Department of the Interior
Bureau of Reclamation

# OPERATION AND MAINTENANCE EQUIPMENT AND PROCEDURES

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CONTENTS

Good Concrete on Operating Projects

# INTRODUCTION

This release, No. 11 of the Operation and Maintenance Equipment and Procedures Bulletin, is devoted to suggestions that may help in obtaining good concrete on operating projects. Several years ago an O&M Superintendent who had some engineering construction background and who happened to be familiar with what it takes to make good concrete was aware that concrete placed by his maintenance crews could be considerably better with very little added cost for either materials or labor. Accordingly, he took advantage of a little slack time to teach his foremen and principal workmen how they could improve their concrete work. Because of his obvious belief in what he was teaching them and its evident practicability, the men became truly interested and looked forward to trying out the new ideas on their next concrete job.

The day came and late that afternoon the Superintendent met them as they drove into the yard and asked how the concrete had gone. "Do you know, Harold," the foreman said in amazement no less than if he had just that day discovered the law of gravity, "When we did those things you told us to do, <u>that</u> Gol Darn concrete was UNIFORM."

Of course it was uniform and that unusual uniformity was one indication that concrete placed that day was of better quality than usual. But why was it uniform? What were the things Harold told them to do? What things concerning concrete materials also affect concrete quality? What other precautions are necessary to be sure that good well-placed concrete will become strong and durable? After all, what <u>is</u> good concrete?

For the benefit of O&M people on other projects some of these questions are being answered in this issue of the Bulletin by L. H. Tuthill, Concrete Engineer, Commissioner's Denver Office, Bureau of Reclamation. Not only the rules are given but an attempt is made to explain them and tell why they are necessary and how they help in obtaining good, uniform concrete at little, if any, additional cost.

Equipment like that shown on the cover, although used by a contractor in construction could well be adapted in some instances to O&M use. The truck bed has been divided into several compartments; each compartment of a size suitable for the prebatched cement, sand, and gravel for about a half cubic yard of concrete. The batches can be dumped directly into the loading skip for the 16S (16-cubic foot) mixer. Prebatching can in some circumstances save hauling of excessive materials, avoid wasting of cement, sand and gravel, and provide for uniformity of batches, resulting in a better and more uniform concrete. Mr. Tuthill has promised that he will help prepare additional articles on O&M concrete for future releases of the Bulletin.

This, like all issues of the O&M Equipment and Procedures Bulletin, is circulated for the benefit of irrigation project operation and maintenance people. Its principal purpose is to serve as a medium of exchange of operating and maintenance information. Reference to a trade name does not constitute an endorsement of a particular product and omission of any commercially available item does not imply discrimination against any manufacturer. It is hoped that labor saving devices or less costly equipment developed by the resourceful water users will be a step toward commercial developement of equipment for use on irrigation projects in continued effort to reduce costs and increase operating efficiency.

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# MATERIALS FOR GOOD O&M CONCRETE

One might think that cement is just cement, and that sand and gravel are just sand and gravel. Actually cements differ materially from plant to plant and in types, and sand and gravel differ from place to place. Often there are several choices that can be made in available materials. Correct use or choice of these materials can often make the difference between a serviceable, long lasting concrete job and one that has poor durability and short life.

## Cement

Choice of cement is most important when white alkali sulfate is prominent in the structure area. The photographs below, show a structure that has been in service about 20 years in such a locality. The invert in the drop structure of the lateral in the right foreground of the upper photograph has been completely disintegrated by the corrosive attack of sulfate laden soils and water in the area. In the lower photograph on this page and the upper one on the following page, the advanced stage of disintegration of the lower portions of the structure also are apparent.



In the second photograph on the following page, the disintegration of a concrete check on another of our projects in the southwest is shown. In service about 25 years, the chemical attack of the sulfates on the cementing material that holds the aggregate together is clearly illustrated.

We have learned considerable about cement and aggregates and know that the use of the right cement and aggregate can delay the disintegration of concrete used under such conditions and prolong, materially, the useful life of such concrete structures. One test for this



sulfate is its bitter unpleasant taste. If sulfate is present, there is probably evidence of its corrosive attack on some project concrete; bottoms of drops and tops of outlet wing walls are often severely attacked and deteriorated by the alkali sulfates.

