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CONCRETE SILOS

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CONCRETE SILOS

A BOOKLET OF PRACTICAL INFORMATION FOR THE
FARMER AND THE RURAL CONTRACTOR

Prepared by the
INFORMATION BUREAU
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IN preparing data for this booklet, the Information Bureau of the Universal Portland Cement Company investigated during the Spring of 1911, one hundred and ten monolithic and block silos located in the North Central States. Methods of silo construction and operation were carefully studied and data on the actual cost and labor required, and other important information was obtained. Valuable assistance was received from a number of sources, particularly from the bulletins of the Department of Agriculture and the State Experiment Stations, several paragraphs from which have been used verbatim.

The reader seeking further information on the subject of silage and silo construction will find in the following pamphlets a comprehensive course of instruction:

Cement Silos—Farmers' Bulletin No. 405, U. S. Department of Agriculture.

Silos and Silage—Farmers' Bulletin No. 32, U. S. Department of Agriculture.

Cost of Filling Silos—Farmers' Bulletin No. 292 U. S. Department of Agriculture.

Concrete Silo Construction—Bulletin No. 214, University of Wisconsin, Madison, Wis.

Cement Silos in Michigan—Bulletin No. 255, Michigan State Experiment Station, East Lansing, Michigan.

Silage and the Construction of Modern Silos—Bulletin No. 83, Wisconsin Agricultural Experiment Station, Madison, Wisconsin.

The Silo—Monthly Bulletin No. 2, Volume 6, Missouri State Board of Agriculture, Columbia, Missouri.

The Reinforced Concrete Silo—Circular No. 49, by the Missouri Agricultural Experiment Station, Columbia, Mo.

Silage and Silo Construction—Bulletin No. 4, Vol. II, Kansas State Agricultural College, Manhattan, Kansas.

Silos and Silage in Maryland—Bulletin No. 129, Maryland Agricultural Experiment Station, College Park, Maryland.

The Silo and Silage in Indiana—Bulletin No. 40, Purdue Agricultural Experiment Station, LaFayette, Indiana.

Soiling Crops, Silage and Roots—Bulletin No. 9, Series II, College of Agriculture, Cornell University, Ithaca, New York.

(Farmers' Bulletins published by the Department of Agriculture may be obtained by addressing Joseph A. Arnold, Editor-in-Chief, Bureau of Publications, Department of Agriculture, Washington, D. C.)

In addition to the publications mentioned above, "Modern Silage Methods," published by the Silver Manufacturing Company, of Salem, Ohio, contains much valuable information which the silo builder and farmer should have.

For the information of parties planning the erection of concrete silos, we quote the following from the opinion of our patent counsel relative to the Harder patent No. 627732.

"The Harder patent as interpreted by Judge Ray is limited to a silo having a continuous opening from top to bottom, a series of sliding doors, reinforcing strips and braces of peculiar form. The court said in its opinion, 'It is obvious that the braces of the Harder patent would be superfluous in stone or brick silos'; this being true, the Harder improvement would be wholly unnecessary in silos made of concrete.

Therefore we advise you that the Harder patent does not cover all forms of silos; that it is limited and restricted to substantially the exact construction which it shows and describes and that it is unnecessary, if not undesirable, in silos made of concrete."

Since concrete silos are not covered by the Harder patent, farmers and contractors need have no hesitancy in building silos of concrete and are requested to advise the Universal Portland Cement Company of cases where any claim of an infringement is made.

Concrete Silos

Silos and Silage

HISTORY will record the Nineteenth Century as an era of unprecedented agricultural progress. During the first fifty years the steel plow, the cultivator, and the harvester came into use, and succeeding decades brought the tractor, the gasoline engine, the great irrigation and dry farming projects and the silo—the latter destined to become one of the most potent factors in American farm economy.

Conservation is the watchword of the present century. With the farmer the question is not only "How much corn can I raise?" but also "How can I get the most out of my corn?" * * * It is this spirit which has dotted the dairy and stockraising sections of the country with silos, from Maine to Oregon, and from the Gulf to the Canadian Provinces, until, as a recent writer has put it, "A good dairy community can be judged by the number of silos on the horizon just as an oil district may be known by the number of derricks in use."

The silo is one of the true conservators of the nation's resources. Several state experiment stations have estimated that 40 per cent of the value of corn is in the stalks, almost all of which is saved if the latter are placed in a silo. When other crops are used the saving is almost as great. The results have enabled stock and dairy men to keep more cattle on the same sized farms, as well as to maintain the herds in better health, and increase the milk flow. Several Southern Michigan farmers keep 20 head of dairy cattle on 20 to 30 acres by feeding them from the silo all year round, and having but small pastures. In such cases silage has been found equal to June grass, and entirely without harmful effect, even when used 365 days out of the year.

Definitions:—The silo is an air-tight chamber or tank often wholly above ground, but very frequently having as much as one-third of its capacity below the surface. In its original form the silo was merely a large pit, being entirely below ground. The function of the

Fig. 1. Two 60-foot Polk silos, being constructed for Mr. Peter Emge, Fort Branch, Ind., showing forms in position for last filling.

silos are to preserve green succulent food which is thus available during summer droughts when pastures are used up, and during the winter when dry feed alone results in shrinking milk flows and checked growth in fattening stock.

Fig. 2. J. C. Eastman's concrete silo, Crown Point, Ind. Height, 41 feet; Diameter, 18 feet. Capacity, 238 tons. N. L. Smith, Crown Point, architect.

The term "ensilage," or more properly "silage," is used to denote the fodder preserved in the silo. In the corn belt States silage is usually made from corn, while in other parts of the country sorghum, pea vines, alfalfa, clover, soy beans and cow peas, supplement corn to a considerable extent, or are sometimes substituted for it.

The Theory of Silage:—Silage is kept in the silo very much as fruit, vegetables and other articles of human food are preserved in airtight cans. The germs which cause fermentation can grow only when supplied with oxygen, and if air is kept from the silage it can be preserved for an indefinite period. As soon as the silo is filled, fermentation begins, continuing until the supply of oxygen is exhausted. If

the silage is well packed, and neither too green nor too ripe, it will continue the ferment for but a short time, and will be practically uniform below the top coating. The sweetness of the food depends upon the stage to which the fermentation was carried, and the subsequent exclusion of air. Sour silage is not as wholesome as sweet silage, nor will the cattle partake of it so freely. The best silage can only be made in a practically air-tight silo.

Silage Crops:—Corn is undoubtedly the best silage crop wherever it will grow to full maturity. The yield per acre is heavy, the losses small, and the cost of harvesting lower than for most other crops. Sweet corn is not as desirable for silage because the sugar tends to produce excessive acid. Sweet sorghums are objectionable for the same reason, but those of the non-saccharine or kaffir-corn variety make good silage and will undoubtedly be used largely in the semi-arid portions of the southwest, where sorghum is a better crop than corn. Alfalfa and clover both make good silage but are little used as yet. Pea vines are commonly used where they can be obtained as a cannery by-product, and make excellent silage when mixed or used in conjunction with corn.

The Advantages of Silage:—Someone has compared the difference between silage and dry feed to that "between a juicy, ripe apple and the green dried fruit." Because of its succulence, silage has a beneficial effect on the digestion of the animals and they become very fond of it. The economy of storing silage is a feature which appeals at once to

the average farmer. Two and one-half to three tons of silage is equivalent in feeding value to a ton of hay and may be stored in one-half to two-thirds the space occupied by the latter. As already mentioned in a previous paragraph, more cattle can be kept on a given amount of land with silage, and there is the additional advantage that after the crop is in the silo the feeder is not dependent to any extent whatever upon weather conditions. The Missouri Farmer's Bulletin No. 11 sums up the advantage of silage as follows:

1. Silage keeps young stock thrifty and growing all winter.
2. It produces fat beef more cheaply than does dry feed.
3. It enables cows to produce milk and butter more economically.
4. Silage is more conveniently handled than dry fodder.
5. The silo prevents waste of corn stalks, which contain about one-third the food value of the entire crop.
6. There are no aggravating corn stalks in the manure when silage is fed.
7. The silo will make palatable food of stuff that would not otherwise be eaten.
8. It enables a large number of animals to be maintained on a given number of acres.
9. It enables the farmer to preserve food which matures at a rainy time of the year, when drying would be next to impossible.
10. It is the most economical method of supplying food for the stock during the hot, dry periods in summer, when the pasture is short.

In a recent circular, Mr. Chris De Jonge, of Zeeland, Michigan, has written the following as an example of concrete silo economy:

"You can grow only two tons of hay on one acre and ten tons of ensilage on the same acre. Two tons of hay at \$12.00 per ton will bring \$24.00. Ten tons of ensilage at \$4.00 will bring \$40.00. That is \$16.00 per acre in favor of the ensilage. One ton of hay will cost \$1.50 to cut and bring into the barn, and one ton of ensilage will cost only 60 cents to cut and put in the silo. If you feed one cow 40 pounds of ensilage per day, it takes nearly eight tons to feed her one year. So if you only get eight tons of ensilage per acre you can feed one cow one year from it, or two cows one-half year off one acre. If you pasture your cows during the summer, six months, it takes two acres to pasture one cow. So by having a silo you keep four times as many cows as you do without a silo.

Fig. 3. Monolithic silo, nearly completed by the Polk-Genung-Polk system, on the farm of John Creighton, Geneva, Ill. W. H. Warford, Contractor.

TABLE A
Dry matter and digestible nutrients in silage from different crops.

Crop used for silage.	Total dry matter. Per cent.	Digestible nutrients.		
		Protein. Per cent.	Carbo-hydrates. Per cent.	Ether extract. Per cent.
Corn	20.9	0.9	11.3	0.7
Red clover.....	28.0	2.0	13.5	1.0
Sorghum	23.9	.6	14.9	.2
Alfalfa	25.5	3.0	8.5	1.9
Grass	32.0	1.9	13.4	1.6
Cowpea vines.....	20.7	1.5	8.6	.9
Soy bean.....	25.8	2.7	8.7	1.3
Barnyard millet and soy bean.....	21.0	1.6	9.2	.7
Corn and soy bean.....	24.0	1.6	13.0	.7

From Farmer's Bulletin No. 32, U. S. Department of Agriculture.

"If you have ensilage to feed, you can keep your cow for 10 cents per day less than without ensilage. So if you get 10 cents for 200 days for one cow it amounts to \$20.00. Then if you have ten cows your gain is \$200.00, for which you can buy a concrete silo and pay for it in one year."

Effects of Silage on the Flavor of Milk*

Prof. W. J. Fraser, of the Illinois Experiment Station, recently made some interesting observations on the effect of silage on the flavor and odor of milk. The dairy herd at the University was divided into two lots, one of which was fed 40 pounds of corn ensilage per cow daily, while the other was fed only clover, hay and grain. The milk from each lot was standardized to 4 per cent and otherwise cared for in exactly the same manner. Samples from each lot sent to milk experts in experiments were submitted to 372 persons for an opinion as to any difference in the flavor of the two samples, anything objectionable about either, and any preference. The results showed that 60 per cent preferred silage milk, 29 per cent non-silage milk and 11 per cent had no choice. When the silage was fed at the time of milking, the percentage in favor of silage milk was much higher than when the silage was fed one hour before milking. Five samples of each lot were sent to milk experts in different cities, three of whom preferred silage milk, one non-silage, and one had no choice. No complaint was received from a hotel to which silage milk was delivered for a period of one month. On the whole it was apparent that the greater number of people were able to distinguish between the two kinds of milk, but found nothing objectionable about either kind.

Fig. 4. Concrete block silo on estate of E. Evenson, Litchfield, Minn. Diameter, 14 feet; height, 32 feet. Cost, \$312.00.

The Effect on Cows of a Silage Ration*

During the winter and spring of 1904 the Ohio Experiment Station conducted an experiment with ten dairy cows, representing five different breeds, "to determine what effect the feeding of more silage than is usually fed by dairymen, with a corresponding reduction in the grain portion of the ration, might have upon the production of milk, butter fat, gain in live weight, cost of ration and consequent profit."

*From Farmers' Bulletins No. 267, 222.

The cows fed on the silage ration produced 96.7 pounds of milk and 5.08 pounds of butter fat, while those fed on the grain ration produced 81.3 pounds of milk and 3.9 pounds of butter fat, on an equivalent amount of feed.

The cost of feed per hundred pounds of milk was \$0.687 with the silage ration and \$1.055 with the grain ration. The cost of feed per pound of butter fat was 13.1 cents with the silage ration and 22.1 cents with the grain ration. The average net profit per cow per month (over cost of feed) was \$5.864 with the silage ration and \$2.465 with the grain ration.

Fig. 5. Lewis McNutt's monolithic silo, Brazil, Ind., showing cutter and blower in position, ready for filling.

Capacity and Dimensions

Capacity:—The capacity of the silo depends upon the number of cattle to be fed, and the length of time that silage is required. This period usually lasts from 180 to 240 days, although very frequently silage is fed almost the entire year. The following table shows the approximate amount of silage required to feed 8 to 100 dairy cows 180 and 240 days, based on a daily consumption of 40 pounds of silage per head.

TABLE B.

Quantity of Silage Required, and Economical Diameter of Silo for the Dairy Herd.

Number of Dairy Cows	Feed for 180 Days	Feed for 240 Days	Diameter of Silo
8	29 tons	40 tons	8 ft.
10	36 "	48 "	10 "
15	54 "	72 "	10 "
20	72 "	96 "	12 "
25	90 "	120 "	14 "
30	108 "	144 "	16 "
35	126 "	168 "	16 "
40	144 "	192 "	18 "
45	162 "	216 "	18 "
50	180 "	240 "	20 "
60	216 "	288 "	22 "
70	252 "	336 "	22 "
80	288 "	384 "	22 "
90	324 "	*432 "	22 "
100	360 "	*480 "	22 "

*Where more than 400 tons of silage are required, the use of two silos is generally advisable.

Diameter:—After determining the approximate amount of silage required, the most economical diameter for the silo must be decided on. The diameter should depend upon the number of cattle to be fed, and at least 2 inches of silage must be removed each day to prevent spoiling. The diameter required for various numbers of cows is about as given in the two right columns of table "B." Dairy cows eat from 30 to 40 pounds of silage per day, which amount equals about one cubic foot. Horses and mules eat about one-half and sheep about one-third as much as cows.

Height:—The height of the silo must be such that the required capacity may be obtained with the most economical diameter, providing, however, that the height does not run above 40 feet for the small diameters, and 50 feet for the large diameters, according to the limitations of table "C." Extremely high silos are not as accessible and are more difficult to fill than less lofty structures. For these reasons two silos are often preferred. The high silo of small diameter has less waste than the silo of larger diameter, and the greater weight of silage in high silos reduces the amount of tramping necessary and silos of smaller diameter allow greater variation in the size of the herd without loss from spoiling of silage.

Example:—Required, a silo of sufficient capacity to feed 30 cows for a period of 180 days. Referring to table "B," run down the ver-

Fig. 6. Concrete block silo and barn of Thomas Coyne, near Fond du Lac, Wis. The silo is constructed of Coyne's double-wall hollow blocks. It is 14 feet in diameter by 30 feet in height, and cost \$350.00.

tical column headed "Number of Dairy Cows" to 30. Running across horizontally, it will be seen that for 180 days' feed, 108 tons of silage will be needed, and that for a silo of this capacity, the diameter should be 16 feet. Referring to table "C," run down the column headed "16 feet" to the numbers nearest the estimated capacity (108 tons). For a 16-foot silo of 109 tons capacity the height will be 28 feet.

Location

LOCATION:—The silo should be placed where it will be convenient for filling, and if possible, where the ground is firm, so there will be no danger of settlement. Silage is heavy feed, and therefore an unhandy arrangement with respect to the feeding alley always greatly increases the work connected with feeding. One of the best arrangements for convenient feeding is to place the silo or silos at the end of the alley. If this be done, a silage car can be used to advantage without having sharp corners to turn. The silo should not be surrounded by buildings and pens in such a way as to interfere with filling. Obstructions hinder the work greatly, increasing the cost to the owner.

In most cases where the ground is soft, it will pay to carry the foundation down to a firm bottom, or to fill in with gravel. If it is impractical to go down to solid earth, the footings must be increased to at least twice the breadth recommended on page 36, and more if there is the least uncertainty.

In parts of the country where winters are severe, there is an advantage in placing the silo on the south side of the barn, where it will be protected from the north winds. In the past quite a large number of silos have been built within the barn, but this practice is not recommended for several reasons. Such silos are inconvenient to fill, and silo odors are objectionable in the barn, for unless great caution is taken, the milk is apt to be contaminated.

