

CONCRETE CONSTRUCTION AT
NAVAL AMMUNITION DEPOT
HAWTHORNE, NEVADA

THESIS FOR THE DEGREE OF C. E.

L. C. Davies

1931

THESIS

Concrete construction

CONCRETE CONSTRUCTION AT NAVAL AMMUNITION DEPOT

HAWTHORNE, NEVADA

A Thesis Submitted to the Faculty

of

Michigan State College

of

Agriculture and Applied Science

by

L. G. Davies

Candidate for Degree

of

Civil Engineer

June, 1931

THESIS

Concrete Construction At Naval Ammunition Depot
Hawthorne, Nevada

<u>Chapter Title</u>	<u>Page</u>
1. Preliminary Tests And Specifications.	3
2. Formwork And Reinforcement.	13
3. Aggregate Supply And Its Effect On Concrete.	22
4. Findings And Criticisms.	30
5. Placing And Protecting Concrete.	37
6. Conclusions.	50

95460

1. Preliminary Tests And Specifications.

- (a) Introduction.
- (b) Concrete to be placed.
- (c) Specifications for work.
- (d) Methods used in carrying out the specifications.



1. Preliminary Tests and Specifications.

When the Navy Department of the United States Government decided to build an Ammunition Depot on the desert surrounding Hawthorne, Nevada, one of the first moves It made was to send Lieutenant-Commander Cotter, of the Civil Engineering Corps, to the scene to take charge and make preliminary investigations. The sight chosen covers 211 square miles of desert territory bounded on the East, South and West by mountains rising from 1500 to 7000 feet above the desert floor, and on the North by Walker Lake. Besides its beauty, and the mellowing effect it has upon the climate, we can thank Walker Lake for the deposits of gravel near its shores. For it was from these deposits that we obtained all of the aggregates for use in our concrete construction work.

The preliminary work was done in the summer of 1928. Test holes were dug in a great many places in the area to determine soil conditions and in the natural gravel pit to determine the quality and amount of aggregate available. I was not present during these investigations and will only set down the facts and how they were established as I found them on arriving in June 1929.

Commander Cotter placed me in charge of all work relating to concrete: tests, aggregate inspection, steel work, formwork and the placing and curing of concrete.

Preliminary Tests and Specifications.

The concrete was to be placed in twelve reinforced concrete buildings, varying in size from a 40 by 50 foot two story fire-engine house to a 230 by 100 foot garage, and including twenty-two brick quarters, with concrete construction to the first floor level and full basements; a 600,000 gallon two bay reservoir and eighty-four magazine buildings varying in size from 25 by 40 to 25 by 80 feet. These magazines are shaped like a cylinder cut in two along its axis and then slid down with this axis horizontal so that their roofs are arched. We had a total of about 20,000 cubic yards of concrete in this contract. The specifications for our concrete called for a strict control of the amount of water in each of three classes which we called our 2000 lb., 2500 lb., and 3000 lb., mixes. Here follows the data as it was outlined in the contract:-

"3-05. REINFORCEMENT.- Reinforcing bars shall be deformed and of intermediate grade in accordance with standard specification No. 46Sl6. Steel fabric (mesh) shall be approved type of electrically welded wire fabric having a mesh 4 by 4 inches, and shall be heavily hot galvanized. The 44 by 62 pound (per 100 sq. feet) mesh shall have sectional areas in each direction of not less than 0.062 and 0.087 square inch per foot in width, respectively. Wire for the fabric shall be cold drawn steel having a tensile strength not less than 80,000 pounds per square inch. The fabric shall be lapped not less than six inches and shall be securely wired. Rods and fabric shall be secured in place in a manner such as will prevent displacement during the placing of

Preliminary Tests and Specifications.

the concrete. All reinforcement shall be free from rust scale. Bar supports and spacers of an approved commercial type shall be provided to properly support, space and hold reinforcing bars in position.

3-06. AGGREGATES.- The grading of the concrete materials (sand and gravel) encountered in the test pits is indicated. These materials shall be washed sufficiently to remove organic matter and silt. The gravel shall be passed thru a 1-inch screen and all particles retained on a No.4 sieve shall be used as coarse aggregate. The sand shall be passed thru a No.4 sieve and not more than 3 per cent shall pass a No. 100 sieve.

3-07. CLASSES OF CONCRETE for the various parts of the work shall be as follows:

(a) For division and side walls of storage reservoir, including columns, 3,000-pound.

(b) For arches of magazines and all other parts of storage reservoir, 2,500-pound.

(c) For all other concrete (except where specified otherwise), 2,000-pound.

3-08. PROPORTIONS AND CONSISTENCIES.- All concrete shall be proportioned by weight. The proportions shall be as indicated in the table below. The class of concrete to be used in any particular structure or part of structure shall be as specified or indicated.

Preliminary Tests and Specifications.

Class	Mixture by weight cement...sand...gravel			Maximum water per sack of cement	Time of mixing
	Lbs.	Lbs.	Lbs.	Gallons	Minutes
2000 lb...	94	242	287	7	1½
2500 lb...	94	200	258	6¼	2
3000 lb...	94	156	218	5½	3
	Approximate equivalent volumetric proportions cement...sand... gravel			Estimated yield, sacks of cement per cubic yard	
2000 lb....	1 cu.ft.	2.76 cu.ft.	2.80 cu.ft.	5.8	
2500 lb....	1 cu.ft.	2.26 cu.ft.	2.52 cu.ft.	6.6	
3000	1 cu.ft.	1.77 cu.ft.	2.13 cu.ft.	7.6	

The weights of aggregates indicated above are based on dry materials; allowance for the moisture in the aggregates shall be made in weighing. Moisture determinations shall be made at such intervals as directed. The quantities of water indicated in the table are based on the free water in the aggregates (not including absorbed moisture) plus the water to be added at the mixer. The contractor shall provide an approved apparatus especially designed for the weighing of concrete aggregates; and the mixer shall be provided with an accurate water-measuring and control device. The mixtures specified above are approximate. In order to obtain proper workability and a smooth, dense, homogeneous, plastic mixture free from segregation the relative weights of sand and gravel may be varied. However, the ratio of the weight of the cement to the sum of the weights of the fine and coarse aggregates

Preliminary Tests and Specifications

shall be not less than 94 to 529, 458, and 374 for 2000, 2500 and 3000 pound concrete, respectively, and bids shall be based on these proportions. Not more than the quantities of water specified shall be used for each sack of cement. The range of slump shall be between 3 and 7 inches. The times of mixing specified are to be taken after all materials, including water, are in the mixer. The designation of the class of concrete indicates the estimated 28-day compressive strength of standard cylinders tested in accordance with the standard methods of the A.S.T.M. These strengths shall be verified at such intervals as directed by taking samples of freshly mixed concrete from the forms. The cost of molds, storing, shipping, and testing in connection with these tests will be borne by the Government. In the event that cement in addition to that specified in the above table is necessary to obtain the estimated 28-day strength or for proper workability, extra compensation for such additional cement will be made in accordance with article 3 of the contract; in such cases, additional water may also be used, but in no case shall the specified water-cement ratios be exceeded. The approximate volumetric proportions and the estimated yield per sack of cement have been determined from trial batches made on the site with the materials to be used in the work and are given merely as a guide to bidders; the volumetric proportions and yields will necessarily vary with variations in the gradations of the aggregates."

All gravel to be washed. The necessity for this was determined by the colorimetric test for organic matter. While the organic content in our aggregates was not high there were large

Preliminary Tests and Specifications

amounts of sagebrush roots in them and it was thought better to wash all materials.

Gravel was defined as all material passing a 1-inch screen and retained on a No.4 sieve. We later allowed the contractor to use a $1\frac{1}{4}$ inch round screen for obtaining the maximum size, however.

Sand was all that which passed thru a No.4 sieve and not more than 3 per cent passing a No. 100 sieve. I shall have more to say of this later.

The water used in any batch included the moisture in the aggregate and this was determined by continually drying out samples at the bunkers. Compensation was made in the weight of moist materials for their water content.

The weights of materials given were determined by taking samples from the pits and screening them as called for in the specifications. Then taking cement and water in the correct proportions for each class of concrete, sand and gravel were added until a workable mix was obtained with a slump of about 5 inches. The weight of dry sand and gravel used was tallied and in this way the results were obtained for the specifications. We repeated these tests as the contractor opened up new pits or the material in the pits changed and it was from these tests and the results noted that we based the weight of materials used in our mixes. We made cylinders of all these test batches as we did of each days pour and had these broken in 7 or 28 days as the case demanded.

Preliminary Tests and Specifications

Carrying on the work assigned to me required a number of assistant inspectors. One man was located at the bunkers. His duty was to watch the grading and amount of sand and gravel which went thru the screen and washing plant. We had two sets of bunkers divided into 3 bins each. Each bunker was filled on alternate days so that it would have from 12 to 16 hours for the excess water to drain off. The first thing this man did at the beginning of each day was to dry out a sample as it came into the weighing hopper. If he found a 5 per cent moisture content in the sand he added 5 per cent of weight to the sand and sent a note with the truck driver to the mixer. It was found that our gravel ran fairly constant with 1 per cent moisture and after a little experience it was not necessary to run many tests on this for it never went above 2 per cent without having free water in it. So the bunker man sent a note with his figures based as follows:

Sand	Gravel	Water
Using 240# dry weight	290# dry weight	7 gal. $\times 8.34$ 58.38#
Water $\times 5\%$ moisture content	$\times 1\%$	-14.90#
Add 12.00#	2.9#	$\frac{43.48}{8.34} =$
Totals-252# sand	293# gravel	= 5.21 gal
$\times 6$ (for six sack batch)		
1512# sand	1758# gravel	31.26 gal. water

So with each truck load of 3 or 4 batches we would get a note. This note was received at the mixer by another assistant who stayed at the mixer all the time. His duty was to take care

Preliminary Tests and Specifications

of setting the proper amount of water on the water control apparatus, check the cement, check the number of loads and also to make the cylinders and cap them. Slump tests were taken whenever cylinders were made and at intervals during each pour.