For concrete that will be exposed to such corrosive attack, best durability can be assured only with Type V, sulfate-resisting cement. This cement will cost a premium of as much as 30 cents a sack and then sometimes is not readily available. Calcium chloride should not be used in concrete which will be exposed to alkali sulfate.

For other exposure and ordinary service conditions, any good standard cement is usually capable of making a good strong, serviceable concrete. Cement should be in good condition, free of lumps and foreign matter. For larger work requiring more than 100 sacks, it is safest to purchase cement under standard Bureau specifications, which are readily available. This is particularly advisable if Type V, sulfate-resisting cement is to be used.

Purchase of cement under Bureau specifications also has the advantage of insuring that a cement containing a desirably low amount of alkalies is obtained when this is necessary to assure good durability with certain aggregates. Any cement may be high or low in alkali and this has nothing to do with its resistance to attack by alkali sulfates in soil or ground water. Many sands and gravels in the western part of the United States contain elements which cause concrete to swell inside and produce severe map-type cracking on the surface as shown in the photograph on the following page. This is particularly true when the cement contains more than 0.6 percent of alkalies. For this reason it is safest to use a "low-alkali" cement, unless the aggregates are known to be free of these


dangerous elements. For the same reason many cements are now made with little if any alkali more than 0.6 percent. When low-alkali cement is specified, a premium of as much as 7-1/2 cents per sack may be charged.

Sand and Gravel

In most cases sand and gravel sources in Bureau of Reclamation project areas have been tested and their concrete-making capabilities are a matter of record in the office of the Assistant Commissioner and Chief Engineer in Denver, Colorado, and in the various Region Offices, located in Boise, Idaho; Sacramento, California; Boulder City, Nevada; Salt Lake City, Utah; Amarillo, Texas; Billings, Montana; and Denver, Colorado. Existing information is available on inquiry. Untested sources intended for use should be investigated. At least an effort should be made to see whether local concrete made with the sand and gravel has been serviceable. If such local evidence is lacking on a source to be used, arrangements should be made with the Assistant Commissioner and Chief Engineer or Regional Directors of the several regions for tests to confirm its reliability.

So much for the general quality of sand and gravel sources, but there are several factors which can be and should be considered in making a choice of materials available on the project.

1. Sand and gravel should be clean and free of dirt and clay when closely examined. It should be kept clean and uncontaminated on the job.

2. It should also be reasonably free of weak particles that can be broken easily; or pieces of foreign materials like wood, coal clay lumps, shale, mica; or pieces with heavy coatings that will break off in handling.

3. Sand should appear to be well-graded and contain some of all sizes up to 3/16 or 1/4 inch. No one size should appear to predominate, particularly among the fine sizes. If sand is too fine, lower concrete strength and durability will result unless additional cement is used.

4. Gravel also should be well-graded and contain a fair share of each size larger than sand and as little as possible of sizes like sand.

5. For most structure and lining work the best size of gravel is that graded up to 1-1/2 inches for the largest pieces. For the gravel in each concrete mixer batch to be well-graded, it is best to have the gravel screened into two sizes:

a. Small gravel usually ranges in size from 3/16 to 3/4 inch. Pea gravel smaller than 3/8 inch should be less than 20 percent of this gravel for easiest finishing of unformed concrete, and less than 40 percent for formed concrete.

b. Medium gravel should range in size from 3/4 inch to 1-1/2 inch. It is well-graded when about one third of it is in each 1/4-inch range in the 3/4- to 1-1/2-inch size range, that is about one-third in 3/4 to 1 inch, one-third 1 inch to 1-1/4 inch, and one-third 1-1/4 inch to 1-1/2 inch.

c. About the same amount each of small gravel and of medium gravel should be used in concrete mixes.

6. If an attempt is to be made to produce uniform and durable concrete, pit run mixed sand and gravel should not be used. Although such concrete *may* have sufficient serviceability, it can be very disappointing. It *will* not be uniform and part of the structure will not be durable. Pit run sand and gravel should be used only in a real emergency and then only with addition of at least one more sack of cement than usual per cubic yard of concrete.

## Admixtures

Air-entraining agents.--A discussion of materials for good concrete would be incomplete without mention of certain admixtures which have been found to be unusually effective in improving workability and durability. These are the air-entraining agents. Since 1945 an air-entraining agent has been used in all concrete in new construction on

Bureau projects. Results have been excellent and no field concrete with entrained air has yet shown susceptibility to freezing and weathering. For these reasons all O&M concrete placed, no matter how small the quantity, should include a proper dosage of an air-entraining agent and have the benefit of entrained air.