Perhaps the most common fault made in locating silos is to get them too far away from the barn. In cases where this distance is made too great, the only way of remedying the situation is to build a room connecting the silo with the barn, thus incurring needless expense and increasing the distance to haul the silage. The distance from silo doors to barn need never be over 4 feet, which is sufficient for a chute of the ordinary size.

Fig. 7. Monolithic silo of Hugh Ferguson, near Rockford, Illinois, with concrete chute and roof. Diameter, 14 feet; height, 45 feet. One of several similar silos constructed by Edward Kuharske, Rockford, Illinois.

Filling the Silo

WHEN TO HARVEST:—The corn should be cut while the stalks are still green, but after the lower leaves have begun to dry. At this stage the kernels have hardened or “glazed” on the outside, but are yet in the “dough” condition in the middle. If cut too green the silage will lack protein, sugar and other nutritive

elements, and will contain an excess of moisture, generally making it sour. If too matured, it will be dry and unpalatable, with the fibre very prominent. In this condition it contains less nutriment, is relished less by the cattle, and is apt to mold or “fire-fang,” causing it to be greatly damaged. Corn dried out in the shock makes poor silage unless wet when put into the silo.

Fig. 8. Monolithic silo on L. A. Crawford farm, Walworth, Wis. Capacity, 114 tons; cost, \$325.00.

Harvesting the Crop:—The harvesting of corn or sorghum for the silo may be done by hand with the ordinary corn knife, but the corn harvester or binder is the implement almost universally used for this work. In some sections of the country corn has been cut with a sled equipped with saw-like knives projecting from both sides, but this

method of harvesting is not now used to any great extent. Except where the corn has fallen down badly, as was the case in some sections of Michigan in 1910, the binder can be used to advantage. It not only saves time in cutting the crop, but also binds it into bundles which are easier to load on the wagon and feed into the cutter than the loose corn.

The Cutter:—Corn is sometimes placed in the silo uncut, but this practice is not to be recommended because the stalks will not pack closely, and the resulting air spaces cause excessive fermentation. The material is not as easily handled as cut silage, nor is it as economical to feed. The crop must be cut up fine for best results and when corn is used the entire plant, including ears, should be fed into the cutter. Although practice varies greatly, it is safe to say that corn for the silo should be cut one-half inch or even shorter. It is a well-known fact that corn will pack better in the silo the shorter it is cut, increasing the capacity to a considerable extent. Cattle like short silage better and will eat it up cleaner.

Elevating and Distributing:—From the cutter the silage is elevated by a blower or conveyor, and deposited in a chute or automatic distributor. One or two men are required within the silo while it is

being filled, to tramp down the sides close to the walls, and to keep it leveled off (thus preventing the formation of air pockets), and to mix the heavier portion of the silage with the lighter. Silage has a tendency to cling to the sides of the silo unless well tramped, and the heavier particles roll to the edges while the lighter remain near the discharge. The automatic distributor greatly simplifies the work of filling the silo and does away with much of the tramping. The operator is simply required to guide the mouth of the tube, and the material descends with sufficient force to pack it nicely, making a minimum amount of tramping necessary.

Economy of Filling the Silo Rapidly:—It is common practice to fill the silo as rapidly as possible, that is, keeping the cutter and blower busy continually. This is the only economical method where the engine and cutter are rented, or hired labor depended upon. However, if these considerations do not enter in, there is no objection to filling the silo gradually, so long as fresh silage is put in before mold is formed on the surface of that previously placed. In rapid filling, a day or two should be allowed for settling, and the silo filled up a second and perhaps a third time in order to utilize all of the space.

During the process of filling all doors above the height of the silage should be left open for the purpose of letting out the carbonic acid gas which is given off.

Wetting the Silage:—When the filling is finally completed, the top should be wet down at the rate of about one gallon of water per square foot of surface, and thoroughly tramped. This aids greatly in compacting the silage near the top, reducing the depth of the spoiled material on the surface. In many communities it is a practice to run in a quantity of straw or chaff after finishing with the silage, and then planting oats or other small grain. Where this is done there is seldom any loss of silage worth mentioning, and the growth on top is generally fed to the cattle.

Cost of Filing:—Condition of crop, length of haul from the field to the silo, size of silo, method of harvesting and the cost and arrangement of labor are all elements which affect the cost of filling a silo. Farmers' Bulletin No. 292, Department of Agriculture, says: "In many cases a poor arrangement of help is responsible for extra expense. It is not necessary for men and teams to be rushed to their full-

Fig. 9. Monolithic silo of Howard and Sylvester Thompson, Rose Creek, Minn. The first silo in Mower county. Cost, complete, \$214; capacity, 83 tons. Work done by men without previous experience in concrete work, with local materials. Silo has stood five years, and shows no cracks nor checks.

est extent in order to get the work done cheaply. Some of the most expensive work was conducted with the greatest furore and hurry. The scheme where all are working and no one is hindered by the others, is the most economical.

The table on pages 44 and 45 shows the cost of filling 59 concrete silos

Fig. 10. Silo with concrete roof and chute on the farm of Dr. Hammond, Wheaton, Ill. Built by the New Enterprise Concrete Machinery Company, Chicago.

during the season of 1910. Although the location of the various silos is not set down in this table, this information may be found by comparing the numbers of the silos with those given in the tables on pages 31 and 32. Almost without exception the figures contained in these tables are considerably higher than usual, due to a poor crop of corn in most sections touched by the investigation and also to the peculiar condition of the crop in some sections of Michigan, where it fell down so badly as to make the use of harvesters impossible.

See Table D, Pages 44 and 45.

The average cost of filling 16 concrete silos in Illinois was found to be 57½ cents per ton; average of 22 silos in Michigan, 64 cents per ton; average of 10 silos in Wisconsin, 57 cents per ton; average of 4 Minnesota silos, 72 cents per ton; of 2 Ohio silos, 89 cents per ton; and of 2 Missouri silos, 50 cents per ton. The average cost of filling silos of 100 tons or less capacity was found to be 70 cents; 100 ton to 200 ton silos 58 cents, and silos over 200 tons 57 cents. The average for all the silos investigated was found to be 62 cents.

Recent investigations by the University of Illinois show the average cost of filling silos, including cutting crop in field, to be 58 cents per ton in Illinois, which figure compares favorably with the average of 57½ cents obtained in the investigation conducted by this company. Farmers' Bulletin No. 292 on the "Cost of Filling Silos," shows a range of 46 cents to 86 cents per ton on the 31 silos investigated, giving an average of 64 cents as against the average of 62 cents obtained in the investigation conducted by this Company.

Total Cost of Silage:—The same elements which determine the cost of filling the silo, determine the total cost of the silage, with additional items including cost of the land, cost of tillage and interest on investment. Farmers' Bulletin No. 32 states that "In the writer's experience in the Central West the cost on high-priced land has been

about \$1.50 per ton. F. S. Peer in a recent book which treats of silos and silage, gives the cost in his experience as \$1.20 per ton. Professor Wall of Wisconsin, places it at \$1.00 per ton to \$1.50 per ton, including cost of seed, preparation of land, interest on investment, cultivation of the crop, cutting and filling the silo. King, when studying this subject in Wisconsin, found that for a number of farms in that State, the cost averaged $73\frac{1}{4}$ cents per ton."

Farmers in the vicinity of Orchard Ohio, have computed the cost of their silage at \$1.12 per ton. Mr. James Dorsey, of Gilberts, Illinois, puts the full cost at \$1.00 per ton in his section of the country. Some years ago silage cost \$1.50 per ton at the Purdue Experiment Station and farmers in various parts of Indiana estimated the cost of their silage at 50 cents to \$2.00 per ton.

If these figures on the cost of silage are compared with those for hay or other dry feed, silage will be found much cheaper; to this advantage must be added that of the larger milk flow obtained where silage is fed.

Fig. 11. Concrete stave silo of Mr. H. R. Hanson, near Clarkfield, Minnesota. Built by the Minnesota Silo Company, Willmar, Minnesota.

Using off the Silage

SILAGE is always used off the top of the silo. Any opening in the bottom would admit air, which would cause the silage to spoil. A large number of farmers commence to feed out of the silo as soon as filling is completed, thus avoiding any loss whatever on the top. If this is not done, the shallow covering of spoiled silage must be removed and thrown away when feeding is begun. The silage must be fed off in layers of at least two inches each day in order to prevent the formation of mold.

Most authorities advise that the surface of the silage be kept as nearly level as possible so as to present the smallest possible surface to the air. In some parts of the country, however, where the winters are severe, it is common practice to keep the edges lower than the center, making the surface of the silage cone-shaped. This is said to prevent to a large extent the freezing which sometimes occurs around the edges near the top.

Never throw down the chute more silage than will be required immediately, being careful to keep the doors between the chute and the barn closed whenever not in actual use. Care in this respect will keep silage odors from reaching the barn.

The Advantage of Concrete as a Silo Material

IT HAS been admitted by those who have studied the subject from an impartial standpoint, that silage can be kept in good condition in a silo of any material—be it concrete, stone, tile, or wood—if the material selected is properly used. The length of time for which the silo will continue to fulfill in a satisfactory manner the

service required of it depends, however, upon the selection of the material best able to combat the action of the elements, withstand the heavy strains due to the silage, and furnish a reserve for such extraordinary conditions as fires and cyclones.

Fig. 12. Monolithic silo at the Experimental Farm of the South Dakota State College, Brookings, South Dakota.

Concrete—whether placed in forms or cast in blocks—is the ideal silo material because it is permanent, wind-proof, rodent-proof and fire-proof, and is economical in first cost and maintenance. As regards permanency, there is no question but that a good concrete silo will remain indefinitely. Concrete grows stronger and tougher with age, outlasting almost every other known material. Reinforced concrete is the strongest and most enduring construction known. It is selected for

the great engineering projects—long bridges, massive dams, and lofty skyscrapers.

While great financial loss seldom follows the collapse of a silo due to wind pressure, the matter is worthy of consideration because of the frequency with which wooden silos blow down. Indeed, in many parts of the country wooden silos can be found which have blown down three or four times. The development, during the past ten years, of slender reinforced concrete chimneys of great height, shows that from a standpoint of safety against wind resistance, this type of construction is unequaled.

Mice have been known to cause considerable loss by burrowing into wooden silos. Mice holes allow the air to get in, often causing the silage to spoil for a foot or more in all directions from the holes. Mrs. L. H. Adams, of Parma, Michigan, had an experience of this sort, and as she has a concrete silo of the same size adjoining the stave silo, a fair comparison between the two is easily made. The loss of silage from mice holes in the wooden silo brought the total loss in that silo up to more than twice the loss in the concrete silo, notwithstanding the fact that the latter was not provided with roof, chute, or doors, the continuous door openings being roughly boarded up.

Concrete silos prevent silage from drying out. The old idea that the juices of the corn seep through concrete walls with bad effect upon the latter has been entirely disproved—in fact, it never has been entertained for a minute by owners of concrete silos. The bugaboo of a concrete silo disintegrating through the action of corn acids is an absurdity. There are hundreds of cases where the concrete bases and floors of wooden silos have been in use for a long term of years without discoloring or disintegrating in the least, showing conclusively that silage acids have no effect on good concrete.

Fireproof Construction

The farmer, of all people, is at the mercy of fire. Let a blaze once start in or about his barns and the chances are small for saving any of the surrounding structures. Fire fighting apparatus is out of the question, the water supply is generally limited, and in nine cases out of ten help cannot be summoned until the flames are beyond control.

Silo fires usually cause great loss because the feeder of silage is entirely dependent upon his silo all through the feeding season, which covers the greater part of and sometimes the entire year. The loss of the silo frequently means that the cattle have to be sold off, always at considerable sacrifice. Concrete silos of either the monolithic or block type are absolutely fireproof—of such a construction that they might be used for chimneys. If equipped with a concrete chute the concrete silo will protect the silage perfectly, and in the event of a fire not a pound need be lost.

Mr. George Pulling's Silo:—During the winter of 1910 fire destroyed the barn of Mr. George Pulling, near Parma, Michigan, adjacent to which was Mr. Pulling's new 85-ton monolithic silo, erected at an expense of \$300.00. This silo, one of a large number of similar ones put up in that part of the country by Mr. Charles Nobles, of Kalamazoo, came through the fire in good shape, with silage in perfect condition. At the time of the fire the silo contained about 50 tons of corn silage, and as hay was then selling in the vicinity for \$15 per ton, dry feed to take the place of the silage would have cost probably \$500, an amount greater than the cost of the silo and silage combined.

Fig. 13. 11x28 monolithic silo, built by Garrett Wierenga, Hudsonville, Mich. Capacity, 51 tons; cost, complete, \$105. This silo was put up in 15 days by Mr. Wierenga, with the assistance of farm hands. Since completion, two years ago, the silo has given excellent satisfaction.

Mr. A. B. Main's Silo:—A striking example of the value of fire-proof silo construction is presented in the accompanying illustrations, showing the 550 ton concrete block silo of Mr. Arthur B. Main, Delaware, Ohio, before and after the disastrous fire which destroyed his barn in October, 1910. This silo was built for Mr. Main during the

Fig. 14. Concrete Block Silo of Arthur B. Main, Delaware, Ohio. This silo is 20 feet in diameter and 60 feet in height and was built by the Perfect Cement Silo and Cistern Company, Delaware, Ohio. The adjoining barn with 180 tons of hay burned during the autumn of 1910. The silo shows no other effects of the fire than those which can be seen in the illustration. Its 530 tons of silage were kept in perfect condition with a loss of less than 300 pounds.

summer of 1909 by the Perfect Cement Silo & Cistern Company of Delaware.

At the time of the fire Mr. Main was feeding between 80 and 90 head of cattle and had on hand 530 tons of corn silage and 180 tons of hay, the latter being stored in the end of the barn adjacent to the silo. The barn burned to the ground, leaving nothing but the concrete footings, which will be noticed in the lower illustration.

Although the silo was subjected to intense heat, the only damage done was the burning out of the continuous wooden doors. Perhaps the most remarkable fact brought out in connection with the fire was that of the small amount of silage lost. After the destruction of the doors the surface of the silage presented to the flames was seared and charred to a slight extent, but the charred or spoiled layer had a thickness of less than half an inch, and the amount actually lost was insignificant.

Had Mr. Main been deprived of his silage by fire, it is safe to say that his dairy business would have been ruined, temporarily, at least. At the time of the fire hay was selling at \$15 per ton. Had it been possible for him to have substituted a daily ration of 40 pounds of hay per cow for the 40 pounds of silage and 10 pounds of hay being fed, the cost would have been no less than \$4,000. Mr. Main could not, however, have purchased the dry feed with which to have fed his herd through the season; even had that been possible, the hauling of a sufficient quantity of dry feed a considerable distance over bad roads would have been impractical, according to his statement. The only course left open would have been to dispose of his cattle, which would have meant a large loss.

The cost of Mr. Main's silage was estimated at \$1.12 per ton, or a total of \$593.60. The silo cost \$750 complete. The total cost, therefore, of silo and silage as they stood at the time of the fire was about \$1,343.60. Had the silage been destroyed, the cost of substituting dry feed would have amounted to about three times the cost of the concrete silo and its contents. These figures are sufficient to convince the thoughtful farmer of the desirability of putting up fireproof silos.

Fig. 15. Silo of Mr. George A. Fox, Sycamore, Ill. 16 feet in diameter; 40 feet in height. Built by the Polk-Genung-Polk Company. This illustration shows clearly the Polk elliptical door openings.

The Element of Waste

All available data tend to show that the waste of silage in silos built of concrete is fully as small, if not smaller, than in silos of any other material. Of 50 silos in the states of Illinois, Michigan, Wisconsin, Indiana, Ohio, Kentucky and Missouri, on which reliable data was obtained, 25 showed a loss of less than one-half ton of silage

from all causes, 18 showed a loss between one-half ton and two tons, and 7 showed a loss of more than two tons. In terms of percentage of the total silage in each silo, it was found that thirty-four had an annual loss of less than one per cent, thirteen had a loss between one and three per cent, three had a loss greater than three per cent. The greatest loss in any case was about six per cent.

These figures are somewhat lower than those recorded at some of the state agricultural colleges, probably for the reason that the college dairymen are more particular than the average farmer, rejecting silage which the latter would consider fit for use. It may be stated conservatively that with silage crop in good condition when put in, properly tramped down and fed out at the rate of 2 inches or more per day, the loss in concrete silos of

Fig. 16. Monolithic silo on the farm of John Judge, St. Charles, Ill. Built by C. A. Anderson, St. Charles. Cost, complete, \$490, including concrete chute; capacity, 175 tons of silage. Forty silos of this type have been put up by Mr. Anderson in Kane county, Ill.

either the monolithic or block type will seldom, if ever, reach 5 per cent.