During the placing we used two concrete pavers; a Koehring 27E and a Rex 13 because of their mobility. Four to seven sack batches were made depending on the mixer and class of concrete being placed. On some pours I inspected the placing alone but generally I had one helper and sometimes two.

I do not want it understood that we always set our water entirely from the above figures. This was the maximum amount to be used and only in rare instances did we ever exceed it. Generally we ran below the required amount.

In placing floor and roof slabs we generally had a $3\frac{1}{2}$ inch to $4\frac{1}{2}$ inch slump and reduced the water content about a gallon of water per sack. While often in narrow walls the full amount was used.

The actual placing of the concrete was handled by a crew of 10 to 16 Mexican laborers using buggies filled from a hopper. No concrete ever stood in this hopper more than a few minutes after being deposited there from the mixer.

The specifications called for all form lumber to be tongue and grooved and all formwork to meet the approval of the inspector in charge.

In the buildings all floors were topped with a 1-inch pea-gravel topping to be placed within 45 minutes after the base.

Preliminary Tests and Specifications

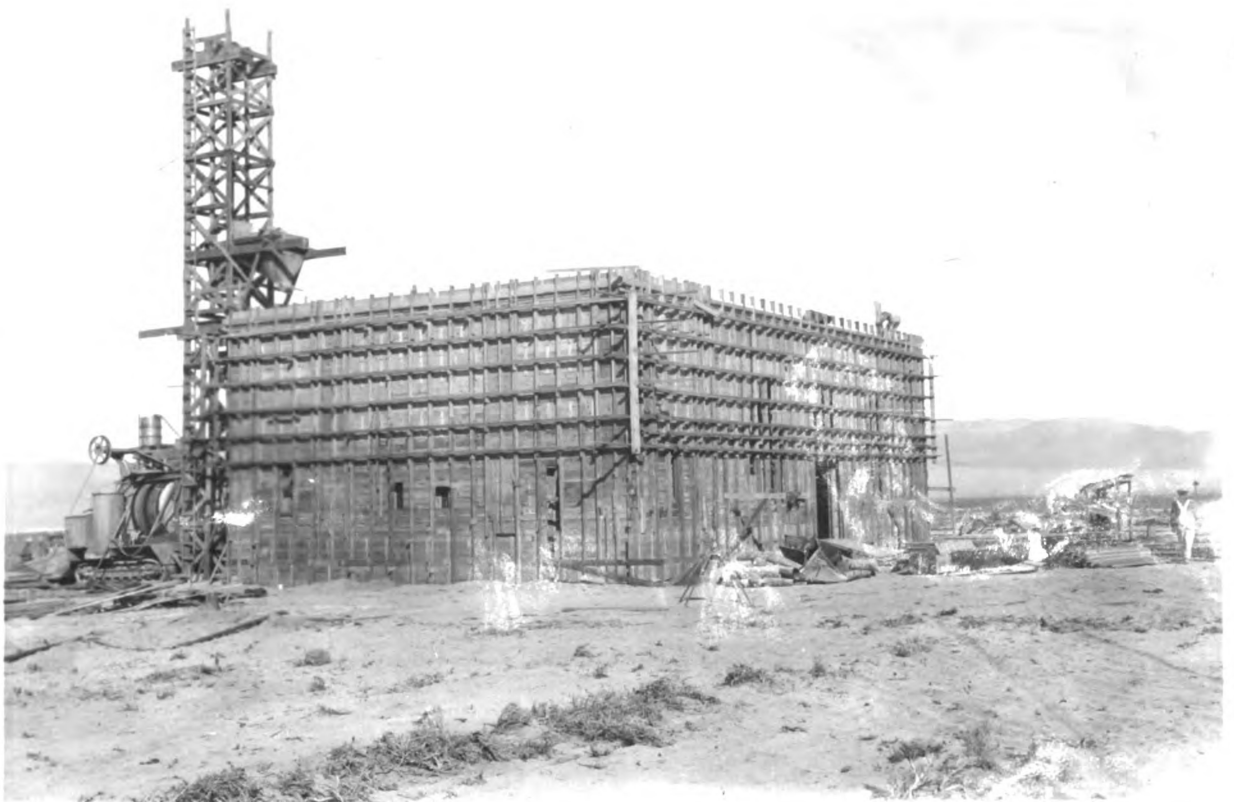
This topping to be one part cement--one part sand and two parts pea-gravel graded from one-fourth to three-eighths inches. The magazine floors had a 1 to 2 cement sand finish.

The curing periods for watering and protection from drying ran from 7 to 14 days. This question will be taken up in part 5 more fully.

In the buildings 2000-pound concrete was used thruout. In the arches of the magazines and reservoir floor we used 2500-lb. concrete and 3000-pound concrete was used in the walls of the reservoir only.

2. Formwork And Reinforcement

- (a) Material Used.
- (b) Practical problems of design in relation to forms.
- (c) Relation of formwork to placing concrete.
- (d) Form ties and spreaders.
- (e) The magazine building forms and reinforcement.
- (f) Construction joints.



2. Formwork and Reinforcement

As has been stated all forms were constructed of tongue and groove material. Both pine and spruce were used. While the spruce was more durable and could be used repeatedly with the best results, forms built of it could not be left standing any length of time in this particularly dry climate or the boards would shrink so that the resulting surface would be badly "finned" due to concrete going into the cracks. In general, however, we obtained very good results and even surfaces in our buildings with these forms.

When we started on the magazines the contractors made up sectors of circles for the arches. There were 5 sectors on each side with a 1-foot beveled keyway at the top for the removal of the forms. Three sections made up each end wall. All were bolted and wedged together and proved satisfactory with one exception. After they had been used the second time the boards started to shrink and warp. Here we had some difficulty in getting the contractor to renew or relay by turning the boards on these sectors. In my technical report on this job I strongly recommended that hereafter all such forms be metal covered. We tried to prevail on the contractor to do this for his own benefit, but he would not, so he simply had to keep renewing his form boards and in some cases where he would use his forms for the third time the cost of finishing to him was more than covering that set of

Formwork and Reinforcement

forms with a light metal would have been. Then, we did not have as neat a finished job as a metal covered form would have given us.



Example of excessive roughness due to warped boards in forms

The magazines when finished are completely covered with earth excepting the front wall. This wall is only 4 inches thick and has only a single 4 by 4 mesh reinforcing. The reason for this narrow wall is to make it the weakest point so it will fail first in case of an explosion. We found this wall form very hard to place

Formwork and Reinforcement

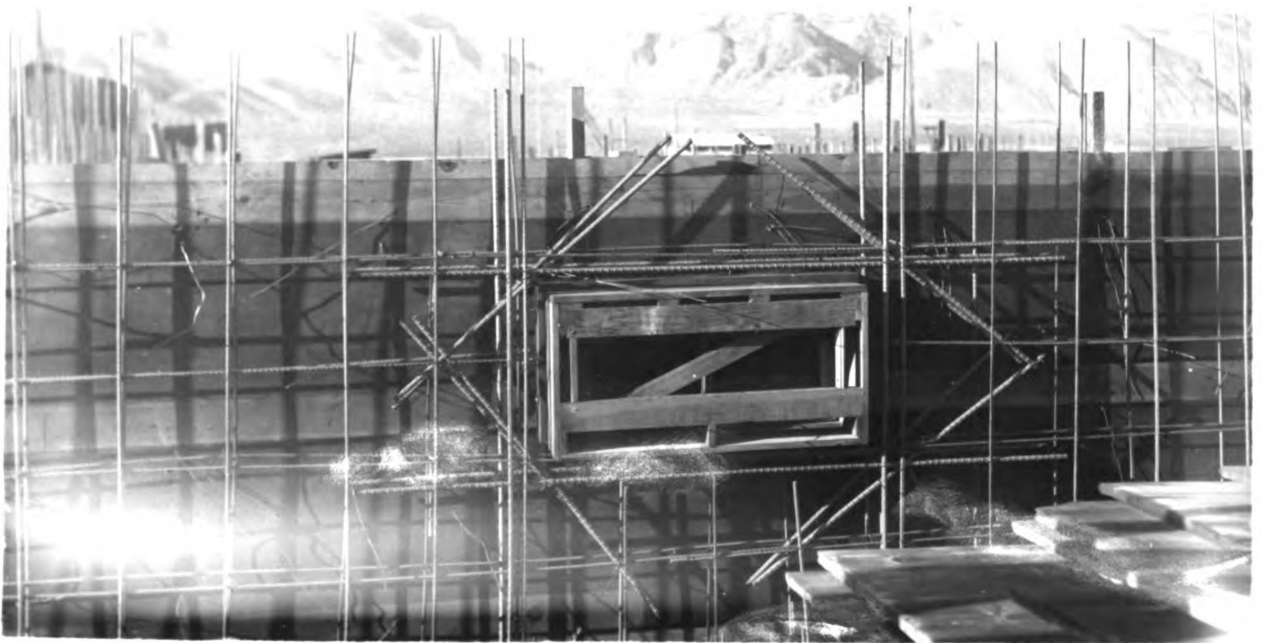
concrete in due to it being only 4-inches thick and were convinced of the folly of such narrow design in any ordinary building. Try as we would with even a 7-inch slump and a good mix we had places where the concrete would arch and form a 6-inch to 8-inch hole completely thru the wall. With the same reinforcement in the 6-inch rear wall we were not troubled in this way.

