4) wood trusses with wood ceiling joists was the most economical type of construction.

There is a definite relationship between cost and quality in storage buildings. In Table 6, the most substantial construction, that of steel primary supports, metal bar-joists, steel roof deck and board form insulation, is the most expensive. In some cases, this construction might command a substantial reduction in insurance rates. Wood trusses are the most economical and probably will require the most maintenance.

Many storage designers believe it is not economically sound to insulate and seal around supporting members. Instead, they advocate the use of a separate ceiling below the supporting members when wood beams or trusses are used. High humidity levels that favor rot and decay are always present in a refrigerated fruit storage and it is difficult to construct and maintain a perfect vapor barrier on the warm side of the insulation. If the vapor barrier leaks, it will allow moisture to accumulate and condense in the insulation, and on the

structural timbers which will lead to rotting and roof failure. Therefore, there is justification in being reluctant to insulate around and seal in the supporting members.

A design providing ventilation of the space around wood supporting roof members will change the relative cost of the different types of roofs. Fill type insulation in a drop ceiling is more comparable cost-wise to the metal roof deck type of construction or the board form insulation roof deck type of construction than when the insulation is placed between the joists that support the roof.

Estimating the Cost of a Storage Building

The data that have been presented in Tables 2, 3, 4 and 6 can be used to estimate the cost of a storage building. The electrical and refrigeration contracts are normally separate from the building contract and they will be treated below. A cost estimate for a 40×60-foot storage building is illustrated in Table 7. The length of foundation and footing and area of floor, wall and roof can be obtained from the storage plan or sketch. The estimated cost is the sum of the unit costs as illustrated in Table 7. Any additional features of the storage must be included to have a realistic estimate. In Table 7, a single refrigerator door at \$350.00 is included.

The building costs in Table 7 are calculated on the net cost basis, as mentioned above; however, if a contractor is to handle the entire

TABLE 7—Building cost estimate sheet for 40 x 60 concrete block refrigerated apple storage—12 inch filled concrete foundation wall on concrete footings, 20 ft. concrete block wall with board form insulation, steel truss roof with wood joist and fill insulation, 1—5x9 refrigeration door. (Electrical system and refrigeration system not included)

Unit of building	Unit cost	No. of units	Cost
Excavating and backfilling.....	\$ 44.50/100 lin. ft....	2	\$ 89.00
Footing.....	\$292.50/100 lin. ft....	2	\$ 585.00
Foundation (12 inch block wall filled with concrete).....	\$392.50/100 lin. ft....	2	\$ 785.00
Floor (4 inch).....	\$ 27.50/100 sq. ft....	24	\$ 660.00
Walls.....	\$126.00/100 sq. ft....	40	\$ 5,040.00
Roof.....	\$ 1.59/sq. ft.....	2,400	\$ 3,816.00
Door.....	\$350.00 each.....	1	\$ 350.00
Total net cost.....			\$11,325.00
Overhead plus profit (26¼% of net cost).....			3,000.00
Contractor cost estimate.....			\$14,319.00

storage building construction, then an allowance must be made for overhead and profit which will increase the cost by about 26½ percent, which is also calculated in Table 7. In considering this cost estimate, the prices listed on Table 1 will apply. By purchasing lower cost material or higher cost material, the final price of the building can be altered considerably and these changes should be taken into consideration in preparing an estimate.

The electrical cost can be estimated as being approximately 5 percent of the net building cost.

The graph in Fig. 4 shows the estimated cost of refrigeration for average loading conditions using water cooled condensing and 3-phase electrical equipment. The data in Fig. 4 can be converted into cost for a given size storage through the use of the factor 2.5 cu. ft. of

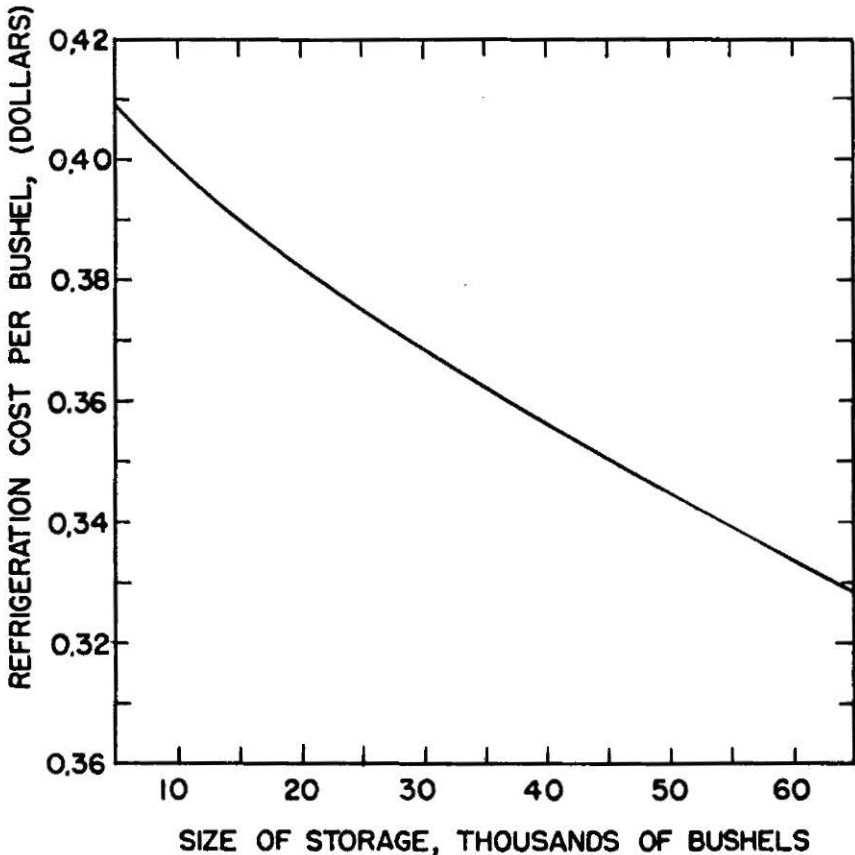


Fig. 4. Estimated refrigeration cost as a function of size of storage.

space per bushel, when the fruit is stored in crates, or 2.25 cu. ft. of space per bushel when 16 to 20 bu. bulk boxes are used. About 10 percent more fruit can be stored in the same space using bulk boxes than when crates are used.

SUMMARY

The results of a study to evaluate the cost of Michigan fruit storage building as affected by size and type of construction are presented. The relative cost of different types of foundation, floor, wall and roof construction are discussed on a unit basis so that they can be readily compared.

It was found that floor and roof cost (per sq. ft.) are not appreciably affected by size. However, wall, foundation and footing (per sq. ft.) are directly a function of the size and shape of the storage. Refrigeration costs (per bushel) decrease with increased size.

The data are presented in such a way that it is possible to use them to estimate the cost of a storage building.

The costs of different types of construction vary quite widely; however, variation in quality accompany these variations in cost. In storage building construction, quality factors are: longevity, freedom from maintenance, fire resistance, and utility. The person who is planning a storage should carefully weigh these factors in light of cost before deciding on a type of construction. In general, the resultant building will reflect its cost.

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