There is practically no waste in cases where the cattle are placed upon a silage ration as soon as filling is completed. Where this is not done, the waste is minimized by wetting and tramping the silage down and planting oats or rye on top, as previously suggested.

The Effects of Freezing

The subject of frozen silage has attracted considerable attention, more perhaps than its just due. The fact has been pretty well established that freezing is an inconvenience rather than a real detriment. Silage which has been frozen has to be handled an extra time, being either pitched to the center of the silo with the warmer silage, or removed to the barn to thaw. In either case, only enough of the frozen silage is thawed out each time to supply the next feeding. Silage keeps indefinitely while frozen, and instances are noted where it has not spoiled after thawing, when left packed in the silo.

After thoroughly thawing out, silage which has been frozen is equally as nutritious as before freezing, and the cattle eat it with as great relish. Silage in the frozen condition is liable to produce harmful effects, and should never be fed. "All careful stockmen heat their drinking water," says Wisconsin Bulletin No. 125, "but it is a

much more serious matter to feed a cow 40 pounds of silage at 32 degrees than to give her 20 to 30 pounds of ice water."

Freezing is caused by the loss of heat through the walls and from the contact of the feeding surface with the air. The former loss is made somewhat less when hollow block or monolithic walls with air spaces are used, but even in the case of single monolithic walls, loss of silage from freezing is extremely rare. In northern Minnesota and North Dakota, where the temperature frequently reaches 30 degrees below zero during the winter, and occasionally goes as low as 40 degrees below, both monolithic and concrete block silos are in successful use. For parts of the country where such extremely cold weather is encountered during the winter months, the hollow wall construction is to be preferred. However, a recent investigation of concrete silos in Minnesota failed to disclose any in which the silage froze more than one foot back from the wall on the north side. Freezing to this extent occurred when the temperature was between 30 degrees and 40 degrees below zero.

Prof. J. H. Shepperd, dean of the North Dakota Agricultural College, says in a recent letter:

"I might say that our experience here indicates that there is no difficulty in putting up the ordinary type of silo in this state by reason of the cold weather which occurs during the winter season. Our farmers who have had experience with them recommend building them outside of the barn rather than to put them inside to protect them from heavy freezing of the ensilage on the walls. I think there will be a large increase in the number of silos in this state in the next few years."

Fig. 17. A concrete silo which failed. Miss Kate Virtue, owner, Hudson, Wis. The contractor in this case used poor materials, lean mixtures and inadequate reinforcing. The walls cracked during the first filling, and were reinforced with iron bands. They were later repaired with grout. The silage has kept in perfect condition notwithstanding the faulty construction.

Silo Failures

ALTHOUGH failures of concrete silos are extremely rare, the few cases which have arisen have been given wide publicity as proof that concrete is not a suitable material for this class of work. Almost without exception, the failures which have occurred have been due to insufficient reinforcing, a cause which affects silos of other materials to as great an extent. One or two cases have been seen where poor materials have contributed to the failure, and in one instance cracks occurred between the courses of a monolithic silo due to poor bond at points where concreting was discontinued. This condition might have been prevented by the treat-

ment described on page 54. The use of dirty, poorly proportioned, weak aggregates, mixed without sufficient water or cement, will not give satisfaction, and the sooner discontinued, the better. There is no reason for a single failure, if sufficient reinforcing is properly put in, materials are clean and well proportioned, and the work done in accordance with the directions laid down in the following pages.

Fig. 18. Large monolithic concrete silo, built for the Waukesha Canning Company, Waukesha, Wisconsin. One of the largest silos in the world. Capacity, 2,250 tons; cost, \$2,500. Filled with pea vines, producing silage as a bi-product of the cannery.

The silo shown in Figure 18 is especially interesting, because it has been widely used by manufacturers of other types of silos, as a strong example of concrete silo failure. So far as can be learned, however, none of these parties have ever tried to ascertain the true reason for the failure, which might have been made perfectly clear by a short investigation. Bulletin No. 100 by the Iowa State Agricultural College says:

"There is an excess of juice in pea vines and in order to pre-

vent an accumulation of this and a consequent excessive internal pressure, a large drain was placed at the center of the silo. This drain for the first two years accomplished its purpose, but upon the third filling it became clogged, allowing the juices to accumulate to a depth of at least 20 feet. By calculation it was determined that the bursting pressure in the silo due to the 20 feet of juice was more than double the strength of the steel reinforcement in the wall for the bottom 18 inches. This shows conclusively that the concrete was not at fault and this instance cannot be used as an argument against the concrete silo. If the silo is filled with corn, that is properly matured, the above conditions cannot occur."

The above only partly explains the difficulty. An investigation shows that the walls were reinforced by five-eighths-inch rods, spaced eighteen inches apart at the bottom, increasing to three feet at the top, which is not enough to properly reinforce a silo twenty feet in diameter. This silo has a diameter of sixty feet, a height of forty feet, and a capacity of 2,250 tons, about eight times as great as that of a silo of the same height, twenty feet in diameter.

Concrete Silos in the South

A large number of monolithic, concrete block and cement plaster silos have been put up throughout the South, many excellent examples

being reported in the states of Maryland, Virginia, North and South Carolina, Georgia, Alabama and Mississippi. Without exception these silos are giving splendid satisfaction, and it is only because of the lack of time in preparing the present booklet that the methods of constructing silos in the southern states are not fully discussed.

Cement plaster silos built by applying a coat of stucco to a metal frame is a type peculiar to this section and has been recommended by one or two of the Southern Agricultural Schools.

The following extract from a letter from Prof. J. A. Conover, of the U. S. Naval Academy at Annapolis, gives his experience in constructing concrete silos in North Carolina:

"In connection with my work with the North Carolina Department of Agriculture, I have built during the past five years a large number of concrete and cement plaster silos and they are all giving excellent satisfaction. Where the silage was properly packed it has kept splendidly. These silos were all given a coat of coal tar inside before filling, which I believe is a necessity.

"The concrete silos had 6-inch walls reinforced with woven wire fencing all the way up. We used a standard fence from 30 to 48 inches in height. The plastered silos had walls only about $2\frac{1}{2}$ inches thick, the plaster being put on expanded metal lath bent and wired in a circle. No other reinforcing was used. One of these silos has been up five years and as far as I can see it is just as good as it was when first completed. "These silos were all put up by farm labor and did not cost nearly as much as they would had they been built by such labor as one gets in the city. One silo 12x24 only cost its owner \$80.00. One of the expanded metal lath plastered silos 14x28 cost \$181.00 including roof, painting (tarring) and everything complete. Wood has reached such a figure and lasts such a short time that I believe it is much cheaper to build of concrete. I am not familiar with concrete silos in the North, but for the South I do not think there can be anything better. I expect to build two concrete silos 16x32 for the Naval Academy Dairy this summer."

Fig. 19. Concrete block silo, built for Rev. Joy Halliday, Delaware, Ohio, by the Perfect Cement Silo and Cistern Co., of Delaware, O. Dimensions, 15 feet in diameter by 50 feet in height. As in the case of other silos in this vicinity, no roof is used.

What It Costs to Build a Concrete Silo

TABLES E and F show the dimensions, tonnage, and actual cost of 78 monolithic and 30 block silos, compiled from data collected during the Spring of 1911. Total costs given include material, labor, superintendence and all miscellaneous expenses incurred in putting the silos in place to receive the crops. Exchange labor has been figured in at the prevailing rates for day labor in the same communities. Where sand and gravel have been obtained on the place, the expense of hauling plus a fair price for the materials has been included in the total cost. The following figures given in terms of cost per ton of capacity represent averages taken from the tables:

Fig. 20. Monolithic silo on the farm of Mr. S. S. Lee, Lowell, Mich., built during 1910 by R. C. Angevine, Coldwater. Diameter, 14 feet; height, 36 feet. Cost, \$350, complete except for gravel and scaffold.

Average Cost of Silos.

	Per Ton of Capacity.	
	Monolithic.	Block.
Illinois	\$2.83	\$2.44*
Michigan	2.31	3.21
Wisconsin	2.10	3.36
Minnesota	2.26	3.34
Average cost of all silos, capacity 100 tons or less.....	2.89	3.52
Average cost of all silos, capacity 100 to 200 tons	2.38	2.88
Average cost of all silos, capacity more than 200 tons	2.18	
Average cost of all silos	2.30	3.11

The cost of a concrete silo depends primarily upon local conditions. The price of gravel and cement and the cost of labor are the determining factors. These vary so greatly, however, with time and place that no attempt will be made to give them here. A good concrete silo of either monolithic or block construction usually costs no more, and in some cases a great deal less, than a good wood, brick or tile silo. The concrete silo has the advantage of a lower cost of up-keep.

*Taken from only two silos. A fair average for the State would undoubtedly be much higher.

TABLE E.
COST OF MONOLITHIC SILOS.

Silo No.	Diameter in ft.	Height in ft.	Capacity in tons	Entire Cost	Cost per ton of capacity	Location
1	16	37	161	\$ 525	\$ 3.26	Belvidere, Illinois
2	16	44	207	695	3.36	Carlton, "
3	15	30	105	400	3.81	Downer's Grove, "
4	16	32	131	500	3.82	Downer's Grove, "
5	20	40	282	550	1.95	Dundee, "
6	20	40	282	720	2.56	Dundee, "
7	12	27	58	241	4.15	Effingham, "
8	18	40	228	620	2.62	Elburn, "
9	18	40	228	620	2.62	Elburn, "
10	20	40	282	680	2.41	Elburn, "
11	20	40	282	680	2.41	Elburn, "
14	16	40	180	550	3.05	Kaneville, "
15	17	42	218	650	2.98	Lake Forest, "
16	17	42	218	650	2.08	Lake Forest, "
17	18	46	277	650	2.35	Marengo, "
18	18	36½	200	409	2.09	Pingree Grove, "
20	18	34	181	490	2.70	St. Charles, "
21	16	30	119	405	3.40	St. Charles, "
22	20	40	282	680	2.41	St. Charles, "
23	18	38	212	575	2.72	St. Charles, "
24	12	38	94	300	3.19	St. Jacob, "
25	18	40	228	550	2.41	Wheaton, "
26	24	50	550	....	....	
27	24	50	550	1600	.97	Winslow, "
28	24	50	550	....	....	
29	20	40	282	500	1.76	Coldwater, Michigan,
30	20	40	282	500	1.76	Coldwater, "
32	14	45	165	306	1.87	Eau Claire, "
33	14	46	170	400	2.35	Eau Claire, "
34	12½	36	95	163	1.72	Eau Claire, "
35	14	36	118	200	1.70	Eau Claire, "
36	..	..	55	190	3.45	Grandville, "
37	11	28	51	105	2.06	Hudsonville, "
38	14	28	83	250	3.00	Kalamazoo, "
39	12	30	67	250	3.72	Kalamazoo, "
42	14	30	91	130	1.43	Lansing, "
43	14	32	100	169	1.69	Lansing, "
44	18	40	228	550	2.41	Marquette, "
45	14	40	138	295	2.14	Parma, "
46	14	40	138	300	2.18	Parma, "
47	12	36	87	230	2.64	Parma, "
48	12	36	87	240	2.75	Parma, "
49	12	36	87	300	3.45	Parma, "
50	14	47	175	300	1.72	Sodus, "
57	20	45	330	550	1.67	Cedarburg, Wisconsin,
58	20	45	330	550	1.67	Cedarburg, "
61	16	30	120	500	4.16	Elkhorn, "
64	16	40	180	275	1.53	Hudson, "
65	14	52	190	600	3.16	Irma, "
66	14	36	118	175	1.48	Lake Geneva, "
68	14	36	118	293	2.48	Madison, "
71	16	30	120	260	2.16	New Richmond, "
72	16	30	120	260	2.16	New Richmond, "
73	16	37	161	199	1.24	New Richmond, "
74	13	30	79	168	2.13	Roberts, "
75	16	30	120	114	.95	Roberts, "
76	16	30	120	180	1.50	Roberts, "

TABLE E—Continued.

Silo No.	Diameter in feet	Height in feet	Capacity in tons	Entire cost	Cost per ton of capacity	LOCATION	
77	16	30	120	177	1.47	Roberts,	Wisconsin
78	16	38	167	195	1.17	Roberts,	"
79	14	35	114	325	2.85	Walworth,	"
80	14	28	83	400	4.80	Walworth,	"
81	60	40	2250	2500	1.11	Waukesha,	"
85	14	29	87	115	1.32	Jordan,	Minnesota
89	20	32	205	380	1.85	Owattona,	"
90	14	28	83	214	2.58	Rose Creek,	"
93	16½	33	144	475	3.30	Wheaton,	"
94	20	40	282	500	1.77	Centerville,	Indiana
95	16	38	167	500	2.99	Fort Wayne,	"
96	16	40	180	550	3.05	Huntington,	"
97	14	30	91	340	3.74	Oil City,	"
102	16	40	180	344	1.91	Roanoke,	Missouri
103	16	32	131	315	2.40	Springfield,	"
104	12	30	67	250	3.72	High Bridge,	Kentucky
105	18	38	211	204	.97	West Paint Lick,	"
106	12	24	49	145	2.96	Fort Collins,	Colorado
107	12	24	49	165	3.36	Fort Collins,	"
108	17	38	190	400	2.10	Iowa City,	Iowa
110	18	40	228	600	2.64	Warren,	Pennsylvania

TABLE F.
COST OF CONCRETE BLOCK SILOS.

Silo No.	Diameter in feet	Height in feet	Capacity in tons	Entire cost	Cost per ton of capacity	LOCATION	
12	16	38	167	\$ 450	\$ 2.70	Kaneville,	Illinois
13	16	44	207	450	2.18	Kaneville,	"
31	12	32	74	163	2.20	Coloma,	Michigan
40	12	30	67	138	2.06	Lansing,	"
41	12	38	94	180	1.92	Lansing,	"
51	8	37	40	227	5.70	Sodus,	"
52	12	30	67	300	4.48	Sodus,	"
53	12	30	67	180	2.70	Zeeland,	"
54	10	20	36	110	4.20	Zeeland,	"
55	10	28	42	160	3.80	Zeeland,	"
56	10½	28	45	170	3.78	Zeeland,	"
59	16	34	143	340	2.38	East Troy,	Wisconsin
60	14	35	114	300	2.64	East Troy,	"
62	14	30	91	450	4.95	Elkhorn,	"
63	18	33	174	400	2.30	Elkhorn,	"
67	12½	38	100	500	5.00	Lake Geneva,	"
69	16	32	131	410	3.13	New Richmond,	"
70	16	32	131	410	3.13	New Richmond,	"
82	16	42	193	550	2.83	Austin,	Minnesota
83	16	30	119	400	3.36	Claremont	"
84	16	32	131	400	3.05	Claremont,	"
86	14	32	100	312	3.12	Litchfield,	"
87	14	32	100	380	3.80	Northfield,	"
88	14	32	100	375	3.75	Northfield,	"
92	14	32	100	225	2.25	Stillwater Jct,	"
98	20	60	530	750	1.42	Delaware,	Ohio
99	14	40	138	420	3.04	Greenfield,	"
100	12	33½	80	250	3.12	Lorain,	"
101	12	30	67	200	2.98	Marysville,	"
109	16	34½	146	475	3.25	Butler,	Pennsylvania

Time Required to Build Concrete Silos

THE average time required to construct a monolithic silo is from one to two weeks, depending upon the height, number of men on the job, conditions of weather, and the height of wall accommodated by the forms at a single filling. Where the work is done by home labor and there is no contractor or competent foreman in charge, occasionally more than 2 weeks are required to complete the work. The block silo can usually be put up in 4 days to a week, depending upon its size and the number of block masons employed. After completion it should be allowed to stand at least a week before filling, to allow the mortar to become firm and hard. If the silo is to be filled during the early part of September, work on the foundation should be commenced no later than August 20th. In all cases the silo should be completed several days before being subjected to the strain caused by filling.

A Comparison of the Monolithic and Concrete Block Types.

Two general methods of concrete construction are available for silo work—the monolithic and the concrete block. With the former method, the materials are hauled to the site of the silo and there mixed and placed within forms; the latter method requires that the block be made and cured in some convenient place, and later hauled to the site to be laid up in the wall.

Each method has certain advantages and disadvantages, but the matter of personal choice generally influences the decision to build either with monolithic walls or with block. The monolithic silo is generally the easier of the two for inexperienced persons to build, and is usually a little cheaper than the block, as it does not require the service of good masons or the use of a block machine; the block silo, however, makes the use of forms unnecessary, produces a wall with continuous vertical air spaces, and slightly reduces the amount of materials used.