Most of our building walls were 8-inches thick with $3/8$ " rods in both faces, both directions on 1-foot centers. Here again we had trouble at times placing our concrete and we found where we had 10-inch walls or wider that the extra amount of concrete often paid for itself in the reduced labor cost of placing and finishing. It is a problem of design that must be kept in mind when trying to reduce the volume of concrete and add steel in a wall. Most of our wall pours were made with a height of 10 to 12 feet. A great deal of our trouble lay in the fact that we had a large number of openings. Each opening was required to have a $5/8$ -inch rod diagonally across each corner and parallel with each side in each face of the wall. It can be readily seen that with all this reinforcement around the openings we often had an arching effect resulting in a honeycomb.

We did find a great advantage in leaving out all window sills when we placed the walls. These were formed later and poured to a true line and good finish. It also gives the advantage of being able to tamp thru this opening below the window ledge as you place the walls.

The Navy plans on this job called for roof slabs and some

Formwork and Reinforcement



Typical wall and opening reinforcement

other slabs to be $3\frac{1}{2}$ -inches thick. Here again the question of saving concrete in design arises. Many of these slabs contained a large number of electrical conduits besides the reinforcing and in a number of instances it was practically impossible to cover the steel and hold it properly in place with the conduits cutting thru it. I am very much in favor of holding to a minimum 4-inch thickness in slabs. This is particularly true when

Formwork and Reinforcement

the slab requires a finish or topping for a floor.

As I stated in part I, we tried to hold somewhere near a 4-inch slump and not over 5-inches in placing any deck. There are several reasons why this is good practice. First, of course (in our case) is the added strength obtained with the drier mix. Second, in finishing a floor if the weather is not very warm all of the water comes to the surface and must be "hosed" off by dragging a hose over the surface, or dried up with the application of a cement and sand drier or by some other method. No method is good where a true surface is required. It is much better not to have the water there. Third, with a dry mix a floor is finished easier and quicker thus saving money in finishing. Fourth if the base in a two course monolithic floor is wet it mixes in with the topping to a great extent and destroys the object of using the topping. Fifth, if you are placing a roof slab, which has a $\frac{1}{2}$ -inch per foot pitch with a wet mix the water will run over the green concrete and wash out the cement in streaks so that it must be worked over again to obtain good concrete.

For walls we have a different problem. Given a wide wall (12 to 15 inches) a relatively dry mix can be used to good advantage even with fairly close reinforcement. However, where we had an 8-inch wall and reinforcement as I have noted above I believe it is better to use a wetter mix which will insure a good job after the removal of forms. I think it is good economy to even add more cement to gain added strength if it is needed rather than to dry up a mix so that the resultant wall will be

Formwork and Reinforcement

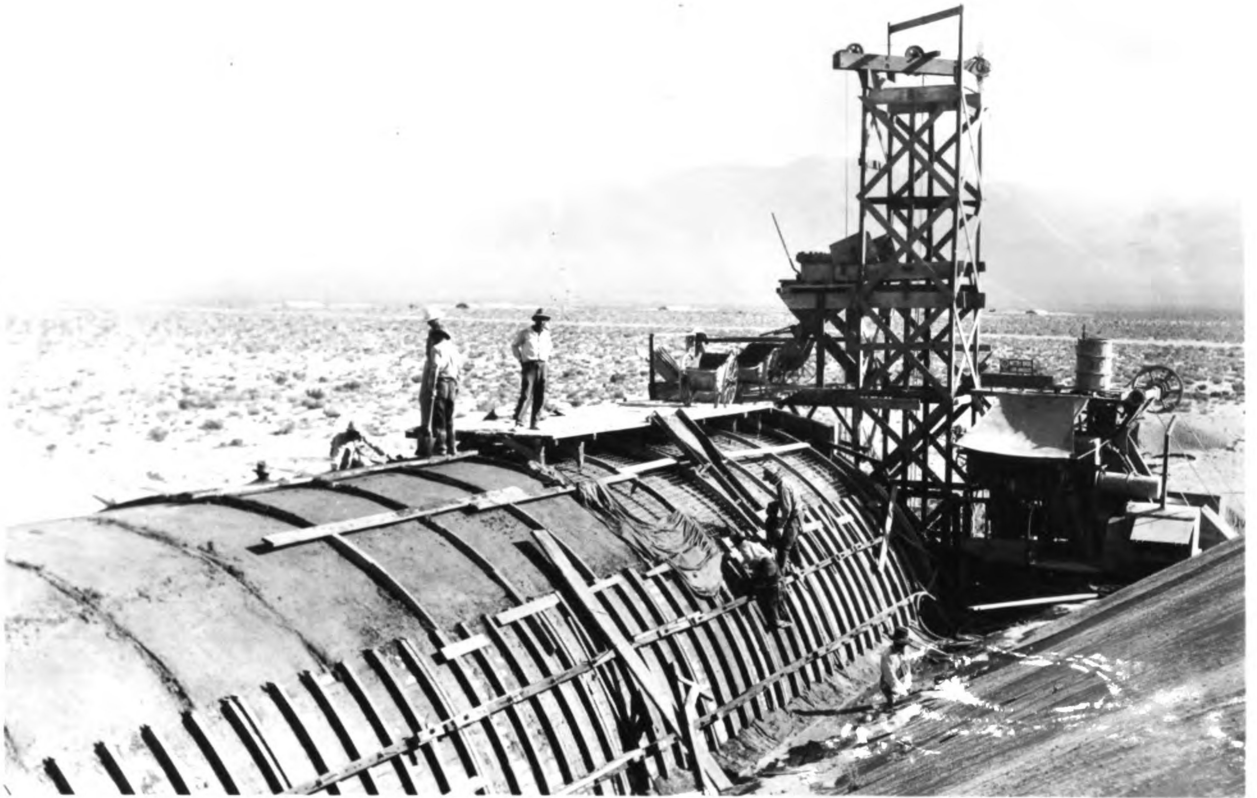
honeycombed in spots. The cost of finishing such a wall is too great and the cost of placing a dry mix in a narrow wall will cut down more profit than adding a small amount of cement would.

The Navy does not dictate the type of tie to use in formwork and both wire and 3/8-inch rods with buttons were used. If wire is used correctly it is satisfactory. But there is one big advantage in using a combination tie and spreader due to the saving made in not having to remove the wall spreaders before or during the placing of concrete. Many good kinds are on the market and many more ingenious ones will be found in use by building men today.



Formwork and Reinforcement

View on previous page shows reinforcing steel and six foot outside form height.



General view of magazine during placing of concrete using an 8-foot outside form height.

Enclosed will be found a view of formwork for a magazine . The base of the arch is 10-inches thick and the top of the arch 5-inches thick. $5/8$ -inch rods imbedded in the footing were run way up the sides with 2 layers of 4 by 4 mesh weighing 62lbs. per 100 sq.ft. over the top. The placing of this reinforcement was difficult and we were very fortunate in having excellent steel-

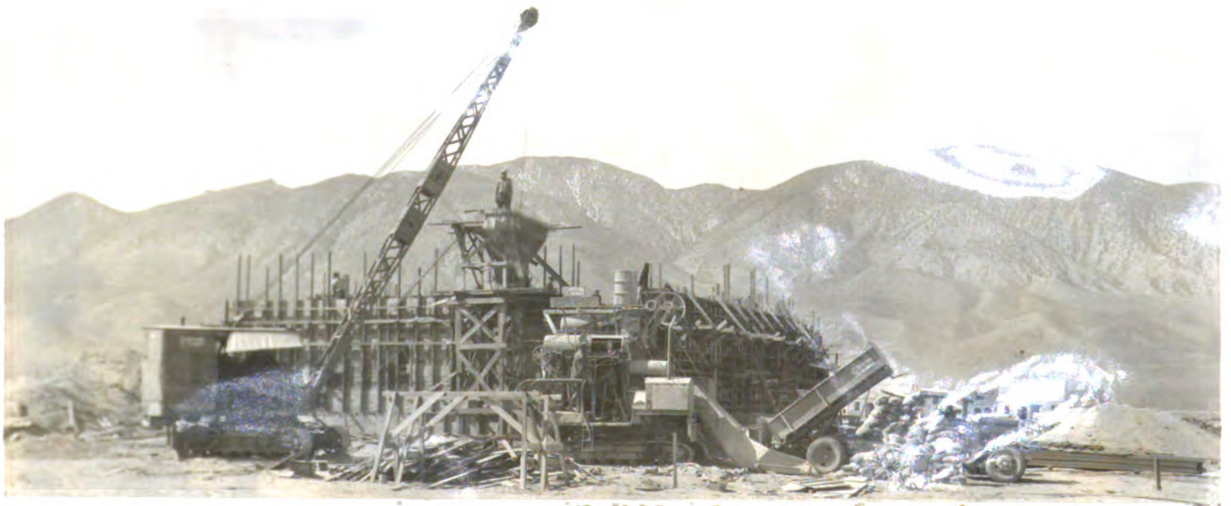
Formwork and Reinforcement

men on the job to handle it. It took a little experimenting to determine the correct height to which to run the outside forms. The contractor, against our advice, attempted a 6-foot height at first but we insisted on 8-feet and eventually used between 8 and 9 feet for these outside forms. The lower section was placed using a slump of 6 to 7-inches and the upper section with a slump of 3 to 4-inches. Here was found the value of having a minimum slump clause in the specifications. For with a 6-foot height the contractor wanted to use a 1 to 1½-inch slump on the portion just above the 6-foot outside forms. It left a poorly placed honey-combed under side and it was partly by using our 3-inch slump as a lever that we managed to get him to raise the outside forms higher. Rods and buttons were used entirely as form ties for the magazines and were often pulled 12 hours after the arch was placed. Inside forms were removed from 2½ to 4 days after placing of the concrete.

The best results were obtained in making a horizontal construction joint in a wall where we used a fairly dry mix for the last foot or so, and as the concrete got its initial set we troweled the outer 2-inches to a smooth straight line. Then in the first whaler below the concrete the form tie would be drawn up tightly, after the initial set when shrinkage had taken place. The lower forms could then be removed and there would still be no bulging nor narrow ledge when another pour took place. Indeed in many places it is next to impossible to find the construction joint.

3. Aggregate Supply And Its Effect On Concrete.

- (a) General discussion.
- (b) Quality of aggregates which we used.
- (c) Finess modulus of our aggregates.
- (d) Relation of aggregates to yield.
- (e) Bettering the gradations to increase workability.
- (f) Importance of grading in aggregates.
- (g) Use of admixtures in concrete.



3. Aggregate Supply And Its Effect On Concrete

In the study of aggregates we come to one of the most important of all factors controlling concrete. Here we control the cost of our mix per yard, the ease of placing is in direct proportion to the workability and a uniform supply of aggregate means a uniform concrete.

It is quite necessary to have clean, hard particles that are durable and strong, in both sand and gravel. We had all of these requirements in our sand and gravel deposits. The maximum size used was passed a 1-inch round screen. Next we want a well graded aggregate from the smallest grains to the largest. This we did not have. We all know that the more rock we can get into our mix, up to a certain point, the better yield we will have; but in placing more rock in a certain mix we increase the harshness of the mix. As it was imperative that we have a good plastic mix in placing narrow walls we were forced to use more sand than we would have liked to.

From the first day we placed concrete we started a struggle to try and obtain better grading and especially a higher percentage of the fine material passing a 50 screen. We had a harsh mix at best and for this reason the screening plant designed to take out a portion of the peagravel between $\frac{1}{4}$ -inch and $\frac{3}{8}$ -inch. Of this we had at least 50% too much and were very fortunate in having this particular size specified for for all floor topping, so the contractor made a special bin for it in his bunkers and

Aggregate Supply And Its Effect On Concrete

wasted about 50% of what normally would have gone into the gravel bin.

I give below the mechanical analysis of the sand as used on November 12, 1929 near the beginning of operations.

Size of Sieve	% retained on	Cumulative % retained on
4	3.1	3.1
8	45.6	48.7
14	12.7	61.4
28	24.1	85.5
50	11.5	97.0
100	2.2	99.2
Passed 100	0.8	

394.9

Or giving a fineness modulus of 3.95. Note carefully in the above that there is only a total of 3% which passed a No.50 sieve. The American Society for Testing Materials specifies that from 2 to 30% of fine aggregate pass a 50-mesh sieve but the Joint Committee Report for 1924 recommends 10 to 30%. I heartily agree with the Joint Committee in holding this lower figure to 10% and think this grading should be a part of every specification. Note also the 45.6% which we have between a No.8 and a No.4 sieve. This was what gave us the high fineness modulus of 3.95.

The Navy specifications called for 5 to 30% passing a 50 mesh sieve so I immediately started out prospecting to find a finer sand

Aggregate Supply And Its Effect On Concrete

to mix with the sand deposits which we had on the beach. A few days later we ran a complete analysis of the sand and gravel, before any change had been made, with the following results.

Size of Sieve	Gravel		Sand	
	%retained	Cum. % retained	% ret.	Cum. % ret.
1½	0	0		
¾	13.9	13.9		
3/8	58.3	72.2		
4	26.7	98.9	11.0	11.0
8	1.1	100.0	25.7	36.7
14		100.0	21.8	58.5
28		100.0	22.6	81.1
50		100.0	15.6	96.7
100		100.0	2.3	99.0
Passed 100			1.0	
		685.0		383.0
		Mc 6.85		Mf 3.83

Using the formula $M = rMf + (1-r) Mc$ taken from the Portland Cement Association pamphlet on Design and Control of Concrete Mixtures (1927 Edition) we get $M = .497 \times 3.83 + .503 \times 6.85 = 5.35$. So by using 2.76 cubic feet of sand to 2.80 cubic feet of gravel we were obtaining a mixture which had a suitable fineness modulus but still was not what we wanted. It was too harsh, it did not yet have enough fines passing a 50-mesh sieve, and note that 37.3% of the total material was between the #8 and 3/8 sieves. What would it

Aggregate Supply And Its Effect On Concrete

have been if we were not wasting a great deal of this material!

And we were still sacrificing uield to get our mix by using so much sand. Calculating our yield we have :-

$$\text{Cement} \quad \frac{95}{3.1 \times 62.5} = .49 \text{ cubic feet}$$

$$\text{Sand} \quad \frac{2.76 \times 88}{2.65 \times 62.5} = 1.47 \text{ cubic feet}$$

$$\text{Gravel} \quad \frac{2.8 \times 102}{2.65 \times 62.5} = 1.724 \text{ cubic feet}$$

$$\text{Water} \quad \frac{70}{7.5} = \frac{.934 \text{ cubic feet}}{4.62 \text{ cubic feet}}$$

$\frac{27}{4.62} = 5.84$ sacks of cement per yard. And this figure was very closely proven in our actual yields obtained on various pours.

We now pointed out to the contractor that there was not enough fine material in the sand he was getting and if he would haul some fine sand from another place and mix it he would gain by increased workability of his mix, and more than likely he would increase his yield per sack of cement.

We located a sand deposit for him of the following analysis.

Aggregate Supply And Its Effect On Concrete

Sieve	% retained	Cum. % retained
4	2.3	2.3
8	8.0	10.3
14	9.1	19.4
28	14.6	34.0
50	34.2	68.2
100	27.3	95.5
Passed 100	4.5	<u>229.7</u>

$$Mf = 2.30$$

This should surely give us more of the fine material we wanted and it did as was shown by a sieve analysis taken in a few days.

Sieve	% retained	Cum. % retained
4	6.2	06.2
8	12.55	18. 75
14	23.68	42.43
28	33.07	75.5
50	20.11	95.61
100	2.58	98.19
Passed 100	1.81	<u>336.68</u>

$$Mf = 3.37$$

We still only had a 4.4% passing a 50-mesh screen but we had lowered the percentage retained on a No.8 sieve and were obtaining better workability in our concrete. In order to gain a more plastic mix and get away from handling any more material at

Aggregate Supply And Its Effect On Concrete

the bunkers than necessary the contractors started using 2-lbs of celite in his mix with each sack of cement. This helped out to a great extent in placing concrete.

However from January on we managed to keep increasing the quality of material from the bunkers until we obtained a sand that rarely had less than 5.5% passing a # 50 sieve and ran about 20% retained on a No.8 sieve. Our fineness modulus settled down to about 3.5 and Mc held to about 6.8 for a M of 5.2. While there was still something to be desired in our aggregate we were obtaining good results with the mix and good strengths from our cylinders.

The specifications had called for a maximum 1-inch size and although we increased this to $1\frac{1}{4}$ -inches we still did not have enough of the size from $\frac{3}{4}$ -inch to $1\frac{1}{4}$ -inch aggregate to get a much better yield from the mix.

While I was still placing concrete in the magazines we had let another contract for paving and while I was not in charge of this work I was in touch with it somewhat and my former bunkerman took charge of the new bunkers for the contract. Their problem was somewhat different in that a maximum aggregate of 2-inches was used--a lower slump wanted and the placing was ~~all~~ mass work. A strength of 3000-lbs. was called for. Here the trouble was in finding enough LARGE aggregate. It was difficult to obtain the 1-inch to 2-inch size and keep this size 40% of the total large aggregate. (Navy specifications call for 40--70% passing screen of $\frac{1}{2}$ maximum size.) So the yield of 7.2 sacks per yard was not as good as we

Aggregate Supply And Its Effect On Concrete

would have liked to have had. But for the fact that the total weight of aggregate was given, this could have been bettered by adding more aggregate to the mix, for the strengths all went well over 3000-lbs. from the cylinders made.