The decision to build either of monolithic or of block construction very often depends upon the availability of materials. In localities where materials for monolithic work are abundant and of good quality, it is hardly practical to haul blocks farther than eight or ten miles; on the other hand, if there is no good sand or gravel nearby, block work may be preferred to the monolithic. In such cases, it may be found economical to haul blocks from a greater distance, or make them on the site, if need be.

Fig. 21. Block silo of C. E. Deaner, Sodus, Mich. Although Mr. Deaner has but 17 acres of land, he has a 40-ton silo (diameter, 8 feet; height, 37 feet). Mr. Carl Tillstrom, Benton Harbor, Mich., was the contractor. This silo was erected complete in 8 days.

Building the Silo

CONTRACT WORK:—Where the services of reliable concrete silo contractors can be obtained, it is generally advantageous to have the silo built under contract. The cost of silos built in this manner is generally no more than otherwise when quality of the work, convenience and time are considered. The advantages of good

system, competent overseeing and general experience in the work justifies a greater cash outlay than is needed for home-made silos, although in a great many cases the actual expense of a silo built under contract is no greater than if built by the owner. If it is desired to put up the silo during a time of year when work is over plentiful or farm labor scarce, building the silo under contract will solve the labor problem.

Fig. 22. One of the numerous concrete silos around Coldwater, Mich. E. W. Treat, owner. Diameter, 14 feet; height, 40 feet; capacity, 140 tons.

Of 110 concrete silos recently inspected, 74 were built by contractors, 9 by the owners under experienced foremen, and 27 by the owners without any assistance whatever. In over one-half of the cases where the silo was built under contract the owner furnished a part of the labor, and in about one-fifth of the cases the owners furnished the cement. Almost without exception, the owners of contract-built silos furnished the sand and gravel, for which they received credit on their accounts, at a stipulated rate.

Work Under Hired Foremen:—In a large number of instances farmers have built their own silos under the supervision of a competent foreman hired by the day. Foremen who make a business of superintending silo work frequently have their own forms which they rent to the farmer for a nominal sum. When the silo is built under contract, the farmer usually does the hauling, and sometimes furnishes the materials and a part of the labor; when a foreman is employed, the farmer must buy and haul the materials, furnish the labor, and pay for the work as it progresses, without an accurate previous knowledge of the cost. In addition he sometimes has to build his own forms.

Work Under Home Supervision:—If neither a good contractor nor a good foreman is available, the farmer may undertake the building of the silo, but he must pay close attention to the details of the work. The inexperienced worker with concrete too often considers cement a sort of magic material which may be used without precaution and still secure first class work. On the contrary, precautionary measures are constantly necessary and the directions given on the following pages must be carefully complied with if the best results are to be obtained. To acquaint inexperienced contractors as well as those desiring to build their own silos with the best practice, is the purpose of the two sections immediately following. A later section is devoted to a description of several of the leading commercial silo forms now upon the market.

Co-Operation in Silo Work:—Where there are several silos to be built in the immediate vicinity, and it is desired to use home-made forms and do the work with home labor, a very considerable saving can be made by co-operation. With moderately fair weather, such as usually prevails from April to October, four or five farmers working together can construct moderate size silos in an average time of less than two weeks, working but 4 hours per day, with one set of forms. In about two months' time they can complete a good silo on the place of each, without having this work interfere seriously with general farm duties, and at a comparatively small expense, as only one set of forms is used.

In "The Farmer" for April 29, 1911, Mr. Charles Nelson, of Meeker County, Minnesota, concluded a letter on "Co-operation in Silo Building" with the following paragraph: "Farmers, get together, buy in carload lots material for silos of whatever material desired. Co-operate in building, filling, and in the purchase of machinery. It means a saving of dollars and cents which may be needed for the home or for other improvements."

Fig. 23. Monolithic concrete silo on farm of F. J. Murphy, near Wheaton, Minn., built under the direction of Martin Peterson, contractor. Height, 33 feet; capacity, 144 tons.

Foundations

Laying Out the Work:—The site of the silo having been selected and its size determined, the excavation should be laid out. This may be done conveniently with a sweep similar to the one shown in Figure 24. A heavy stake is driven in the center of the spot selected for the silo and allowed to project above the surface about one foot. The arm of the sweep may be made of a two-by-four at least two feet longer than one-half the inside diameter of the silo. The arm swings about the stake as a center, being held to the latter by a large spike. A chisel-shaped board or template is placed as shown on the arm of the sweep, so that when the latter is swung around the stake, the chisel-shaped board will describe a circle with a diameter $2\frac{1}{2}$ feet greater than the inside diameter of the completed silo. This will give the outer line of the excavation and also foundation.

Figure 24. Simple sweep, convenient in laying out excavation.

Excavating:—The excavation should be carried to a depth not to exceed 6 feet below the floor of the barn where the silage is to be fed. The objection to going deeper is that it adds to the labor in removing the silage. In all cases, however, the foundation should be established below frost. All of the earth within the line described by the sweep should be removed down to a point one foot from the bottom, and below this the excavation should be made the shape and size of the foundation, 2 feet wide by 1 foot in depth, so placed that the outer edge will come directly up to the edge of the excavation, assuming that the sides of the latter are perpendicular.

If the silo is to be equipped with a concrete chute, the foundation for the chute should be put in at the same time as that for the silo. As the chute is rectangular in shape, no difficulty should be encountered in excavating for the foundation, which will be at the same depth as the silo foundation, and two feet in width by one foot in depth.

Placing the Concrete:—The concrete for the foundations should be made in the proportion of 1 sack Portland cement to 3 cubic feet of coarse sand, to 5 cubic feet of screened gravel or crushed stone. The sand should be free from clay or organic matter, and the gravel or stone should contain no particle smaller in size than $\frac{1}{4}$ inch. The materials must be thoroughly mixed and enough water added to give a quaky consistency. The concrete may usually be placed in the exca-

vation without any forms whatever, but in some kinds of soil light boards, held in position by stakes, may be necessary. The top of the foundation must be levelled off with a straight edged board and spirit level. After 24 hours, the foundations have generally hardened sufficiently so that the walls may be built upon them. Where soft ground or quicksand is encountered, the foundation may be made 3 or 4 feet in width, to provide plenty of footing.

Figure 25. Concrete Silo Footing and floor, suitable for either Monolithic or Block Silos.

Imbedding Reinforcing Rods:—If a monolithic silo is to be built, the vertical reinforcing for the walls, consisting of $\frac{1}{2}$ -inch round rods spaced 3 feet apart, should be imbedded in the foundation a distance of 8 or 9 inches. If a block silo is to be built no vertical reinforcing need be placed.

TABLE G

MATERIALS FOR SILO FOOTINGS AND FLOORS.

Silo Diameter in feet or Silo	1.25 Concrete Cu. Yds.	Footings'			4" Base 1.25 Concrete Cu. Yds.	Floor			Footings and Floor		
		Quantities				Quantities			Total quantities		
		Cement Bbls.	Sand yds.	Gravel yds.		Cement Bbls.	Sand yds.	Gravel yds.	Cement Bbls.	Sand yds.	Gravel yds.
8	1.5	1.8	0.7	1.4	0.5	.62	.25	.46	2.42	0.93	1.86
10	1.8	2.2	0.8	1.6	0.8	1.00	.37	.75	3.19	1.17	2.34
12	2.2	2.7	1.0	2.0	1.0	1.25	.46	.92	3.94	1.46	2.92
14	2.5	3.1	1.2	2.4	1.6	2.00	.75	1.50	5.08	1.94	3.77
16	2.9	3.6	1.3	2.6	2.2	2.75	1.00	2.03	6.33	2.31	4.62
18	3.2	4.0	1.5	3.0	2.8	3.50	1.30	2.58	7.47	2.79	5.58
20	3.6	4.4	1.6	3.2	3.5	4.35	1.60	3.22	8.74	3.21	6.42
22	3.9	4.8	1.8	3.6	4.3	5.33	2.00	4.00	10.13	3.78	7.56

The Floor:—After the foundation is completed, the earth within should be dug out for a depth of about 8 inches, and a concrete floor built as shown in Figure 25. The floor should be given a slight pitch in all directions toward the center, and, if necessary, an outlet to a line of drain tile should be put in. Outlets are not usually provided in silo floors, but in one or two instances silos have failed because of the pressure of a large quantity of water accumulated under unusual conditions, with no provision for escape. In such cases the stress on the walls may reach two or three times that usually imposed by the silage. Although the majority of silos are not provided with a drain, it is undoubtedly a desirable feature. The top of the drain should be protected from accumulations on the silo floor, by a small wire mat. A 4-inch or 6-inch drain tile will be sufficient. The floor should be made of 1:2½:5 concrete. A smooth finish is not considered necessary.

Figure 26. Model of the Farmers Institute Silo Forms, which has been the means of showing scores of Northern Wisconsin farmers how to build concrete silos. Forms built after this model cost \$60 to \$75. Mr. David Imrie, of Roberts, Wisconsin, is owner of this model.

Monolithic Concrete Silos

THE word "Monolithic" coming from "mono" meaning one, and "lith" meaning stone, is used in concrete work to denote the objects of concrete which are one continuous solid mass or "as one stone." Contrasting with the monolithic are several systems of concrete construction such as the concrete block, concrete brick, concrete tile, unit column and slab, and cement plaster. The systems of concrete construction most commonly used are the monolithic and the concrete block. The object of the present section is to supply the necessary information for constructing monolithic silos, in cases where the work is all done by the owner who is dependent entirely upon his own resources, or by contractors not familiar with this class of work.

Home-Made Forms.

The form described and shown on the following pages is a combination of the Wisconsin form, designed by the Agricultural Department of the University at Madison, under Professor C. A. Ocock, and the Farmers' Institute form, designed by Messrs. John and David Imrie of Roberts, Wisconsin. Both of these forms have been used with great success among the farmers of Wisconsin and adjoining states and appear to be in many respects the most practical forms yet devised. Figure 26 shows a photograph of a model of the Farmers' Institute Form. The model was obtained through the courtesy of Mr. David Imrie, who has introduced this form to hundreds of farmers in conjunction with the work of the Wisconsin Farmers' Institute.

Description of Forms:—The inner form consists simply of 16 segments or ribs made of 2"x12" plank, 16 cleats made of 2"x6" plank, a number of 1"x6" matched floor boards, a quantity of No. 28 gauge galvanized sheet steel, and 64 ½-inch bolts 4½ inches long. (See Figures 28 and 29.)

In making the form it will be convenient to refer to the table of materials given on page 43, for the dimensions of the ribs. The procedure should be about as follows:

Draw a circle on the barn floor, of a diameter two inches less than the inside diameter of the silo. For this purpose use a sweep

Fig. 27. The first monolithic silo in Northern Wisconsin, built by G. W. Graham, of Roberts, with the Farmers Institute Silo Farms, a photo of which is shown on page 38. Mr. Graham's silo cost \$114, and has a capacity of 120 tons.

with a soft pencil or crayon attached to one end. Do not use a cord and chalk as the former will stretch enough to distort the circle, and the latter will make too wide a line. Space off the circumference into eight equal distances. (These may be obtained by taking distance "C" from the table of materials.) For the ribs lay down the 2"x12" planks on the circle drawn, marking the arc on each plank with the sweep. The length of the rib should also be marked off on the plank in a radial direction, using the sweep as a guide. All of the dimensions for the ribs may be obtained from the table of materials, if desired. A hole 4"x4½" is cut in the center of each rib, as shown in the sketch accompanying the table of materials, page 43.

Figure 28. Plan of home made wall forms, and details of outside form.

The 1"x6" flooring boards are sawed up into 3-foot lengths and nailed to the outer edges of the ribs, the latter being placed 2 feet apart center to center. These boards are covered with the galvanized sheet metal. Eight similar sections are made and are held together with 2"x6" cleats 2 feet long, cut to the same circle as the ribs. This is very important, as the sections are thus held to a true circle. The

Figure 29. Perspective of Inner Wall Form, showing position of 2 in. x 4 in. Uprights upon which the Form is raised.

Figure 30. Sectional Plan and Elevation of Continuous Doorway Used on Wisconsin Silos, also Sketches of Continuous Door and Device for raising outer Forms.

cleats are bolted on, and the form then tightened by means of two keys directly opposite, as shown in the plan and perspective Figures 28 and 29. The keys are made of 2x4's 3 feet long, having a very slight taper. After the form is bolted together, the keys should be driven down.

This form is provided with a very simple arrangement for supporting, also for raising and lowering. Each rib has a hole 4 inches by 4½ inches centrally located, through which passes a 4x4 upright made of two 2x4's nailed together. One-half inch holes are drilled in these at intervals of two and one-half feet, corresponding holes on all of the uprights being at the same level. After raising the form to a new position, bolts are inserted in the holes directly under the bottom ribs of the form. As the work progresses upward additional 2x4's are spliced on alternately.

The outside form is made of heavy (No. 18 or No. 20 gauge) galvanized sheet steel 3 feet in width. The form is made in pieces connected with one-half inch bolts 12 inches long and threaded to permit loosening and tightening of the form when raised. Three strips of heavy band iron are riveted on each side of the joint, the ends near the joints being turned out at right angles and provided with holes to receive the bolts. These strips are clearly shown, in a somewhat exaggerated form, in the photograph of the model. A heavy wire handle is put on the outside form opposite each pair of 2x4" uprights for the purpose of raising. To each handle is fastened

Figure 31. Illustration showing the method of bracing the upright supports on which the inner forms rest. Bracing between adjacent uprights is put in every five feet; those joining opposite uprights are put on every fifteen feet.

a ¾-inch rope 6 feet long. This rope is run over a little bracket which slides up and down the uprights.

TABLE H

MATERIALS FOR HOME MADE SILO FORMS

For Silos with Inside Diameters 8 feet to 22 feet.

16—2"x12" plank, cut as per sizes given in table.

1"x 6" boards, for quantity see table.

16—2"x 6" cleats—3' long, cut on radius "r."

2"x 4" studding planed. (Required quantity equal to 16 times the height of the silo.)

No. 22 Gauge galvanized sheet iron 3 feet wide. (For quantity see table.)

No. 18 " " " " 3 " " (" " " " ")

64 ½-inch bolts 4½ inches long (for cleats).

8 ½- " " 6 " " (under forms).

6 ½- " " 12 " " (for outer forms).

4 Iron Straps ¼"x2"x3' 0"

12 " " ¼"x2"x2' 6"

Fig. 32—Inner Form Ribs

Inside Diam. of Silo	Dimensions of inner form ribs				No. of "x6" Boards 3' long in inner form	No. 18 gauge galvanized sheet iron 3' wide Feet Needed	No. 28 gauge galvanized sheet iron 3' wide Feet Needed
	A	B	C	R			
8 ft.	9 "	2' 5¼"	3' 0⅞"	3' 11"	51	30' 3"	25' 0"
10 "	8 "	3' 3 ¼"	3' 10½"	4' 11"	63	36' 7"	31' 6"
12 "	6¾"	4' 1½"	4' 7⅞"	5' 11"	76	42' 10"	37' 8"
14 "	6 "	4' 10½"	5' 5¾"	6' 11"	88	49' 3"	44' 0"
16 "	5 "	5' 9 "	6' 2½"	7' 11"	101	55' 6"	50' 0"
18 "	4½"	6' 6½"	7' 0¼"	8' 11"	113	61' 9"	56' 6"
20 "	3 "	7' 4¾"	7' 9¾"	9' 11"	126	68' 0"	62' 10"
22 "	2½"	8' 3 "	8' 7¼"	10' 11"	138	74' 5"	69' 2"

Cost of Forms:—Forms of this type can be made for twenty-five to fifty dollars, and in one instance a farmer built an equipment similar to that described here at a cash outlay of only \$15.00. Forms can generally be disposed of after use at a price equal to the total cash outlay to the builder, so that the use of these in building his silo only costs him his labor. A single set of forms is often used on several silos, each user selling his forms to the next man for a sum slightly less than what he paid for them.

Care in Bracing Supports:—As the inner form is moved upwards it will be necessary to securely brace the upright supports. This is very essential. No weak or rotten lumber should be used, and all bracing should be put where it will carry the load in the best and most secure manner. The double two-by-four supports recommended have ample strength to carry the weight if properly braced, but this precaution must not be neglected.

The uprights should be braced at intervals of five feet (every two courses) with horizontal boards running from one upright to the next, and braced back against the wall as shown in Figure 31. Boards 1"x6" or 2"x4" will be large enough for this purpose. About every 15

feet braces should be run across to opposite uprights, 2x4" or 2x6" material being used.

Importance of a Smooth Wall:—In handling the inner forms, great care must be observed in keeping the inside surface of the silo perfectly smooth. Horizontal, "steps" in the wall are particularly objectionable. Projections, "steps" and other irregularities cause uneven settling of the silage, thus forming air pockets. The presence of an air pocket frequently causes silage within a foot of the pocket on all sides to spoil.

Painting the Forms:—The inner surfaces of the forms should be painted before using, with crude oil or whitewash, which will prevent

Figure 33. Continuous Steel Doorway, showing manner of anchoring frames to the vertical reinforcing, and position of plank doors.

the concrete from sticking. This treatment is especially important where forms have wooden surfaces, but is also beneficial when applied to galvanized iron surfaces.

Doorways

Continuous and non-continuous doorways are used about equally in monolithic silo construction and the question of which to use is generally settled by personal choice. The continuous doorway has the advantage of providing a larger space through which to throw the silage and for this reason is preferred by many. The non-continuous doorways, as used by some of the best contractors, have no disadvantage except they provide a smaller space through which to remove the silage.

Continuous Doorways:—The best kind of a continuous doorway can be made by using two 4-inch 5¼-pound steel channels, of a length 1 foot greater than the distance from the floor of the barn to the top of the silo. Holes large enough to receive ¾-inch rods must be

drilled in both channels in the same relative position at intervals of 12 inches. Through these the $\frac{3}{4}$ -inch stay rods are placed as shown in Figure 33. Between each stay rod hole in each channel, a hole is drilled to receive the $\frac{1}{2}$ -inch hooked bolts, which are fastened to the vertical reinforcing rods, adjacent to the doorway.

Frames and Doors:—Before commencing work on the silo walls, the channel for the door frame should be drilled as shown in Figure 34 and the frame assembled by means of the bolts.

It will probably be found convenient to order the channels and rods from the local blacksmith, who has facilities for drilling the holes in the channels and threading the rods as required. The door frame may then be brought on the job ready to be assembled. The doors should also be made before the wall is commenced. These consist simply of 2x12-inch plank planed on both sides, 34 inches long, with $\frac{3}{8}$ -inch holes drilled through the center to accommodate the bolt and hook by which the door is held to the $\frac{1}{2}$ -inch bolt in the frame. The bolt in the center of each door has a screw eye on the outer side on which hangs a common gate hook. (See Figure 33). The doors are given a slight taper all around towards the outside.

Erecting and Anchoring Door Frames:—

As soon as the silo wall has been brought up to within 1 foot of the level of the barn floor, the door frame is raised to the position it is to occupy in the silo and held securely in place by means of wooden bracing and guy ropes. The wall is then continued up to the level of the barn floor.

In the case of tall silos, where the steel frames have to be made in two or more sections, it will be found convenient to put in only one section at a time. The sections may be joined together with splice plates. Five or six of the wooden doors should be painted with crude oil and then put on and the concreting resumed.

These doors are placed in position for the purpose of keeping the concrete from running around the steel frames on the inner side of the wall, which would otherwise be possible since the distance between the inner and outer forms is 6 inches and the width of the frame but 4 inches. After the work has proceeded upwards a short distance some of the lowest doors may be removed, taking care not to knock off corners of

Figure 34. Spacing of holes in Steel Channel Side Frame for continuous door openings.

Fig. 35. Wooden form for a non-continuous doorway and steel frame made of angle iron.

Non-continuous doors are often put in with a distance of about $2\frac{1}{2}$ feet between them, but the spacing may vary to suit the individual owner. In all cases the arches between the doors must contain an amount of reinforcing equivalent to the full amount of horizontal reinforcing put around the silo. Thus, if the doors are 3 feet in height, with a distance of $2\frac{1}{2}$ feet between them, the horizontal reinforcing in the space between the doors should be equivalent in amount to that placed in $5\frac{1}{2}$ feet of the wall where there are no doors.

Doorway Form and Frame: Figure 35 shows a form for a non-continuous door opening. The bottom and top pieces are made of 2x6" plank cut to the arc of a circle with diameter the same as the outer diameter of the silo wall. The two sides are made of two-by-fours. A frame of lighter material is placed around the outside of the form for the purpose of making a recess two inches deep around the opening on the inner side of the wall, into which the door will fit. This frame is tapered to permit removal from the wall as soon as the concrete has hardened. It may then be used again for the next doorway above.

If desired, a door frame of small angle iron (as shown) may be used to protect the corners of the concrete. The frame should be slipped on over the form, and both frame and form then placed in position. The angle iron should be cut a few inches longer than the dimensions of the opening and the ends embedded in the concrete. The frame should also be anchored to the concrete by large spikes. Holes to receive the spikes should be drilled in the angles, 12 inches apart. The spikes should be bent at right angles to secure a better hold in the wall.

green concrete. These doors may then be replaced on the frame at a point above the forms.

Non-continuous doors:—Non-continuous doors are perhaps easier to build than continuous doorways, and if the owners are satisfied that they provide sufficient room for getting the silage out conveniently, there is no objection to their use, although on the other hand, they possess no great advantage over doors of the continuous type. The arguments often heard that the non-continuous door silo is a stronger type than the other, and vice versa, carry little weight, as either type may be made sufficiently strong.

Figure 36. Non-continuous Door, made of double layers of flooring with building paper between.

Doors:—The doors may best be made of two thicknesses of 1x6" matched flooring with a layer of tar paper between. The 1x6" boards are held together by two 1x4" cleats across the top and bottom, and one 2x4" cleat across the center. The middle cleat is made larger than the others in order to take care of the strain caused by the large bolt in the center. A two-by-four, 40 inches long, or a similar piece of material, is placed on the bolt, making a large "button" by which the door is held to the wall. The door is clearly shown in Figure 36.

Fig. 37. Twin Silos of Mr. M. S. Dauberman, Big Rock, Illinois. One is of concrete block, the other of monolithic construction. Both are economical and keep silage perfectly.

Constructing Monolithic Silo Walls

AS soon as the foundation has hardened sufficiently to allow the work to proceed, the wall forms may be placed in position. Much care should be taken to locate them centrally and in such a manner that the sides are perpendicular. The 4x4-inch up-rights should be carefully put in position at this time, being sup-

ported on wooden blocks or flat stones. After the inner form is in position, but before the outer form is placed, the horizontal reinforcing rods for the first three feet of wall should be wired to the vertical rods which were placed in foundation as previously mentioned. The outer forms should then be placed in position and tightened, with the small wooden spacers in place. Before placing the concrete, it will be necessary to clean off the surface of the foundation and moisten it thoroughly. The wall forms, having been previously painted with crude oil or whitewash to prevent sticking, may then be filled with slushy concrete made in the proportion of one sack of Portland Cement to two and one-half cubic feet of coarse sand, to four cubic feet of screened gravel or crushed stone, all of the latter being between $\frac{1}{4}$ inch and $1\frac{1}{2}$ inch in size.

Fig. 38. R. N. Quimby's silo, Batavia, Mich. Built by R. C. Angevine, Coldwater. Capacity, 90 tons; height, 36 feet.

During the Summer 24 hours is usually enough for concrete to harden before raising the forms, but in cool weather a longer time will be required. If the work be undertaken while there is danger of freezing, the usual cold weather precautions must be observed. In such cases the materials should be heated, or at least free from frost, and mixed with hot water. The work in the forms must be protected for several days with manure, straw or a canvas jacket under which live steam is run.

Tables of Materials:—Table I shows the approximate number of cubic yards of concrete required for the walls of monolithic silos of various sizes, with continuous doors, and walls 6 inches thick. Table J shows the quantities of cement, sand and gravel or stone required for silo walls, using proportions of 1 sack of cement to $2\frac{1}{2}$ cubic feet of sand and 4 cubic feet of screened gravel or stone. It can hardly be expected that these tables will be exact in all cases, as

TABLE I

CUBIC YARDS OF CONCRETE.

Required for walls of Monolithic Silos with continuous doors.

Walls 6 Inches Thick.

Height of silo in feet	INSIDE DIAMETER OF SILO.							
	8 ft.	10 ft.	12 ft.	14 ft.	16 ft.	18 ft.	20 ft.	22 ft.
20	9.0	11.4	13.7	16.2	18.3	....	....	....
22	9.9	12.6	15.0	17.8	20.0	22.8	....	....
24	10.8	13.8	16.4	19.4	22.0	25.0	27.7	....
26	11.7	15.0	17.8	21.0	23.7	27.0	30.0	....
28	12.6	16.0	19.0	22.6	25.5	29.0	32.1	35.6
30	13.5	17.2	20.6	24.1	27.5	31.0	34.5	38.3
32	14.4	18.3	21.9	25.8	29.0	33.1	36.8	40.8
34	15.3	19.5	23.2	27.5	31.0	35.1	39.0	43.1
36	16.2	20.6	24.5	29.0	32.9	37.2	41.2	46.0
38	17.1	21.8	26.0	30.8	34.8	39.4	43.6	48.4
40	18.0	22.8	27.2	32.0	36.4	41.2	46.0	51.2
42	....	24.0	28.7	34.0	38.4	43.4	48.3	53.5
44	....	....	30.0	35.6	40.0	46.8	51.0	56.5
46	....	....	....	37.1	42.0	47.8	53.0	58.5
48	....	....	....	....	43.9	50.0	55.0	61.5
50	....	....	....	....	....	51.5	57.5	64.0

the difference in sand and gravel used, as well as other considerations, affect the quantities of materials to a considerable extent. These tables are accurate to within 10 per cent.

Moving up Forms for the Next Course:—To release the inner form, drive out the keys and if need be, remove a few of the bolts. Slide up the inner form on the upright supports and secure in the new position by the bolts passed through the supports just below the form, as previously explained. The inner form will then be bolted together again and the keys driven into place. After attaching horizontal reinforcing rods to the vertical rods for the second course, the bolts in the outer form are loosened and the form raised by means of ropes attached to wire handles and running over the little brackets on the uprights. When the outer form is raised to a position flush with the inner form, the lower bolt should be tightened until the form presses snugly against the wall; spacers should then be placed between the forms and the remaining two bolts tightened until the proper spacing is secured. The forms are then ready for the next filling.

Fig. 39. Twin monolithic silos, built by J. H. McCoy, of Harrisburg, Pa., on the farm of Professor F. R. Lilly, near Wheeling, Ill. Both silos are 18 feet in diameter, and have a height of about 42 feet and a combined capacity of 500 tons. The walls are 7 inches thick.

TABLE J.
CEMENT, SAND AND STONE

Required for Walls of Monolithic Silos.

Thickness of Walls, 6 inches. Continuous Doors, 2½ feet wide. Proportions for Concrete, 1:2½:4.
(For silos with non-continuous doors a slightly greater quantity of materials is necessary.)

Ht. of Silo ft.	Bbls. of Cement Required for given inside diameter in ft.								Cu. Yds. of Sand Required for given inside diameter in ft.								Cu. Yds. of Gravel Required for given inside diameter in ft.							
	8	10	12	14	16	18	20	22	8	10	12	14	16	18	20	22	8	10	12	14	16	18	20	22
	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
20	12.6	16.0	19.0	22.6	25.4	28.0	30.6	33.2	4.6	5.8	7.0	8.4	9.3	10.6	11.6	12.6	7.4	9.4	11.2	13.3	15.2	17.8	20.6	22.8
22	13.8	17.1	21.0	24.9	28.9	32.6	35.0	38.5	5.1	6.3	7.7	9.0	10.2	11.6	12.7	14.1	8.2	10.4	12.4	14.8	16.5	18.8	20.6	22.8
24	15.1	19.2	22.8	27.1	30.7	35.0	38.5	42.0	5.6	7.0	8.6	9.9	11.2	12.7	14.1	15.5	8.9	11.4	13.5	16.0	18.2	20.6	22.8	25.0
26	16.3	21.0	24.8	29.3	33.0	37.8	41.8	45.7	6.0	7.7	9.4	10.7	12.1	13.7	15.3	16.8	9.6	12.4	14.7	17.4	19.6	22.2	24.8	27.4
28	17.6	22.3	26.6	31.5	35.5	40.6	44.9	49.5	6.5	8.4	10.2	11.6	13.0	14.8	16.4	18.1	10.4	13.3	15.8	18.7	21.0	23.6	26.5	29.4
30	18.9	24.0	28.8	33.8	38.2	43.4	48.0	53.5	7.0	9.1	11.2	12.7	14.0	15.8	17.5	19.5	11.1	14.2	17.0	19.8	22.8	25.5	28.5	31.5
32	20.1	25.7	30.7	36.0	40.5	46.0	51.4	57.0	7.5	10.0	11.8	14.0	15.8	17.9	19.9	22.0	11.8	15.0	18.0	21.3	24.0	27.3	30.3	33.6
34	21.4	27.4	32.3	38.3	43.1	49.0	54.5	60.0	8.0	10.5	12.5	14.8	16.8	19.0	21.0	23.4	12.6	16.1	19.2	22.5	25.5	29.0	32.0	35.5
36	22.6	28.7	34.2	40.4	45.8	52.0	57.5	64.0	8.5	11.1	13.2	15.7	17.8	20.1	22.2	24.6	13.3	17.0	20.3	24.0	27.2	30.6	34.0	38.0
38	23.9	30.3	36.2	42.8	48.7	55.0	60.8	67.5	9.0	11.6	14.0	16.4	18.6	21.2	23.6	26.1	14.1	18.0	21.5	25.4	28.7	32.5	35.9	39.7
40	25.1	31.7	37.8	44.5	50.5	57.5	64.0	71.3	9.5	12.3	14.6	17.3	19.5	22.4	24.6	27.3	14.8	18.8	22.4	26.4	30.0	34.0	38.0	42.0
42	26.3	33.5	40.0	47.4	53.7	60.5	67.5	74.6	10.0	13.3	15.7	18.4	20.8	23.9	26.9	29.8	15.5	19.9	23.8	28.0	31.7	35.6	40.0	44.4
44	27.5	34.9	41.8	49.6	56.8	63.8	71.0	78.7	10.5	14.0	16.6	19.4	22.0	25.4	28.4	31.8	16.0	20.8	25.0	29.2	33.0	37.4	41.8	46.4
46	28.7	36.3	43.6	51.8	59.6	67.5	74.0	81.6	11.0	14.8	17.6	20.6	23.4	27.0	30.0	33.6	16.5	21.5	26.0	30.6	34.7	39.3	43.5	48.0
48	29.9	37.7	45.4	54.0	62.5	70.5	76.6	85.7	11.5	15.5	18.6	21.8	24.8	28.6	32.3	36.0	17.0	22.5	27.4	32.0	36.0	41.0	45.0	50.5
50	31.1	39.1	47.2	56.0	65.0	73.5	80.0	89.0	12.0	16.3	19.6	23.0	26.2	30.0	33.8	37.6	17.5	23.5	28.8	33.6	38.0	42.3	47.2	52.6

TABLE K
SPACING OF HORIZONTAL REINFORCING RODS IN MONOLITHIC SILOS.
In Inches.

Diameter of rods in inches	D I A M E T E R O F S I L O I N F E E T											
	8ft.	10ft.	12ft.	14ft.	16ft.	18ft.	20ft.	22ft.				
Dipth from top in feet From top	1	2	3	4	5	6	7	8	9	10	11	12
0-4	18	18	18	18	18	18	18	18	18	18	18	18
4-8	18	18	17	17	17	17	17	17	17	17	17	17
8-12	18	15	12	10	9	8	8	8	8	8	8	8
12-16	18	11	9	17 7/8	15 7/8	13 1/2	12 1/2	12 1/2	12 1/2	12 1/2	12 1/2	12 1/2
16-20	18	9	16	13	12	11	11	11	11	11	11	11
20-24	15	16	13	12	11	10	10	10	10	10	10	10
24-28	15	14	12	10	9	8	8	8	8	8	8	8
28-32	15	12	10	9	8	7	7	7	7	7	7	7
32-36	15	11	9	8	7	6	6	6	6	6	6	6
36-40	12	10	8	7	6	5	5	5	5	5	5	5
40-44	9	4	13	7	6	5	5	5	5	5	5	5
44-48	9	9	9	10	14	13	13	13	13	13	13	13
48-50	9	9	9	9	9	12	12	12	12	12	12	12

Joining Courses:—Immediately before the concrete is placed for each succeeding course, the surface of that previously laid should be thoroughly cleaned off and moistened, and coated with a cement and water grout of about the consistency of cream. This precaution is necessary to secure a good bond between the courses. It should be observed in all cases, as the pressure of the silage is apt to force moisture through any seams which might occur because of imperfect bond. Concreting should not be discontinued with a course partially completed, but if this is unavoidable the concrete surface should be left as nearly vertical as possible.