While an admixture is not strictly an aggregate I would like to discuss it at this point as it is one of the ingredients which we used a great deal in our mixes. I have mentioned previously how it aided in the workability of our mix and I do not believe there was ever a better example than we had, of the value of celite to concrete. It gave us that needed fine material to give a plastic mix and so aided the placing. As an economic factor it probably saved the contractor hundreds of dollars in patching on narrow walls. By adding two or three pounds of celite per sack of cement the workability of the concrete was raised materially at a low cost. This reduced the cost of placing and produced better results in the walls. Obviously it is the most needed in the concretes of lower strengths, for as you increase the amount of cement per yard you increase the workability of your mix, given the same aggregates.

Then it has another effect, in making concrete more dense it adds to its waterproofness and durability. This was one of the great factors in its being in the magazine arches where 2500-lb. concrete was specified. It is light and bulky but acts as a lubricant to the mixture when used.

4. Findings And Criticisms.

- (a) Slumps and cylinders.
- (b) Water-cement ratio and our specification.
- (c) Examples of results obtained.
- (d) Care needed in making cylinders.
- (e) Tests for future work.



4. Findings And Criticisms

Thruout the entire placing of concrete an accurate record was kept of slump, and cylinders were taken for each pour. Also the amount of water used per gallon was observed. We used standard methods in taking the slump and in making of cylinders. I objected a great deal to our cylinder forms which were made of paraffined cardboard. Even taking all precautions it is hard to get reliable cylinders in using these forms. A metal mold is preferable. While our cylinders were supposed to be 6-inches they were actually measured and found to be closer to $5\frac{3}{4}$. Let us see what this $\frac{1}{4}$ " would amount to in a test specimen. Say a specimen broke a 80,000#

$$\begin{array}{lcl} \frac{80,000}{\pi 3^2} & = & \frac{80,000}{28.27} = 2830\text{-lbs. per square inch} \\ \frac{80,000}{\pi 2.875^2} & = & \frac{80,000}{25.95} = 3080\text{-lbs. per square inch} \end{array}$$

This shows the need for accurately calipering the diameter of specimens to be broken.

As can be seen from our specifications we called for the use of a water-cement ratio in limiting the amount of water used per sack of cement. But we also limited the amount of aggregates and by so doing made it impossible to obtain better than a certain yield. A true water-cement ratio specification limits the amount of water per sack, but only limits the amount of aggregates as to workability and slump. If we used all the water allowed us under the specification we had a slump around $6\frac{1}{2}$ " or 7". Now in placing

Findings And Criticisms

concrete in a slab or magazine arch where we wanted a slump of 3 to 4-inches we cut out some of the water. In other words we just increased the strength of our concrete when we did not need this increased strength. We could have just as well increased the aggregate in the mix to get this lower slump and at the same time increased our yield and obtained the desired strength by keeping the water constant.

In the table below I will give some examples of cylinders taken and strengths obtained which will clearly show that by lowering the amount of water used to obtain a lower slump we have clearly increased the strength of our concrete indicating how the theory of water-cement ratio holds true.

Date	Slump	App. gal. water per sack cement	Place of pour.	Strength
12/22/29	6 $\frac{1}{2}$	7 gal.	Walls Civ. Qtrs."a"	2130#
12/22/29	6	7 "	" " "	2000#
12/27/29	4 $\frac{1}{2}$	5 $\frac{3}{4}$ "	Boiler Plant Floor	3230#
12/27/29	4 $\frac{1}{2}$	5 $\frac{3}{4}$ "	" " "	3400#
2/19/30	7	7 gal.	Locomotive Shed Walls	2350#ave
3/14/30	4 $\frac{1}{2}$	5 $\frac{1}{2}$ "	Shop Floor	4320#}3 cyl.
* { 3/16/30	1 $\frac{1}{2}$	-	Reservoir Floor	5380
{ 3/16/30	1	-	" "	6010#
{ 3/16/30	1 $\frac{1}{2}$	-	" "	4070#
** { 3/16/30	7 $\frac{1}{2}$	5 $\frac{1}{2}$	Reservoir interior columns	3180#
{ 3/16/30	7 $\frac{1}{2}$	5 $\frac{1}{2}$	"	2920#
{ 3/16/30	7 $\frac{1}{2}$	5 $\frac{1}{2}$	"	3270#

Findings And Criticisms

*2500# concrete mix used, water cut away down.

**3000# concrete mix used, maximum water used.

Note the last two examples especially. We had a 2 to 1 sloping floor in the reservoir in which it was necessary to use a very stiff mix to hold the concrete in place and it was necessary to cut the amount of water way down. On the same day and under all of the same conditions we placed the interior columns with heavy reinforcement in them. We went to the opposite extreme and used all the water allowable making a sloppy mix. While the floor mix was supposedly a 2500-lb. mix we naturally obtained a much higher strength than with the 3000-lb. mix which had more cement in for the amount of aggregate.

From the above it can be seen that a specification written around the true water-cement ratio is perfectly safe if it is under careful supervision, and results in a saving to both the contractor and to those for whom he is working.

During the period from November 1, 1929 to September 10, 1930 we placed concrete nearly every day, Sundays included. During this time I had four different helpers who made cylinders under my supervision. One of them was very careful and could be depended upon to always take every precaution in making his cylinders and capping them, then taking them to the curing room himself. One of the others was good but a little slack in some place once in a while. While the other two were not very good. Let us sum up the results obtained during each ones work. The personal factor which

Findings And Criticisms

entered is easily seen

Helper	Rating	Class of concrete	No. cyl. made	Aver. Strength	Remarks
11/1/29 (1)	Poor	2000#	55	2064	Cool to cold nights. Heating concrete in latter part of time.
12/18/29					
12/19/29 (2)	Poor	2000#	75	2000	Cold weather. Heating and protecting concrete. Aver. curing 55-60 degrees.
3/11/30					
3/12/30 (3)	Very Good	2000#	39	3206	Cool to cold nights. Heating concrete most of the time. Curing temp. about 55-60.
3/30/30					
4/1/30 (4)	Good.	2000#	37	2888	Warmer weather. Curing only fair to poor.
9/1/30		2500#	54	3302	

While it may look as though the second man was handicapped by the cold weather still the third man had about the same conditions when he first started and we immediately obtained much better results from the first day he started. The last man got excellent results at times and then for no accountable reason he would get a cylinder to test only 1400# or so. Many of the 2500# cylinders went well over 4000#. But this only strengthens the point I made about our cardboard cylinder forms. One must pay attention to every fine point all the time to get good results.

While I am writing this I would like to set down the results of some tests which we have just run and our aims for the future.

Findings And Criticisms

We expect to build a 120-foot dam some time this coming summer and in view of that fact have tried to make up a mix that will give us a 3000-lb concrete with better yields. To do this we will first use a larger aggregate, a maximum 3-inch size. Second, since the concrete will be all mass work we are justified in using more water and still obtaining greater strength over what we would get in a narrow wall. We will use 6 gallons per sack. Also we can stand a harsher mix in this work, so we can use a larger proportion of rock and this will better the yield.

Our greatest trouble lies in the fact that we have not a large enough percentage of the larger aggregate---that between $1\frac{1}{2}$ and 3-inches. It will be hard to get 15% of our aggregate larger than a No.4 sieve between the above sizes. But we have designed a mix using 6 gallons of water with a 2-inch slump which gives us a yield of 5.5 sacks per yard. We then ran test batches of this thru the Depot's two-sack mixer and have made three cylinders of this mix. Following is the result of these cylinders which we have just broken at the age of six days:-

Compressive strength per square inch---2285#, 2130# and 1940# for an average of 2118#. Substituting in the formula $28_s = 7_s + 30\sqrt{7_s}$ results in a strength of 3498# at 28 days. Had we let these cylinders go the full seven days they would have shown better results than this.

Our biggest problem is not solved yet however for we have to obtain the Bureau of Yards and Docks, (Navy Dept.) permission

Findings And Criticisms

to use our specifications in the contract for this mix. The jobs here are some of the first the Navy has ever had where water-cement ratio was used in any form and we are attempting now to have them draw up their specifications for the coming job based on a given maximum volume of water and limiting slumps with a clause calling for a workable concrete.

It is possible that we may resort to obtaining the larger size of aggregate from crushed rocks. The dam site will be located in a narrow mountain canyon where by selecting the material we can obtain good granite or dolorite rock for crushing. Besides obtaining the larger aggregate sizes we would eliminate a 4 to 5 mile expensive truck haul.

5. Placing And Protection Of concrete.

A. Placing

- (a) Mixing units.
- (b) Use of tower and shovel in hoisting concrete.
- (c) Placing concrete in walls and magazine buildings.

B. Protection and Curing

- (a) Protection and curing in cold weather.
- (b) Finishing interior walls in cold weather.
- (c) Finishing exterior walls in cold weather.
- (d) Finishing walls in hot weather.
- (e) Finishing and curing concrete in magazine area during hot weather.

5. Placing And Protecting Concrete

Before the contract was let the point came up as to the type of mixing plant to be used. At this time the Bureau definitely decided against a central mixing plant and so stated in the specifications. I believe that this was a wise move for with the best of handling equipment for the transportation of concrete, there would have been trouble due to segregation, with the materials we had. As has been stated, the contractor used two pavers, a one-yard Koehring and a half-yard Rex, whichever could be used to the best advantage. This gave a very mobile mixing plant and worked well in changing from one building to another quickly. Material was hauled to the skip from the bunkers by trucks having space for three or four batches each.

A fifty-five foot tower placed on skids, complete with hoisting machine and hopper was used for placing all concrete above the first floor. This tower was hauled from one building to another with the shovel which was on the job for excavation of basements and pits.

In some cases when the tower was used for a number of different pours at one building we used a shovel to hoist concrete up to a hopper as shown in the illustration on page 22. This method also worked very well and often let us place a second story slab or first story walls where the forms were ready without undue moving of the tower. While it may seem that the shovel would be clumsy, under the guidance of a good operator it worked alright and we

Placing And Protecting Concrete

did not have a serious accident of any kind during the entire job.

The rate of placing concrete in walls necessarily varied but we held to a maximum of not more than a six foot rise per hour. All concrete was placed in layers around the building and not allowed to "run" in the wall forms.

In the lower part of the magazine arches due to the curve in the forms and the two layers of reinforcement, both mesh and 5/8-inch rods, it was very difficult to use tamping sticks. Here the specifications called for the forms to be vibrated with air hammers. A portable air compressor was used and two hammers used all the time during the placing; one on the outside and one on the inside of the structure. Very good results were obtained with comparatively little honeycombing, although this was difficult placing.

A small tower was used for the magazine placing. It had a platform in connection at a height on a level with a runway placed along the top of the forms. (The set-up is illustrated on page 20). This tower was easily moved by a 30 horse power tractor. As there were only 40 cubic yards of concrete in a forty foot arch with end walls and 70 cubic yards in an eighty foot magazine we had to have a mobile unit, the magazines being about seven hundred feet apart. A new set-up could be made in about thirty minutes. By using this time for lunch hour for the concrete crew no time was lost in moving. The small mixer was kept ahead and used in placing footings and floors. The larger mixer followed and was used for placing

Placing And Protecting Concrete

the arch. By working back and forth between the two mixers we soon worked out a system whereby we placed more than 100 cubic yards of concrete for a daily average. The government working day of eight hours was strictly adhered to. This meant from two to four moves each day. Eight complete sets of forms were the most that were ever used.

During the placing of concrete we had many and varied conditions of temperature to meet besides the added condition of a dry desert atmosphere. Practically all the building concrete was placed during the winter months, from November to April inclusive. While the winters here are not the severe winters of Michigan the daily temperature range is liable to vary quite widely. Owing to the altitude (a little over 4,000 feet) the sun's rays here are more intense and in the middle of winter the temperature is liable to reach 50 degrees F. during the day. But after the sun goes down the temperature falls fast and by morning a reading of 0 degrees was recorded several times.

All concrete was to be protected and heated if the temperature fell below freezing during the twenty-four hour period. So during most of December, January, February and parts of March we heated all concrete and protected it for about two nights afterwards. I say nights because there is rarely a day when the temperature does not go above freezing.

Several methods of heating were used. Two foot diameter cylindrical culvert pipes were placed in the bottom of each bunker

Placing And Protecting Concrete

bin with a smaller pipe leading up thru the aggregate for draft and incidentally used for heating also. These were fired and kept our moist aggregates from freezing, in fact gave an average temperature of 40 degrees F. in the aggregate.

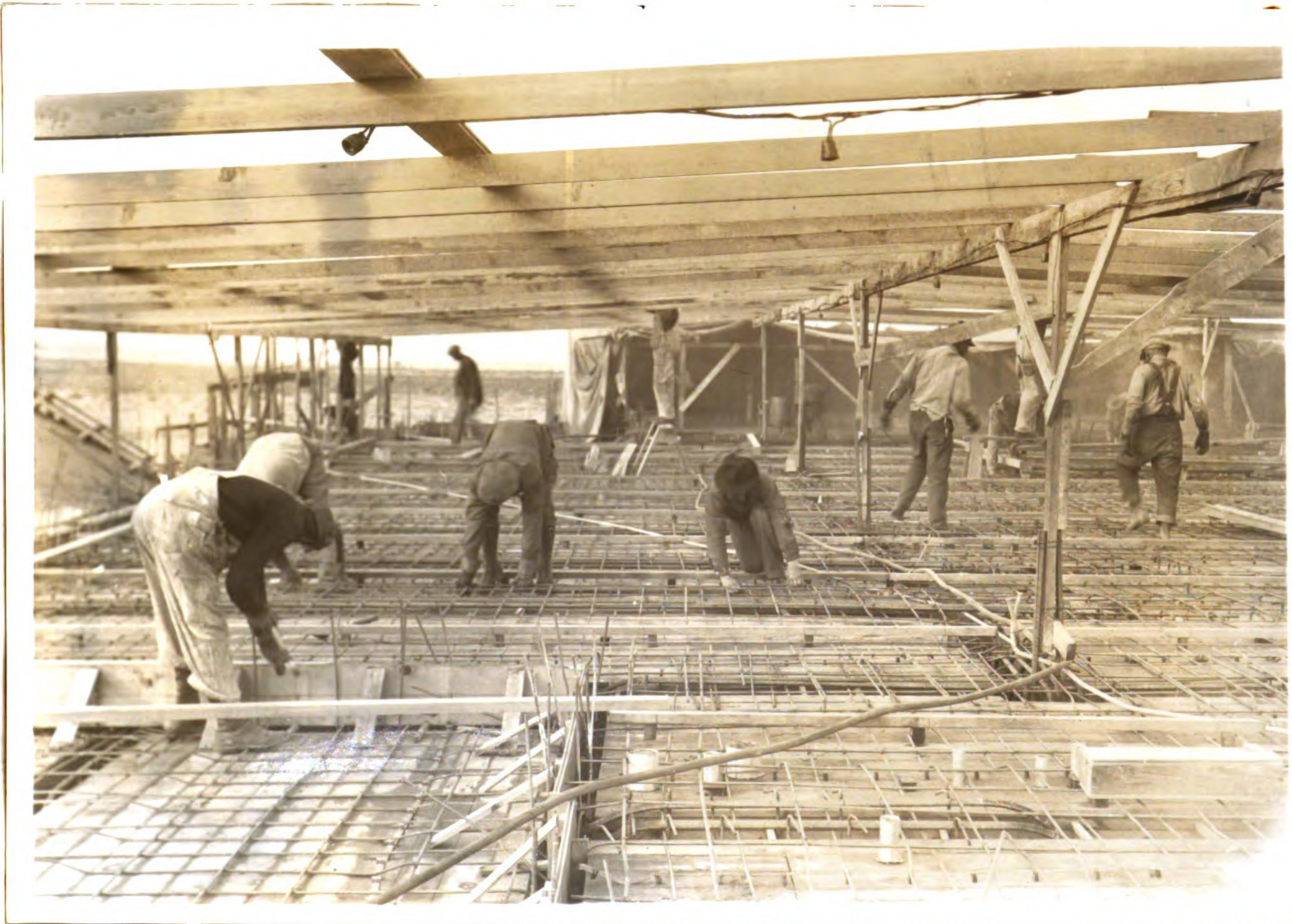
For small pours a large kerosene blow torch was often used at the mixer. By keeping it blowing into the drum a temperature of 60 to 80 degrees F. was obtained in the concrete as it came from the mixer. Rarely was the temperature below 55 degrees after the concrete was placed in the forms.

We also had a vertical water boiler burning crude oil and placed on skids, and by heating the water before it went into the mixer we sometimes had as high a temperature as 80 degrees in the concrete after placing. On stormy days or real cold days (we get many cold winds here) it would be necessary to use both boiler and torch but many times the boiler alone would suffice.

For wall pours during this period canvas was placed over the wall top and extended, on the outside of the forms, down at an angle to the ground. Salamanders were placed between the forms and canvas for exterior heating. As the deck on the top would also be formed when we placed the walls the interior was very easily heated by a few salamanders. Where there was danger from fire, lanterns were used and it is surprising how warm a number of lanterns will keep a closed space.

In placing a floor slab, as shown in the following photograph, a framework was built and canvas covered which completely

Placing And Protecting Concrete



Floor slab just prior to concreting. Overhead framework to support tarpaulins for protection of concrete from freezing and to retain heat from salamanders as in background.

housed the deck. Salamanders and lanterns were used for heating here also. The deck shown was of heavy beam and girder construction and was placed in January during one of our coldest spells. Temperatures were observed regularly and the enclosure was heated for two days and nights after placing concrete. On the fifth day after

Placing And Protecting Concrete

placing, the temperature under this slab was still 56 degrees F. although we had nightly temperatures of 5 degrees F. outside and no heat had been supplied for three days. This gives an excellent idea of how a large mass of concrete given an initial heat of 75 will retain its heat, being aided of course by the heat of setting.

All of the floors were covered with sand 24 to 36 hours after being placed. This sand was moist and kept moist for two weeks for curing. We can thank our Nevada sunshine here for not allowing any place to have ice on it. Whenever it shines, at any season of the year, it will melt out the frost. Walls were cured by sprinkling with a hose. During the colder part of the year the forms were generally left in place a week to ten days to help protect the concrete.

One of the biggest problems in cold weather concrete is finishing exposed surfaces. We finished all exposed surfaces by rubbing with a stone, using a sand-cement grout after the first unevenness was removed. In some cases a thorough sacking was nearly all that was required. Practically all of the grout was removed in any case. Only the pock marks and small voids being flushed to a true and even surface. On the exposed interior walls, forms were removed as soon as possible while the heat was still in the concrete. Openings were covered and by the use of a small amount of heat the green concrete surface was finished with a good bond between the finish mortar and wall.