Height of Wall at Each Filling:—Although the forms are made 3 feet in height, the height of the wall built at each filling (after the first) will be 2 feet 6 inches, allowing the forms to cover 6 inches of finished wall when in position to be filled again. Experiment has shown that this is about the best height to fill at one time, as it makes about one-half day's work for the average farm crew when the mixing is done by hand. In reasonably good weather it should be possible for home labor to raise the forms each morning, refill in the forenoon and have the remainder of the day free for various farm duties.

Labor Required:—The following estimate of labor required to construct monolithic silos is based on experience in a large number of cases, the materials being mixed by hand. The labor here given is approximate, and does not include that required to haul materials:

Silos	8 feet in diameter	10 to 14 days (4 hours per day)	4 men
"	12 " "	" 10 to 16 "	" " " " 4 men
"	16 " "	" 10 to 16 "	" " " " 4 to 5 men
"	20 " "	" 10 to 20 "	" " " " 5 men
"	22 " "	" 12 to 20 "	" " " " 5 men

Reinforcing:—Steel rods are preferable to other kinds of reinforcing only because they come in standard sizes, the strength of which is definitely known. Any other kind of reinforcing, such as heavy wire fencing or other material of steel, having one section rigidly attached to another will do the work equally well, and may be successfully used if a sufficient quantity is put in to give a cross-section area equal to that of the rods recommended in table K.

Spacing of Rods:—For all silos, regardless of diameter or height, the vertical reinforcing should be $\frac{1}{2}$ -inch round or twisted rods placed in the middle of the wall at intervals of about 3 feet. The size and spacing of the horizontal reinforcing depends upon the diameter

Fig. 40. Simon Wierda silo, Zeeland, Mich., built of ornamental blocks with strap iron reinforcing placed on the outside. Capacity, 26 tons; cost, \$110. The blocks are solid and but 3 inches thick. This silo was built in 1905, and although of exceptionally thin block, exhibits no cracks or other evidences of failure.

of the silo and the distance from the top, and may be obtained for any given silo by referring to Table K. The first horizontal rods should be placed 2 inches above the foundation. Wherever rods are spliced, they must be lapped for a distance equal to 64 times the diameter, which is 16 inches for $\frac{1}{4}$ -inch rods, 24 inches for $\frac{3}{8}$ -inch rods and 32 inches for $\frac{1}{2}$ -inch rods. Immediately before the outer form is raised to position the horizontal rods should be wired in place for a distance equal to the height of the forms. The position of the reinforcing is very clearly shown in the sectional view, Figure 61. Where a concrete cornice is put on an extra reinforcing band is put around the top for the purpose of strengthening it.

Example:—Required, the proper spacing of horizontal reinforcing rods in a monolithic concrete silo 18 feet in diameter and 44 feet in height. Referring to Table K, we run across the horizontal column at the top to "18 feet." Referring to the figures directly below we find that four sizes of rods may be used in reinforcing a silo of this diameter. The first four feet of the silo, i. e., starting 44 feet from the top and running to 40 feet from the top (see left hand vertical column) may be reinforced with $\frac{5}{8}$ -inch round rods 14 inches apart, $\frac{1}{2}$ -inch round rods 9 inches apart, or $\frac{3}{8}$ -inch round rods 5 inches apart, as shown in the columns under 18 feet, and parallel to 40 feet—44 feet depth from top. Above this point the intervals between reinforcing should be made larger, or a smaller size rod used, according to the table. Thus at the top of this silo, i. e., at a depth of 0-4 feet from the top, the reinforcing should consist of $\frac{1}{4}$ -inch rods spaced 12 inches apart. Reinforcing rods are sold by weight, in stock lengths. One-fourth-inch rods weigh 16.84 lbs. per 100 feet; $\frac{3}{8}$ -inch round rods 37.5 lbs. per 100 feet; $\frac{1}{2}$ -inch rods 66.7 lbs. per 100 feet.

Hoisting Materials:—The work of constructing the silo will be made much easier if a convenient method of hoisting materials is adopted at the start. The old scheme of raising the concrete by hand with a rope and a bucket wastes time and materials and means much unnecessary labor. Materials may best be raised with a rope and pulley, the latter attached either to a derrick frame, as shown in

Figure 41. Convenient Derrick for hoisting materials. Design adopted from a similar one by the Iowa State College, Ames, Iowa.

Figure 41, or suspended from a frame resting on top of forms, the power in either case being furnished by a horse. The derrick shown in the figure may be built to any height required, in the following manner: Pieces marked "A" (2x6 inches, 16 feet long) are spliced together until a height at least 6 feet greater than that of the completed walls is obtained. Pieces "B" (1x6 inches) are nailed to "A" in such a manner as to make an I-beam as shown in the sectional view in the center. The cross arm is made of a 2x6 inch piece 3 feet long spiked to piece "A" and prevented from raising at the back end by piece "B" which runs flush with the top of the arm. The brace is made of 2x6 inch material, 3 feet 2 inches long. The three No. 9 guy wires are fastened to the cross arm and brought around in grooves provided for the purpose and fastened to stakes driven in the ground for a considerable distance from the bottom of the derrick. This device, which has been recommended by the Iowa Experiment Station, is said to have been tested and found safe for loads less than 400 pounds.

Fig. 42. Two monolithic concrete silos, built by the Polk-Genung-Polk Company for Mr. B. W. Lord, Danville, Ky. The right hand silo has a water supply tank 4 feet in depth on top. Both silos are 16 feet in diameter by 45 feet in height.

Commercial Monolithic Silo Systems

SEVERAL very ingenious systems of silo forms have been devised and put into use in various parts of the country by silo contractors and construction companies. These are of a more substantial type than the home made forms and in most cases the same form may be used to build a great number of silos. Manufacturers of these forms generally contract to build silos by their systems, but often sell the forms and territory rights or rent them to prospective builders for the job. A few of the best systems in use in the central part of this country are briefly described in the following paragraphs:*

The Polk System:—This system, which is shown in its entirety in the illustration, Figure 43, is operated by the Polk-Genung-Polk Company of Fort Branch, Indiana, and a number of licensed contractors. The inner and outer forms are of heavy galvanized sheet iron, stiffened with angle iron. They are suspended by rods and chains from an iron collar which slides on a hollow steel mast. The

Fig. 43. The Polk System in service, showing the patented metallic forms, method of raising and securing forms by the center mast, reinforcing metal, and appliance for hoisting materials. Two sections of the form are removed to permit a view within the silo.

*It is hoped to give a more complete list in a future edition.

inner and outer forms are kept perpendicular and also held at proper distances apart by radial horizontal angle irons. These also serve to hold a platform.

One of the chief advantages of the Polk System is the method of elevating the concrete and depositing it within the forms. The apparatus consists of a steel bucket and cable, the latter running over a pulley attached to a trolley which travels on a steel boom. This boom is attached to the central mast by means of a collar which allows it to swing around in a full circle. After it is filled with concrete the bucket travels upwards until it reaches the trolley on the boom. The trolley is then released automatically and the bucket travels until directly over the forms. The trolley is prevented from going further by a stop consisting of a steel pin placed through a hole in the boom. Power for elevating the materials is generally supplied by a horse. The forms are raised in the following manner: A small flat collar is pinned in position to the mast about two feet below the collar which supports the forms. Two long jacks are then placed on the flat top of the lower collar in such a manner as to raise the upper collars when the jacks are operated. The mast is provided with holes a short distance apart to receive steel pins, and as soon as the jacks have been raised to their limit a pin is placed through the mast just below the upper cylindrical collar to prevent the form dropping while the jacks are being moved up to a new position. The forms must be loosened, of course, before any attempt is made to raise them with the jacks.

The silos constructed by the Polk System have single walls six inches thick, reinforced with twisted steel rods $\frac{1}{4}$ -inch to $\frac{5}{8}$ -inch in size. They are built with elliptical door openings, one door to every five feet in height. Except where especially desired by the

Fig. 44. New Enterprise Concrete Machinery Company's silo form. The form for the round concrete chute, at the right of the illustration is worthy of special note. The form is made entirely of steel.

owner, roofs and chutes are not supplied. The former are considered unnecessary except in cold climates, and on most of the silos constructed by this company the owners have used cheap chutes of wood.

The Polk System is thoroughly protected by United States patents.

The New Enterprise System.—The New Enterprise forms, manufactured by the New Enterprise Concrete Machinery Company of Chicago, and used by the above company and a large number of silo contractors, are built of heavy galvanized sheet iron with angle iron stiffeners. Both inner and outer forms are built in sections which are coupled together with small steel pins or spikes. They are held at the proper distance apart by a steel frame which also supports a derrick. The materials are raised in a steel bucket, horse power being used.

An interesting feature of this system is the form of a semi-circular chute. It is made of the same material as the silo form proper and with it the chute is run up at the same time as the silo. Reinforcing used in both silo and chute consists of heavy bull fencing. Figure 44 shows the New Enterprise form as used for constructing silos with single walls. This form with the necessary modifications is also used where it is desired to build the silo with double walls. In double wall silos the reinforcing is placed in the inner wall, which is $4\frac{1}{2}$ inches thick. The outer wall is 4 inches thick and the air space between is $3\frac{1}{2}$ inches in width. Wall ties, made of gas pipe slotted at both ends, are placed between the walls in each course at intervals of 3 feet, the slotted ends being bent so as to form a crow foot.

Fig. 45. Hollow wall concrete silo with concrete roof, built for Edward Hoyt, Elborn, Ill., by the New Enterprise Machinery Co., of Chicago.

Although a large number of double wall silos have been constructed in various parts of this country by this system, this company considers double walls a precaution rather than an absolute necessity in localities where the climate is not severe. Both single and double wall systems of the New Enterprise Company are protected by patents.

Angevine System:—Mr. R. C. Angevine has built a large number of "all concrete" silos in the State of Michigan, using for his purposes a system of wooden forms made of 1×6 " wood facing attached to the ribs of heavy planking sawed on the arc of a circle. Each form is slightly more than $2\frac{1}{2}$ feet in height and two forms

are used at the same time, one above the other. This makes it possible for the work to proceed at the rate of 5 feet per day during good weather. The materials are hoisted on a small elevator with power furnished by a gasoline engine.

Angevine silos have a foundation footing 30 inches in width generally placed about 4 inches below the surface. The wall is put in 12 inches thick from the foot to grade, above which point the thickness is 6 inches. These silos are reinforced with heavy steel rods or cables spaced 1 foot apart uniformly. The size of the rods varies with the diameter of the silo and the distance from the top. Before the walls have had time to dry out they are finished off, both inside and out, with a coat of cement and water applied with a brush. The door openings are non-continuous, 24 inches wide by 32 inches high, and are spaced 2 feet apart. The doors are of galvanized sheet steel.

The Angevine silos have reinforced concrete roofs, these being made 4 inches thick with a one-fourth pitch. The appearance is greatly improved by a wide cornice running around the base of the roof. Concrete chutes are recommended by Mr. Angevine and are put up wherever the owners desire them.

Figure 46. C. A. Anderson's Silo Forms in use near St. Charles, Illinois. The platform on top of the inner Form is a great convenience. Materials are hoisted with the Elevator shown to the right.

C. A. Anderson Forms:—Mr. C. A. Anderson of St. Charles, Ill., has constructed about fifty silos in Kane and surrounding counties with the patented system of forms shown in Figure 46. The forms are made of heavy sheet iron braced with 2x4" wood studding and strengthened by strap iron hooks. The forms are raised by jack

screws. The materials are hoisted with the device shown to the right of the illustration. Mr. Anderson has made a number of improvements on his forms this season, but pictures could not be secured in time for publication.

McCoy Forms:—For a number of years Mr. John H. McCoy has been successfully using a system of forms of his own invention in the construction of large silos and railroad water tanks in many parts of the country. This system, which is now owned and used by the Steel Concrete Construction Company of Harrisville, Pa., is

Fig. 47. McCoy's system of silo construction used by the Steel-Concrete Construction Company, Harrisville, Pa.

shown in Figure 47. The forms are of steel made in sections, each of which is supplied with a separate rig for hoisting. The materials are raised in steel buckets by horse power and deposited on a trough which travels around a circular track. This track makes it possible to move the trough to any part of the work that it is desired to fill.

Fig. 48. View taken on a Wisconsin farm where silage is the chief ration. Silo and barn of H. M. Hatch, Lake Geneva. Capacity of silo, 110 tons; cost, \$175.00.

Concrete Block Silos

HOLLOW concrete block silos are popular in all of the northern states and more especially so in sections where the winters are extremely cold. In North Dakota and Minnesota there are scores of block silos in service, these being preferred to silos of any other construction, because of the security against freezing provided

by the hollow wall. The cost of concrete block silos is often a trifle more than for those of monolithic construction, although this is not true in a great many cases. The best concrete block silos are those erected by contractors who have made a specialty of this class of work. Good block silos can be put up with home-made blocks and by home labor, but where there is a reliable block contractor in the vicinity it generally pays, in a saving of time as well as in numerous other ways, to have the work done by persons with previous experience.

Fig. 49. A concrete block silo of pleasing appearance on the farm of Mr. Fred Ludtke, near East Troy, Wis. The concrete block chute is a great advantage, and was put on at a slight additional expense. The cost of the silo complete was \$300. The owner does not consider a roof necessary.

Examining Blocks:—When the work is done by a contractor, the owner should take the precaution of examining the blocks which go into his silo, rejecting those

that are damaged or of an inferior quality. A crack of any size, or broken or crumbly edges, indicate a weakness in the block and make it unsuited for use. Blocks may be tested for their water resisting qualities by placing a small amount of water on the surface and observing whether this remains or is absorbed. A block which readily absorbs moisture is obviously unsuited for silo work, which dampness must not penetrate. Warped and distorted blocks should be discarded because of their unsightly appearance.

Laying the Blocks:—The foundation already described will give as good satisfaction for the block silo as for the monolithic (see pages 36 and 37 and Figure 25). The top of the footing must be made perfectly level, being tested frequently with a level board. As soon as the footing has sufficiently hardened, the top should then be cleaned off and moistened and a coat of slushy mortar $\frac{1}{4}$ inch thick put on. The first band of reinforcing should then be put in, and the first row of block laid on this mortar, beginning the blocks at the two ends of the wall next to the doorway and continuing around. The blocks may be more conveniently set in a true circle if a sweep similar to the one used in laying out the foundation is used here. Should the blocks fail to meet exactly, the circle should

be enlarged or made a little smaller, whichever happens to be the more convenient. A guide board with a convex curved edge, cut on a circle of the same diameter as the inside of the silo, should then be made and used in place of, or in conjunction with, the sweep in laying up the remaining courses.

The Mortar:—The mortar should consist of one sack of Portland cement to 2 cubic feet of coarse sand, with the possible addition of a small quantity of lime (not over 10 per cent) if need be to make it easier to work. Before laying up the block see that they are thoroughly sprinkled, which will prevent them from drawing moisture from the mortar. No more mortar should be mixed at one time than can be used up within 30 minutes after first moistening. If lime is used it must be thoroughly slaked.

Reinforcing:—The only failures reported on block silos have been due to a lack of sufficient reinforcing, caused in most cases by the overconfidence of the builder in the strength of the blocks, or failure to realize the enormous outward pressure of the silage. Horizontal reinforcing is of the most importance and must not be overlooked. Vertical reinforcing in block silos is not considered necessary. Table M shows the size of rod which should be placed between each row of block or in the groove in each row of block, if such a groove is provided. Reinforcing rods in block silos are not lapped in the ordinary fashion, but are anchored around a block as shown in Figure 51, or the ends are hooked together.

Example:—For illustration, let it be assumed that the proper method of reinforcing a silo 32 feet in height and 16 feet in diameter is desired, blocks 8 inches in height being used. Referring to table M, page 65, we run down the vertical column at the left until the figures indicating the greatest depth of the silo are reached. In this case these figures are "28-32 ft." Running directly across horizontally to the 16-foot diameter column, we find that the proper reinforcing 28-32 feet from the top of the silo is one $\frac{3}{8}$ -inch rod between each course of block; following up directly the 16-foot diameter column, we find that $\frac{3}{8}$ -inch rods must be used between each course until a point 16 feet from the top is reached. From here up $\frac{1}{4}$ -inch rods are used until 8 feet from the top when No. 6 rods are substituted.

Fig. 50. Block silo on the farm of Henry Brown, near Elkhorn, Wis. Capacity, 92 tons. Cost, \$425, complete. Built by Reinert, Malsch & Baumbach, Lake Geneva, Wis.

TABLE L.
NUMBER OF CONCRETE BLOCK REQUIRED.

Whole Block, 16 inches long (outside) 8 inches high.

Half Block, 8 inches long (outside) 8 inches high.