The exterior walls presented a more difficult problem how-

Placing And Protecting Concrete

ever, The thin coating of grout used in finishing was very easily frozen at night. There were no forms to protect nor mass to hold the heated surface over night. Sometimes canvas protection was enough, sometimes salamanders and canvas were used. But in some instances we had the finishing frosted and later on it flaked off, making it necessary to refinish. A number of the exterior walls were allowed to go until warmer weather in spring when they were rubbed down to an even surface.

The best weather we had for finishing of any kind, and in fact for concrete work of any kind, was the spring weather from late March thru May. When the hot sun of summer came we had to protect all finished surfaces from the sun! It proved a greater foe to us than the cold weather. Huge pieces of burlap were sewed together and hung against the exterior walls. These were kept wet for curing for five days after finishing. On the hottest days it was even necessary to drape these on the outside of a scaffolding while the finishing was in progress. The desert air is less humid than the average lumber kiln and it seems incredible that a mortar will dry and fall off while being applied but this was a fact. It was necessary to raise the humidity of the air and to keep the sun's rays off a wall to finish it so that the concrete could set before drying out.

The benefit of a dry mix in finishing a floor during cold weather was previously mentioned. The value of heat as an aid to finishing a floor during cold weather cannot be emphasized enough.

Placing And Protecting Concrete

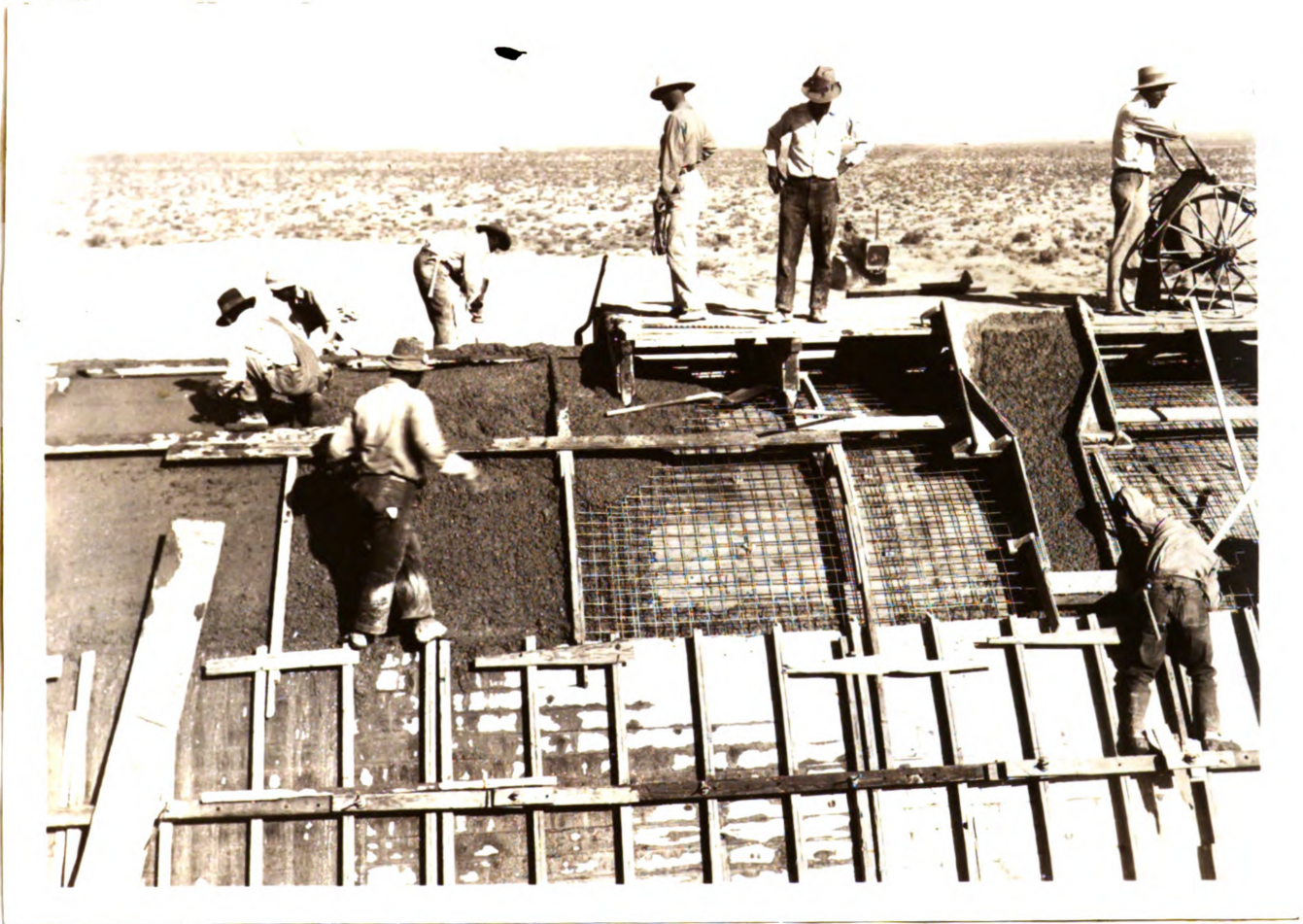
We had examples of the cost of finishing floors during both summer and winter. Often in the winter the last shift of finishers would be just completing a floor at eight A.M. which we had completed placing at four P.M. of the previous day. While during the summer all floors were completely finished from two to three hours after the last topping was placed. And this summer finishing was accomplished with greater ease and at times one third the cost.

During the cold weather it was necessary to wait from 24 to 36 hours after finishing before covering a floor. In the summer they were often covered with sand in 6 to 8 hours after finishing, and many times wet burlap was placed on a hard trowel finish in one to two hours.

Probably the most disagreeable concrete placing was that from May on into September in the magazines. Besides being difficult placing due to the unusual design we had the heat and dry air to take into account. As the weather became warmer in the first of June we started work at 4:00 A.M. so that all placing for the day was finished by noon. Within an hour after footings were completed and finished off they were covered with earth and watered. Next the floors were placed. These called for a hard trowel or a smooth finish. The base was placed and followed with topping inside of forty-five minutes. During the hottest weather it was found necessary to build a canvas canopy over the floors to keep these from drying out too fast. In some cases before this was resorted to the surface would crack nearly as soon as a finisher had troweled a

Placing And Protecting Concrete

spot. We corrected these places by retroweling them. However we gained a great deal by placing our concrete during the early morning hours.

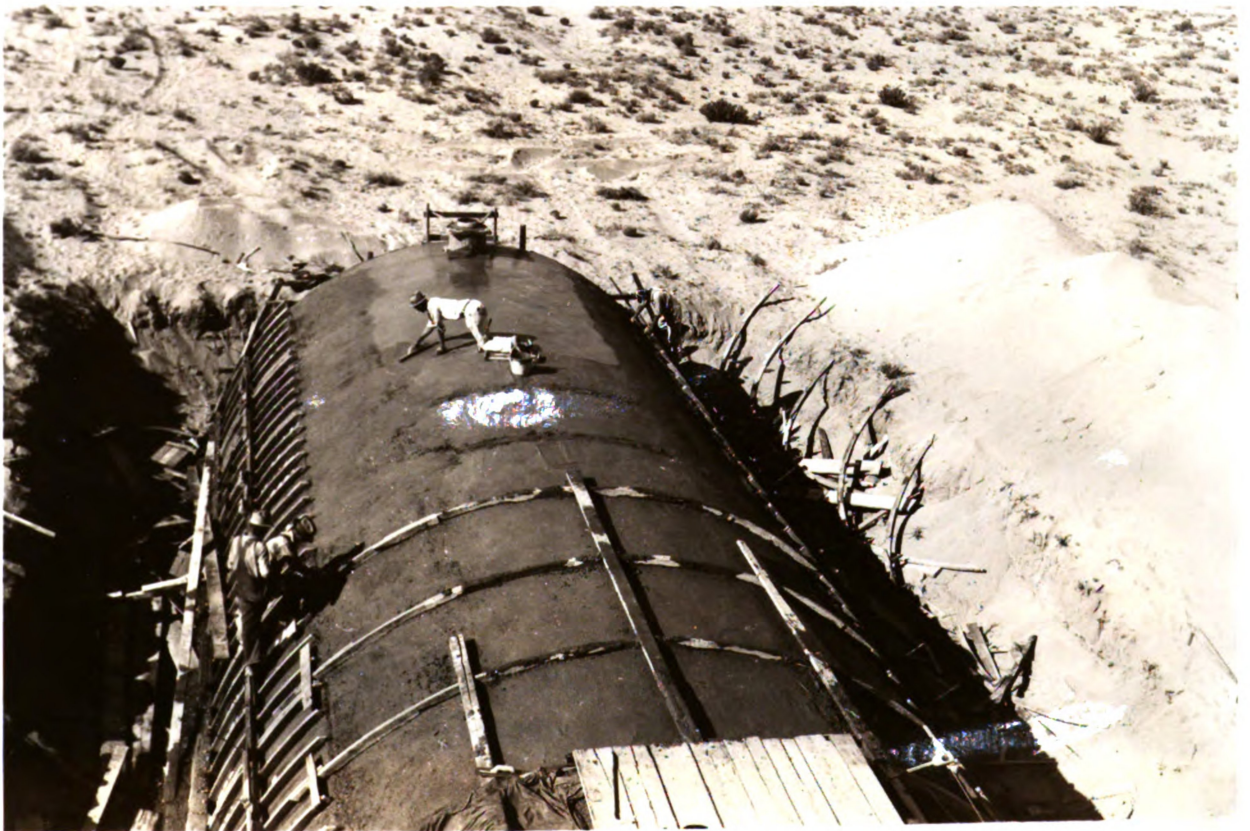


Placing concrete in Magazine Arch.

The magazine arches gave us the greatest problems. In placing these we tried a number of methods. First we tried chuting the concrete, which was unsatisfactory. Then dumping off a runway running along with and over the center of the arch was tried. This

Placing And Protecting Concrete

worked alright while the weather was not too hot, although it caused more or less segregation. Finally we dumped into chutes off from this runway and obtained good results. We had little segregation and no drying out of concrete on the sides of the arch between the outside form height and the crown. Canvas "tents" were used over some arches in hot weather to protect the upper portion from



Finishing top of Magazine Arch. Forms above top whaler will be removed immediately and this part of arch given a trowel finish as shown on top.

Placing And Protecting Concrete

drying out too fast. We placed all of the lower portion to the tops of the outside forms first. Then the remainder was placed complete in sections between screeds as we backed up on the arch. Thus it did not get much of a chance to dry out. Screeds were removed and this upper portion finished "to an impervious surface" immediately. Large burlap covers followed up the finishing and were sprinkled lightly within two to four hours. Watering in the magazine area was done with two 1500-gallon water trucks equipt with power pumps and hose. These trucks were run for 16 hours a day. Sometimes the temporary pipe line to the mixers was used. There was about 7,000 feet of pipe laid out at one time.

I do not mean to say that all went as smoothly as I have here stated. On some days it seemed impossible to keep the cracks from showing up on the surface of the magazine arches. The water in the temporary pipe line got so hot it was impossible to put your hand in it---temperatures of 165 degrees were recorded in this water. We had to cover this line, and then, with a shallow covering of earth it went above 100 degrees F. by 11:00 A.M. many days. The concrete was so warm if a little breeze sprung up and swept over the crown of the arch it often caused cracks to appear nearly behind the finisher's trowel on the lee side. The evaporation factor is so great here that it has immense cooling qualities and this sudden cooling due to evaporation before the concrete could obtain its initial set caused cracking. But with close co-operation and the diligence of all concerned we overcame all nat-

Placing And Protecting Concrete

ural obstacles and as a general rule good results were obtained.



Curing of Magazine Arch.

6. Conclusions.

- (a) Aggregate and Slump.
- (b) Harshness and Workability.
- (c) Economic value of water-cement ratio.
- (d) Conclusion.



Desert scene with Magazines in background.

6. Conclusions.

Given any natural aggregates a good concrete can be obtained from them. It may be necessary to wash and screen them and even to waste part of them to obtain the densest concrete. If all of the aggregate handled can be used, it is obviously the most economical and if the source of supply is known it should be the aim in designing a mix to use all of the pit run that is possible. The proportions of sand to gravel can vary greatly as has been shown by the example given in the previous pages. If the old 1:2:4 method of proportioning had been used with the aggregates deposited here the mix would have segregated badly and would have been much harsher than it was. For at times we used nearly equal parts of sand and gravel.

For the above reasons I think slump alone is a poor measure of concrete. It will give a relative value when the aggregates used are the same, but does not tell anything regarding the workability of concrete. For example, a 5-inch slump in our 2000-lb. concrete would denote a good, plastic, workable mix which would hang together and permit flowing in a chute. Given the same aggregates mixed in a 1:2:4 proportion and 5-inch slump we would undoubtedly have a harsh mix which, if we had attempted to chute would have segregated badly, and adding water to make a wet mix would have increased segregation.

At times it will be found more economical to waste part of the aggregate from a pit. This was true in our case, about 20%

Conclusions

of the material handled being wasted to improve the grading. Careful samples must be taken from the pits and the sieve analysis studied to see what gradation is found in the pit run. As not pit will give a uniform source of supply, the importance of a field laboratory can be seen to be of primary importance.

Nothing is more desirable in building construction than a dense, plastic, workable mix. It will fill all voids around the reinforcement, fill narrow walls, offsets and corbel, and is not as liable to segregate causing honeycombed surfaces. By the addition of more large aggregate to a concrete of above consistency we increase the yield up to a certain point. But the harshness also increases and the extra cost of placing and finishing are not offset by the cost of cement saved. Nor can the aggregate much larger than 1-inch in size be used in walls or around heavy reinforcing.

In mass work, such as dam construction, a dense, impervious concrete is desired but harshness is not such a controlling factor. Yield however, is a primary object in keeping the cost down for a structure of this type, and so, larger percentages of gravel are used. The added harshness is sometimes beneficial for the workmen who must walk in the concrete as it is being placed. Methods of placing necessarily enter in also. Good results may be obtained with a concrete bordering on harshness if placed correctly, whereas, a less costly method of handling would give poor results with the same mix. So any specifications must consider all things----- aggregates available, design of mix, and methods of handling. We

Conclusions

must have workability also, and with the proper gradation a high yield may be obtained without sacrificing the plasticity of the concrete to any great extent.

When a broad view is taken of present methods of handling concrete the facts seem to warrant, more and more, the use of a water-cement ratio specification where any appreciable amount of concrete is to be placed. The kind and source of aggregates must be considered. More likely than not the aggregates delivered to any one job will vary greatly. It is next to impossible to set exact proportions of the amount of sand and gravel to be used for each sack of cement. If these proportions are set in advance, they will of necessity lean toward safety of construction and will be leaning over backward for more than fifty per cent of the job. A safe, exact specification would require a design of mix based on the coldest temperature conditions contemplated during construction and the poorest gradation of aggregates possible under the specification, using the maximum amount of water allowable. All these conditions would rarely occur at any one time, but they might and therefor must be considered.

Given the same conditions and a strict water-cement ratio specification and what are the results? The amount of water per sack of cement is given-----the sand and gravel required to be mixed in such proportions that a workable, plastic mix is obtained. There is no guesswork as to whether or not strength will be obtained. This is assured by countless tests and examples of jobs which have

Conclusions

been successfully completed with just such limitations.

When materials arrive on the job whose gradations are poor their proportions may be varied so as to still produce a good concrete of the required strength. The contractor will begin to think in terms of workability and lower slumps, for he will appreciate that by so doing he is gaining in lower production costs. The quality of material produced will rise, because contractors will soon be demanding a better quality, when they understand it means dollars saved to them. And all this gradually will tend to bring a greater uniformity of materials from sand and gravel pits and a more nearly uniform finished product-----concrete. In colder weather the specifications may require a slightly larger amount of cement but the yield will be gained during the warmer months.

In order to visualize more clearly the significance of the word yield it will be well to illustrate in terms of cost. Given quantities are specified to be used on a job which it is expected will run thru hot and cold weather conditions. Commercial gravel will be used with certain limitations as to sieve analysis, cleanliness and the like. A 2000-lb concrete is wanted with an estimated yield of 5.8 sacks per yard. 20,000 cubic yards of concrete are figured in the job.

A similar job is now figured using a true water-cement ratio specification. The yield is not given but it is expected that yields of 5.2 sacks per yard in warm, and 5.5 sacks per yard in cold weather will be obtained. When these two jobs are completed

Conclusions

it is found that the average yield obtained on the first job was 5.85. The contractor is not very well satisfied. He does not understand that it was largely due to the poor grading that the yield went higher than estimated. He blames the engineers on the job and the owner for figuring wrong.

On the second job a small field laboratory was set up and the contractor and engineers worked together to obtain the best mix from the aggregates that came in. The contractor looked for better material always, and obtained it. Results were better than anticipated. Everyone from the owner to the concrete crew became interested. At the end of the work the average yield was found to be 5.17 for the entire work. Reducing this to cost we find a saving of 0.68 sacks per yard. With cement on the job costing \$0.90 per sack this is $\$0.90 \times 0.68 \times 20,000 = \$12,240.00$. Or an actual saving of over twelve thousand dollars was made.

The owner benefited by a lower original bid for the work. The contractor feels good because he made more money and bettered the yield that had been estimated. He paid a little more for his gravel but this was offset by fewer rejections of material, causing subsequent delays, and a lower cost of finishing due to better workability and uniformity in the concrete. The sand and gravel companies benefited by getting more money for their product.

While the above illustration may sound like a fairy tale the same story can be taken from any number of jobs now in progress in the country today. The study of present day methods and

Conclusions

current concrete practices is as interesting as the varied conditions can make it. There is a story in any large job and all have their problems which have only to be studied and worked into successful answers. It is said that Engineering is the lowest paid of professions but there is a thrill in the building which draws and holds men to it. As I complete this I have just finished a two weeks period during which I have shown a dozen or more contractors' representatives over the site of our proposed dam, the bids for which will be opened in a couple of days. They will gamble to win and we have the prospect of another fine piece of work to look forward to.

Finis.

ROOM USE ONLY

ROOM USE ONLY

Nov 22 1966

MICHIGAN STATE UNIVERSITY LIBRARIES



3 1293 03070 9095