Inside Diameter of silo	8 ft.		10 ft.		12 ft.		14 ft.		16 ft.		18 ft.		20 ft.		22 ft.	
	Whole		Whole		Whole		Whole		Whole		Whole		Whole		Whole	
20 ft.	600		720	30	870	30	1020	30	1140	30	1419	33	1728	36	2226	42
22 "	660		792	33	957	33	1122	33	1254	33	1548	36	1872	39	2385	45
24 "	720		864	36	1044	36	1224	36	1368	36	1677	39	2016	42	2544	48
26 "	780		936	39	1131	39	1326	39	1482	39	1806	42	2160	45	2703	51
28 "	840		1008	42	1218	42	1428	42	1596	42	1935	45	2304	48	2862	54
30 "	900		1080	45	1305	45	1530	45	1710	45	2064	48	2448	51	3021	57
32 "	960		1152	48	1392	48	1632	48	1824	48	2193	51	2592	54	3180	60
34 "	1020		1224	51	1479	51	1734	51	1938	51	2322	54	2736	57	3339	63
36 "	1080		1296	54	1566	54	1836	54	2052	54	2451	57	2880	60	3498	66
38 "	1140		1368	57	1653	57	1938	57	2166	57	2580	60	3024	63	3657	69
40 "	1200		1440	60	1740	60	2040	60	2280	60	2709	63	3168	66	3816	72
42 "	....		1512	63	1827	63	2142	63	2394	63	2838	66	3312	69	3975	75
44 "	....		....	..	1914	66	2244	66	2508	66	2967	69	3456	72		
46 "	....		....	..	....	..	2346	69	2622	69	3096	72	3600	75		
48 "	....		....	..	....	..	....	..	2736	72	3225	75				
50 "	....		....	..	....	..	....	..	....	..						

TABLE M.
HORIZONTAL REINFORCEMENT FOR BLOCK SILOS.

Showing Size Wire and Rods to be used between each course of blocks 8 inches high.

[illegible]

Recesses for Reinforcing Rod:—The reinforcing is commonly laid in the mortar between the courses of block, the strength of the mortar and the downward pressure of the blocks above being depended upon to keep the rods in place under loaded conditions. In the best practice, however, blocks are used which have a recess in the top face deep enough to accommodate the reinforcing rod. Recesses are generally put about two inches in from the outside of the block.

Figure 51. Continuous door opening for concrete block silo. View shows the manner of fastening reinforcing rods to the door frames, also of anchoring rods around a block instead of lapping.

Continuous Door Frames:—The frames for the continuous doorway are made in about the same manner as those placed in monolithic silos, as described on page 46. Two 6-inch 8-lb. channels of

a length equal to the distance between the barn floor and the top of the silo are used. Holes to receive $\frac{3}{4}$ -inch rods are drilled on the center line of the channel at intervals of 12 inches, and holes of sufficient size to accommodate the reinforcing rods are drilled on a line 2 inches from one edge of the channel at intervals equal to the height of the block, which in most cases is 8 inches. The drilling should be done by the local blacksmith unless the farmer or builder has special equipment for doing this work. Great care should be taken to get corresponding holes in the two channels at exactly the same height and distance from the edge.

Bolts $\frac{3}{4}$ -inch in diameter and 2 feet 6 inches long, threaded for 4 inches on each end, should also be ordered from the blacksmith or made at home from $\frac{3}{4}$ -inch steel rod. Four nuts should be provided for each bolt. In assembling the frame one nut will be placed on each end of each rod 2 feet 2 inches apart. The bolts will then be slipped into the $\frac{3}{4}$ -inch holes in the channel, and the other nuts put on, which will hold the channel and bolts tightly in place. The door-frame is then ready to be erected. The frame should be well braced until the walls are up far enough to hold it securely.

As the reinforcing rods are laid upon successive courses of blocks, they are cut off long enough so that the ends will extend about one inch when brought through the channel. After being threaded the ends of the rod will be brought through the holes, drilled to receive them, and the nuts will be put on, but not tightened sufficiently to disturb the rods in case they are laid in the mortar and not in recesses in the blocks.

The doors should be made of 2x12" material in the same manner as those for monolithic silos as described on page 46 and shown in Fig. 33.

Fig. 52. Concrete block silo of Mr. J. W. Cooper, Whitewater, Wisconsin, built by the Charles B. Hurst Company, Chicago.

Home-Made Blocks

A NUMBER of farmers in various parts of the country have put up concrete block silos of blocks made during spare time with a block machine or a home-made mold. Good blocks can be made by either method, but the use of a machine quickens the work, and does it in a more uniform manner with the expenditure of a great deal less labor.

Block Machine Manufacturers:—For the benefit of those who may wish to manufacture silo blocks with a machine designed for the purpose, the following list of manufacturers, who exhibited their machines at the Chicago Cement Show, is given. There are also a large number of other machines on the market capable of making good silo blocks. Any of the following will be glad to send full information regarding their machines on request:

The American Hydraulic Stone Co., Chicago.
 The Anchor Concrete Stone Co., Rock Rapids, Iowa.
 Ashland Steel Range & Mfg. Co., Ashland, Ohio.
 Cement Machinery Co., Jackson, Mich.
 Century Cement Machine Co., Rochester, N. Y.
 Hayden Automatic Block Machine Co., Columbus, Ohio.
 Hobbs Concrete Machinery Co., Detroit, Mich.
 Ideal Concrete Machinery Co., South Bend, Ind.
 Inman Concrete Block Machine Co., Beloit, Wis.
 Marsh Co., Old Colony Bldg., Chicago.
 Miles Manufacturing Co., Jackson, Mich.
 Multiplex Concrete Machinery Co., Elmore, Ohio.
 Somers Bros. Manufacturing Co., Urbana, Ill.
 U. S. Gas Machine Co., Muskegon, Mich.

Figure. 53. Home-Made Silo block mold.

Home-made Molds:—The mold shown in Figure 51 is a modification of that used by Wm. Stoll of Lansing, Mich., to construct blocks for his silo during the summer of 1907. It can be used to make blocks of any length up to 24 inches and of any width up to 8 inches. The height of the blocks may be 8 inches or less. The mold can be made from a piece of old railroad tie 30 inches long, 8 inches wide and $6\frac{1}{2}$ inches high sawed on the arc of a circle, with a diameter 4 inches greater than that of the inside of the silo. One-half-inch holes are drilled $1\frac{1}{2}$ inches from each end to receive 18-inch bolts, by which the sides of the mold are held at the desired distance apart. The end pieces are made of 1-inch planed lumber and have tapered wooden blocks 8 inches long, 5 inches wide and $\frac{7}{8}$ -inch thick screwed to them for the purpose of making end cores on the blocks. The end pieces are held in place by wedge-shaped wooden blocks inserted between them and the bolts. If hollow blocks are desired, the air spaces may be provided by cores made of tapered 4x4" pieces. The inside of the mold should be well greased before use to prevent the concrete from sticking.

Size of Block:—Although concrete blocks are made in a large variety of sizes, those most commonly used in silo work are 8 inches high, 8 inches thick and either 16 or 24 inches long, with half and quarter lengths as required. Blocks of these sizes are recommended as preferable to those less than 8 inches in height which require more labor to lay, or blocks more than 8 inches in height which are unhandy because of their weight.

Fig. 54. Concrete silo and dairy barn, University of Nebraska Agricultural School, Lincoln, Neb. Construction of this type is frequent among the state agricultural colleges; fully a score have concrete silos.

Commercial Concrete Block Silos

THE PERFECT SILO:—The Perfect Silo, built by the Perfect Reinforced Silo & Cistern Block Company, of Delaware, Ohio, has met with great favor amongst Ohio farmers and a large number have been put up in Delaware and adjacent counties. Some of these silos have been built by the owners with block purchased from the above company.

This system differs from all others in the dimensions of the blocks and the method of reinforcing. The blocks are made on an arc, 24 inches long, 12 inches high, and 4 inches thick. Each block is reinforced with two iron bands running lengthwise 6 inches apart. Each rod is looped and turned 6 inches from each end. These loops are spaced so as to correspond with $\frac{1}{2}$ -inch round vertical holes which are formed in the block. When the blocks are laid in the wall these vertical openings are filled with cement and water grout and steel dowel pins are passed through this soft material and inserted about half way in the block below. The rods should be of such length that they will reach up about half way in the blocks above. The blocks have a groove $\frac{1}{2}$ inch deep in the top edge which provides space for a larger mortar bed and also for the heavy horizontal rods which span the continuous door openings at intervals of 2 feet. These rods are firmly fastened to the vertical dowel pins. The dowels next

Fig. 55. Two large monolithic silos on the Jelke Dairy Farm, Dundee, Ill. The combined capacity of both silos is nearly 600 tons. The silo on the left was built by a contractor, and that on the right by farm labor under the direction of Mr. W. A. Dickinson, the farm superintendent. Both silos have concrete roofs.

to the door openings are made of heavy pipe in 4-foot sections firmly screwed together.

This system is shown in Figures 56 and 57.

Fig. 56. Detail of Lateral and Perpendicular Reinforcing in the Perfect Silo.

Fig. 57. Sectional View showing Construction of the Perfect Silo and Method of Reinforcing continuous Doorway.

The Zeeland Silo:—A very interesting type of concrete block silo is being used extensively through the region between Holland and Grand Rapids, Michigan, which is known as the Zeeland silo and has been built exclusively by Mr. Chris DeJonge, of Zeeland, Mich.

About 30 Zeeland silos have been put up by him in Ottawa County alone. The Zeeland silo has a number of unique features. It is the only silo of its kind using solid blocks made "tongue and groove" so as to fit any diameter of silo. The blocks are made 24 inches long and 8 inches high and have a thickness of only 3 inches. They are laid up in 1:2 cement and sand mortar and the inside of the wall is plastered off with mortar of the same proportion. Reinforcing consists of a heavy iron rod around each course, laid in a groove provided in the top of the blocks. Early silos of this type were reinforced with band-iron hoops 2 inches wide by $\frac{1}{4}$ inch thick placed four courses apart. The silo of Mr. Simon Wierda shown on page 54 was the first one of this type constructed.

Mr. DeJonge has lately (April, 1911) secured patents on a semi-circular steel chute and ladder which is placed on the inside of the silo. This permits the silo walls to be built up full all around, the only opening necessary being a door in the bottom.

The chute is held to the silo wall by means of hooks and eyelets, the latter being placed in the wall at the time of building. When it is desired to use off the silage, two top sections of the chute are removed, and as the height of the silage is lowered successive sections are removed and hung two spaces higher.

Fig. 58. Large monolithic silo, built by Cornelius Andre, Grandville, Michigan. Cost of materials, \$82.00; cost of labor, \$108.00; total cost of silo, \$190.00. Mr. Andre has many creditable examples of concrete work about his place, including barn floor and dairy house. The silo shown above is admired by all of the farmers of the vicinity.

Concrete Chutes

A PERMANENT chute of concrete is a valuable adjunct to any concrete or masonry silo. The same arguments presented for the concrete silo stand for the chute. The concrete chute is substantial and permanent, fireproof and cold-proof, and it greatly improves the appearance of the silo.

Size of Chute:—Chutes in use in various parts of the country vary in size from 2 feet square to about 5 feet square (inside dimensions), but the former size is much too small and the latter larger than need be. For the average monolithic silo a chute 3 feet by 4 feet in inside dimensions is recommended. The outer dimensions will then be 4 feet by $4\frac{1}{2}$ feet, the walls being 6 inches thick. A monolithic chute of this size will require one-third of a barrel of cement, $\frac{1}{8}$ cubic yard of sand and $\frac{1}{5}$ cubic yard of gravel, per foot of height. For the block silo, the size should be such as will be accommodated by whole and half blocks. The outer dimensions of a hollow block chute (using $8\times8\times16''$ blocks) should be 4 feet 8 inches square, making the inside dimensions 3 feet 4 inches by 4 feet. This size will require $9\frac{1}{2}$ blocks for each course.

Foundations:—The foundation for the chute should be 2 feet wide and 1 foot high, the same as that for the silo, using concrete of the same proportions. (See page 36.) If a monolithic chute is to be built $\frac{3}{8}$ -inch vertical reinforcing rods must be imbedded in the foundation 18 inches apart. Monolithic chute walls may be built up simultaneously with the silo walls, but it is much more convenient to build them after the completion of the latter; chute walls of concrete block must be built at the same time, being built in and kept at the same level as the silo walls.

Monolithic Chutes:—The accompanying illustration shows forms in position for building a monolithic chute. Two-inch planed lumber should be used for the face of the forms, and 2×4 's for the vertical braces. The steel rods used to hold the forms together should be 24 inches long, threaded for 4 inches at each end. Each section of the form should be about 2 feet (4 plank) high. To raise the forms the lower rods are withdrawn and the holes made by them cemented

Fig. 59. 165-ton silo of A. R. McNeill, Willow Wall Poultry Farm, Old Fields, W. Va. Cost, complete with concrete chute, \$405. Built by R. C. Angevine, Coldwater, Mich.

up. The wooden braces are then raised, and the lower panels of planks placed above the others.

The method of joining the chute to the silo is shown in the figure. Two 1x6" boards, with edges slightly beveled to permit of easy removal, are placed in a vertical position on the inside of the outer silo form, 3 inches to each side of the line of the doors. In this manner recesses "a" are produced. Three-eighths inch rods 30 inches long, spaced at intervals of 18 inches, and bent as shown by the dotted lines in the figure, are used to hold the chute securely to the silo. The most convenient way to put in these rods is to have them lightly stapled to the boards occupying recesses "a." This will hold the rods in position until the concrete is placed. The forms and vertical boards may be moved as soon as the walls have hardened sufficiently, and the ends of the rods bent up into a horizontal position. Where windows are desired in the chute, the openings may be made with a form similar to that used for making non-continuous door openings, shown on page 48.

The horizontal reinforcing of the chute should consist of $\frac{3}{8}$ -inch round reinforcing rods so spaced as to correspond with the rods binding the chute to the silo, so that they may lap with the latter. The lap should be 24 inches long. Two horizontal rods should be placed over all windows. Short oblique rods, 24 inches long, should be put in about the corners of all windows, at an angle of 45 degrees, as a protection against diagonal cracks running from the corners of the windows.

Block Chutes:—

If the block silo and chute are put up simultaneously the walls of the two will be held together by the blocks, and no reinforcing will be necessary. Window openings in the chute may be made by using concrete sills and lintels, which are easily obtainable from block dealers. A length of heavy strap iron may be substituted for a lintel, if desired, and the sill cast in place by means of a simple box mold.

Fig. 60. Forms for monolithic concrete chute. The illustration shows the recesses "a" and the $\frac{3}{8}$ -inch re-inforcing rod used in joining the chute to the silo wall.

Fig. 61. Sectional view of a monolithic silo equipped with water supply tank, roof and chute of concrete. The small view shows section of the rectangular chute.

Water Supply Tanks

THE top of a monolithic silo is a convenient place for the farm water supply tank; in fact, if one were about to build a large concrete tank, no better construction could be chosen than that of building the base in the shape of a monolithic silo, whether it could be put to any other use or not. Where both silo and tank are necessities, as on large stock and dairy farms, the two may well be combined.

Fig. 62. Monolithic silo, built for the Agricultural Guild of the University of Chicago by J. H. McCoy (Steel Concrete Construction Co., successors), Harrisville, Pa. This silo is 47 feet in height, and contains a 250-barrel water tank within the top four feet.

Size of Tank:—Every farm should have a water supply tank large enough to take care of all the needs about the house and barn and still leave a reserve for use in case of fire. Table N shows the capacities of tanks advocated for silos with diameters of from 8 to 16 feet, assuming the tanks are filled to a height of five feet. It is hardly practical for inexperienced persons to build tanks of greater diameter than 16 feet, erected on top of silos, unless these tanks are especially designed for each particular silo. Detailed plans of larger tanks will be designed by the Information Bureau, however, to fit individual cases and will be furnished upon request.

Planning for the Tank:—If a tank is to be built on top of the silo, due attention must be paid to this fact in planning the reinforcing for the walls. Thus, if it is desired to build a silo 40 feet in height with a tank 6 feet in height on top, the silo should be reinforced in the same manner as though it were 46 feet in height without any tank. From the floor of the tank to the top, the reinforcing will be put in according to the diagram on page 77.

Bridging Across Continuous Doorways:—In silos with continuous doorways, it is necessary to bridge across the top of the doorway before laying the tank floor. The door-frame should extend up within one foot of the bottom of the floor, and as soon as the walls have been built up to the level of the top of the frame, a reinforced concrete beam 12 inches high and 4 inches wide should be put in, at least $3\frac{1}{2}$ feet long so as to give a bearing of one foot or more on each side of the opening. This beam should be reinforced with four $\frac{1}{2}$ -inch round rods, and may be made in a small mold-box, without top or bottom. It should be placed in the inner side of the wall and the concreting then resumed up to the level of the tank floor.

TABLE N
CAPACITY OF WATER SUPPLY TANKS *

Diameter of tank in ft.	Capacity in barrels
8	60
10	95
12	135
14	185
16	240

*Depth of water—5 feet.

One barrel equals 31.5 gal. or 4.21 cu. ft.

D I A M E T E R O F T A N K									
8 ft.		10 ft.		12 ft.		14 ft.		16 ft.	
S I Z E O F R O U N D R O D S									
$\frac{1}{4}$ inch	$\frac{1}{2}$ inch	$\frac{3}{4}$ inch	1 inch	1 $\frac{1}{4}$ inch	1 $\frac{1}{2}$ inch	1 $\frac{3}{4}$ inch	2 inch	2 $\frac{1}{2}$ inch	3 inch
1 ft.									1 Ft.
2 ft.									2 Ft.
3 ft.									3 Ft.
4 ft.									4 Ft.
5 ft.									5 Ft.
6 ft.									6 Ft.

Distance from top of tank

Use $\frac{3}{8}$ " or $\frac{1}{2}$ " but not both.

Use $\frac{3}{8}$ " or $\frac{1}{2}$ " but not both.

The Floor:—As soon as the wall has been brought up to the level of the tank floor, the outer form should be raised one foot and the inner form lowered one foot. A heavily braced platform which will support the concrete floor should then be erected upon the inner form. The floor form must be made of 2-inch planks supported on 2x10 inch girders, braced to the staging as well as to the inner form, which must be strengthened if much of the weight of the floor is to rest upon it. The floor form must be able to support a load exceeding 125 pounds to the square foot in the case of a 16-foot silo, or 75 pounds to the square foot for an 8-foot silo. The greatest caution must be exercised in getting the framing put up in such manner that it will carry the load without danger of collapse.

Fig. 63. 14½ x 32 foot concrete block silo on the farm of Ed. Bellmes, Fond du Lac, Wisconsin. Built of "Wisconsin Pride" continuous air space blocks, by J. J. Coyne, Fond du Lac, Wisconsin. Cost complete, \$275.00.

The entire floor must be concreted at one operation. The necessary materials must be on hand, and provision made for mixing in large batches and elevating as speedily as possible. These are points which are absolutely essential for perfect work. The concrete should be made in the proportion of one sack of cement to

2½ parts clean, coarse sand, and 4 parts of screened gravel, the latter to contain no particles smaller than ¼ inch. The concrete must be thoroughly mixed with water enough to flow with slight agitation. The following table shows the thickness of floor, amount and spacing of reinforcing and the amount of materials needed for tank floors of various sizes:

TABLE O.
MATERIALS AND REINFORCING FOR TANK FLOORS

Diam. of silo and tank IN FEET	Total thickness of floor	Cement req'd. bbls.	Sand req'd. cu. yds.	Gravel req'd. cu. yds.	Pounds of ¾ inch round reinforcing rods req'd.	Pounds of ½ inch round reinforcing rods req'd.	No. of lengths	Spacing of reinforcing rods (inch. apart)
8	6 in.	1.3	.48	.77	96	...	16-16'	6 in. to 8 in.
10	7 "	2.4	.87	1.4	193	...	32-16'	4 " " 8 "
12	8½ "	4.2	1.52	2.5	...	407	38-16'	5 " " 8 "
14	10 "	6.7	2.42	3.9	...	492	46-16'	5 " " 8 "
16	10 "	8.7	3.17	5.1	...	685	82-16'	4 " " 8 "

Before placing any of the concrete, reinforcing rods for the floor should be laid down upon the platform, as shown in Figure 64. Begin to lay the rods at the center, at the closest spacing shown in the table, then lay the remaining rods running the same direction, working to the wall where the greatest spacing shown in the table

may be used. The reinforcing should then be placed in the other direction in the same manner, and wired at intervals of 2 or 3 feet with ordinary hay-baling wire. The ends of the reinforcing should be long enough to extend up into the wall at least two feet, being joined to the horizontal wall reinforcing.

The reinforcing should be supported about an inch above the platform, on small cubes of concrete or strips of wood placed about 2 feet apart. 1:3 cement and sand mortar should then be put on and worked under the reinforcing to a depth of about one inch, and the concrete immediately placed upon this. In case small wooden strips are used to support reinforcing, these may be withdrawn from the underside of the floor as soon as the framing is removed, and the resulting holes filled with mortar. Concrete cubes are preferable to wooden strips, and may be easily made in the following manner: Lay down two 1-inch boards on a flat floor, one inch apart, and fill in the space between them with 1:3 mortar, trowelling off the top. The long strip of concrete thus formed may be broken up into short sections approximately cubical in shape.

Continuing Walls:—After the floor has sufficiently hardened, the forms and scaffolding should be taken down, the wall forms hoisted up the outside, and placed in position on the tank floor.

Fig. 64. Showing the method of placing reinforcing rods in the tank floor.

Before concreting is continued on the walls, the surface must be cleaned off, thoroughly moistened, and painted with cement and water grout, mixed about as thick as cream. The concrete must then be placed before the grout shows any tendency to dry. Six feet will be found a convenient depth for the tank.

In large supply tanks, where the water is continually agitated, water seldom freezes sufficiently to damage the tank. However, it is much safer to build the tank with a slight batter all around, that is, making the inside diameter greater at the top than at the bottom. The inside line of the wall should slope outward one inch for every foot in height. Ice in forming expands and rises upward, and the batter thus relieves the pressure which would otherwise be communicated to the walls, possibly injuring them, in the case of a hard freeze.

Fig. 65. Concrete block silo of C. D. Ames, Kaneville, Ill. Diameter, 16 feet; height, 44 feet. Built in 1910 from block manufactured by F. W. Merrill, Kaneville.

ing for a tank 14 feet in diameter and 6 feet deep (to hold 5 feet of water net). Running across the top horizontal column until 14 feet is reached, we find (directly below) that two sizes of rods— $\frac{3}{8}$ inch and $\frac{1}{4}$ inch—are used. Running to the bottom of the vertical diagrams, it will be seen that a $\frac{3}{8}$ -inch rod is placed 2 inches from the floor line. The next two rods are also $\frac{3}{8}$ -inch, spaced 7 and 14 inches above the first rod. Above this point $\frac{1}{4}$ -inch rods may be used to the top, as shown, or three more $\frac{3}{8}$ -inch rods may be used, and the change made to $\frac{1}{4}$ -inch rods at a point 2 feet 5 inches from the top.

Piping and Overflow:—The intake and outlet pipes should run up one corner of the chute, far enough from the wall so that they may be covered to prevent freezing. The overflow outlet may consist of a 3-inch pipe passing through the wall about 6 inches below the cornice. This pipe may be run down within the chute or on the outside of the silo, and led to a line of tile. In many cases, however, the pipe is simply made to stick straight out of the wall about a foot, and the overflow is not drained off in any way. This method is not recommended as a general thing, but may be suitable if close watch is kept so that the tank is rarely filled to the overflow point.

Reinforcing:—The vertical reinforcing above the tank floor is put in the same as below, with $\frac{1}{2}$ -inch rods, spaced at intervals of 3 feet around the circumference. The spacing for the horizontal rods may be obtained from the diagram, on page 77. By referring to the diagram, it will be seen that the vertical scale shows the distance from the top of the tank, each small division representing one inch. Across the top of the table are the tank diameters, running from 8 to 16 feet. The heavy black lines indicate the spacing of the rods. This diagram (page 77) may be conveniently used for tanks six feet deep or less.

Example:— Suppose it is desired to know the proper reinforcing

The Concrete Roof

THE functions of a roof on a silo are (1) to prevent the cold from reaching the silage and (2) to make it more convenient to work in the silo during stormy weather. Many farmers and contractors do not consider a roof necessary and in moderate climates this is probably so; all will agree, however, that in sections of the country where the temperature goes below zero a roof is a positive necessity, as well as a great convenience under any circumstances.

The logical way to finish up a concrete silo is with a concrete roof. Of 110 concrete silos recently investigated by this Company, 39 had concrete roofs, 30 wooden roofs, 3 steel roofs, 13 had no roofs of any sort, and on 16 silos no note of the roof was made. Of the silos with concrete roofs, more than a majority were built during the last two years, showing that the tendency at the present time is toward the all-concrete silo—from foundation to pinnacle. If the directions given in the following paragraphs are closely followed, little difficulty will be found in putting on a good roof of concrete—one that will last indefinitely without need of being shingled or otherwise repaired, and which will be in no danger of blowing off.

The Cornice:—A cornice is only necessary where a roof is to be put on, its chief uses being to prevent water from the roof from running down the walls, and to improve the appearance of the silo. Figure 67 illustrates how the forms are made for the cornice on a monolithic silo.

The brackets for the forms are made of $\frac{1}{4}$ "x2" strap iron bent as shown, and drilled to receive three stove bolts. These brackets should be placed on the outer form at intervals of about 6 feet, holes being drilled at the proper points to receive the stove bolts. The bottom of the cornice mold box is made of 2"x6" planks in short lengths, sawed to the arc of a circle with diameter 1 foot larger than that of the inside of the silo. The side of the mold is made of 1"x6" planks spiked to the bottom boards. The mold is held in place by screws through the bracket, as shown. An extra band of horizontal reinforcing is put in the cornice, as may be seen in the figure. The vertical rods in the silo walls and the radial rods of the roof are all brought around the horizontal reinforcing in the cornice, thus holding it in place and strengthening the cornice.

Fig. 66. 100-ton concrete block silo of John Betts, Geneva, Wis. Built by owner in 1909. Cost, \$500.00, complete. Blocks are 20 inches long, 6 inches high, and 8 inches thick.

For the top section of the wall (last filling of the forms) the inner and outer forms are brought up to the line of the top of the completed wall. The forms are then filled to within one foot of the top, the outer form removed, and brackets attached. (If the stove bolts are already in place the form need not be removed to attach the brackets). The mold box will then be put in place. The cornice will be concreted at the same time as the roof, as will be explained later.

Roof Framing:—The roof framing may consist of two-by-fours or similar material, resting on the top of the inner wall form as shown in the sectional view, and the lower left-hand quadrant of the plan view, Figure 68. In case of a silo with a water tank on top, the forms must be removed before the roof framing is put up, and the latter supported on a light framework erected within the tank.

*Forms in place for
Top section and Cornice*

Box for Cornice

The roof frame may be boarded up as shown in the plan view, with boards running either radially or otherwise, as desired. These boards should be placed close together to prevent the concrete from coming through when placed upon them. Table P shows the vertical rise to be given to roofs for silos of various diameters.

A hole about 2½ feet square must of course be left for filling the silo, or if a roof covers a tank the hole will afford access to the latter. Before placing the reinforcing or the concrete, the top of the framing should be covered with old newspaper, building paper, or similar material, which will prevent the concrete from sticking to the forms. This will greatly facilitate their removal.

Placing the Reinforcing:—The lower right hand quadrant of the plan and the sectional view show the spacing of the radial and hoop reinforcing. The former is placed so as to be one foot apart on the circumference, and the latter so that the distance between the

Fig. 67. Mold box for Silo Cornice

Fig. 68. Reinforced concrete roof design. The wooden framing is removed as soon as the cover has become thoroughly hardened.

three bottom hoops is 6 inches, between the next three hoops 9 inches, and between all remaining hoops 12 inches. Extra rods should be put in around the window opening if the regular rods do not follow the outline of the window closely enough to reinforce it. All intersections must be wired together, and the outer ends of the radial wires brought down and bent around the horizontal reinforcing in the cornice, as shown. The reinforcing should be supported one inch above the roof frame, so that when the concrete is put on, the rods will rest on a one-inch bed and be covered by a three-inch bed, the total thickness of the roof being four inches. For amounts of reinforcing necessary for roofs of various diameters, see table P.

Concreting:—Concrete for the roof should be made in the proportion of one sack of cement to two cubic feet of coarse, clean sand, to three parts of screened gravel. The concrete should be mixed as wet as it can be put on without danger of running to the edges of the roof due to the pitch. The top should be trowelled off smooth, in the same manner as a sidewalk. Concreting should begin at the cornice working around the roof, so as to keep the concrete on all sides at an even height. As the work progresses toward the center a broad board, on which to stand, may be laid on the concrete already laid. It will also add greatly to the safety of the men working on the roof if a rope attached to the pinnacle is tied about the waist of each. In place of this, it is often desirable, for the sake of greater safety to the workmen, to put up a scaffolding on the outside of the silo. Special care must be taken to protect the roof from sun, strong wind and freezing until thoroughly hardened. For this purpose a covering of straw, manure, or canvas is generally effective; if either straw or manure is used it may be necessary to weight it down. The effect of sun and wind is to dry the concrete out too rapidly, causing checking and cracking; frost affects the strength of the concrete and is otherwise objectionable.

Monolithic Roofs for Hollow Block Silos:—Where it is desired to put a monolithic concrete roof on a hollow block silo, the wall should be laid up in the usual manner until the third course of block from the top is reached. The blocks used in this course should be

Fig. 69. Block silo of Col. Fred E. Shubel, Sycamore Farm, Lansing, Mich. Diameter, 12 feet; height, 38 feet. Cost, complete, about \$180.00; capacity, 91 tons. Bevel faced blocks were used, and the inside finished with 1:2 cement and sand mortar.

TABLE P
DIMENSIONS AND MATERIALS FOR ROOFS
For Silos with Diameters 8 feet to 22 feet

Diameter of Silo	Vertical Rise	Volume of concrete in cu. yards	Cement required bbls.	Sand required cu. yds.	Stone required cu. yds.	½ INCH REINFORCING RODS		
						No. of rods required	Stock length of rods	No. of pounds of rods
8 ft.	2 ft.	0.63	1.09	0.33	0.49	26	10 ft.	42
10 "	2½ "	1.01	1.75	0.52	0.78	31	12 "	62
12 "	3 "	1.49	2.59	0.77	1.15	33	16 "	88
14 "	3½ "	2.05	3.56	1.07	1.58	45	16 "	120
16 "	4 "	2.71	4.72	1.41	2.08	87	10 "	146
18 "	4 "	3.34	5.80	1.74	2.57	93	12 "	187
20 "	4 "	4.11	7.15	2.13	3.17	107	12 "	226
22 "	4 "	4.93	8.55	2.56	3.80	113	14 "	265

Concrete for roofs is made of 1 sack Portland Cement to 2 cubic feet of coarse sand to 3 cubic feet of stone. Each cubic yard of concrete requires $1\frac{3}{4}$ bbls. of cement, $\frac{1}{2}$ cubic yard of sand, and $\frac{3}{4}$ cubic yards of stone, approximately. The $\frac{1}{4}$ -inch reinforcing rod weighs 16.7 pounds per 100 feet.

solid, namely, made without cores, or if with the cores these should be filled up with mortar. The last two courses of hollow block should then be laid, the cores being left open.

Fig. 70. Cornice block for concrete block silo.

Special cornice blocks should be cast to make the cornice projection, and for this purpose a mold similar to that shown in Figure 53 can be conveniently used. The block should be 14" in width and of the same length on the inside of the wall as the wall blocks. The portion of the cornice blocks directly above the wall blocks should be 6" thick, while the projecting ends of the blocks should be but 5" thick, so as to give a one-inch drop. The roof framing is then put up in the same manner as described on page 82, but in this case it must be supported by the scaffolding instead of on the inner form mentioned there. The reinforcing is placed in the same manner as described on page 82 and shown in Figure 68, excepting that the outer ends of the radial rods are made to extend down through the holes in the block for a distance of a foot or more. Since the holes in the third course of block from the top were either omitted or filled up before these blocks were laid, holes in the two upper courses can be filled up with wet concrete as soon as the reinforcing rods are in position. The roof is concreted as described on page 84. Before the concrete is placed on the cornice blocks this must be moistened and painted with a cement and water grout.

Fig. 71. William Stoll's block silo, near Lansing, Mich. The blocks were made by the owner upon the concrete floor of his dairy barn, and laid up a row at a time, as he had an opportunity. The estimated cost was \$137.50 including labor; capacity 67 tons. One of the first concrete silos in Ingham county.

Fig. 72. Mr. Frank Bennett's concrete block silo, East Troy, Wis. 8-in. by 8-in. by 20-in. rock face block were used, these being obtained from a local dealer. This silo holds 113 tons and cost \$340. The roof is of sheet steel. The contractor was Albert Elbert, of East Troy.

Fig. 73. F. W. Merrill's concrete block silo, Kaneville, Ill. Made with patented block manufactured by Mr. Merrill. Cost, \$450; capacity, 160 tons. This silo was put up complete in 4 days.

Fig. 74. C. Shaw's monolithic concrete silo, New Augusta, Indiana.

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