It is best and most convenient on small work to get these agents in liquid form and measure into each batch by volume the quantity prescribed by the manufacturer. Under average conditions this will entrain about 5 percent of air, for the most part in millions of very tiny bubbles. Four to 6 percent air in concrete is a desirable amount. More air reduces strength; less does not take full advantage of air-entrainment.

There are many factors in the composition, mixing, and placement of concrete that will change the amount of air that can be entrained with a given air-entraining agent. The principal factors are:

1. Temperature - At high temperatures air-entraining agent is less effective. More agent must be used as the temperature increases to secure the same amount of entrained air.

2. Fines - Fine material in a concrete mix, whether it be cement pozzolan, very fine sand, dirt, etc., also increases the amount of agent required. The finer the ingredients the more agent needed to produce the desired 4 to 6 percent entrained air.

3. Long mixing - The effectiveness of the agent is also reduced by long mixing of the concrete. As this is not normally done for economy reasons, it probably is not too important, but if in emergency a batch of concrete must be mixed for a long period, additional agent is needed to secure the desired air content.

The same volume of concrete without air entrainment should weigh 4 percent more than concrete with 5 percent of entrained air. (Concrete contains about 1 percent of air without using an air-entraining agent.) The weighing of representative samples of each fresh concrete, solidly filling the same strong bucket and carefully leveled across the top, will serve as similar volumes for this rough test of the amount of entrained air in air-entrained concrete. Because of the factors listed above, such a test should be made occasionally to determine the amount of air entrained in the concrete.

Air-entraining agents are now relatively standard products and are available from several reliable sources. Most widely available and used are Darex, produced by the Dewey and Almy Chemical Company, Cambridge, Massachusetts, and commercial solutions of Vinsol resin, produced by Hercules Powder Company, Wilmington, Delaware. Any of the Vinsol resin solutions are satisfactory provided their strength is known and their dosage is correct to produce 5 percent of entrained air in the concrete. Protex is a widely used commercial solution of Vinsol resin made in Denver, Colorado. All fluid agents should preferably be protected from freezing and containers should be well stirred each day before use. Good reliable air-entraining agents are available at prices making them cost only a few cents per yard of concrete.

Calcium Chloride.--The only other admixture which should be used at certain times in O&M concrete is calcium chloride. As O&M construction is often done in cold weather between operating seasons, need for calcium chloride might arise in a larger than usual fraction of the work. When day and night high and low temperatures average less than 40 degrees F, 1 percent of calcium chloride, by weight of cement, should be used in the concrete, except, as previously emphasized, when it will be exposed to alkali-sulfate. Where exposed to alkali-sulfate, instead of using calcium chloride, another sack of Type V, sulfate-resisting cement, should be used in each yard of concrete or about 17 pounds for a one sack mix.

Calcium chloride is used in cold weather concrete because it makes the concrete more mature by the end of its period of protection from freezing (this protection will be discussed later). It is emphasized, however, that the use of calcium chloride does not eliminate the need for protection. Because calcium chloride causes concrete to gain strength more rapidly, its use is sometimes advantageous when time for form stripping, backfilling, or time for completion is short. This is often the case on O&M construction. For this purpose, no more than 2 pounds per sack of cement should be used and it should not be used in warm weather. Calcium chloride always should be dissolved first in a portion of the mixing water before placing it in the mixer.

### Mixing Water

Any water that is drinkable is suitable for mixing concrete. Water that is too salty or brackish to taste well, should not be used. Stream water with some cloudiness or suspended sediment in it may be used as this is no different than clear water will be when mixed with aggregate considered amply clean.

## PROPORTIONING AND BATCHING MATERIALS FOR O&M CONCRETE

### Proportioning

Concrete is more dependent on cement for quality than any other of its materials. Other things being equal, more cement in the mix means higher quality. For this reason the cheapest and most effective way to improve ordinary concrete mixes is to add another sack of cement per cubic yard. This is particularly true of O&M concrete and why it is recommended that no less than 6 sacks of cement be used in each yard of O&M concrete, or an equivalent amount of cement in each batch of concrete.

With cement content decided, the concrete material next most important to concrete quality is water; that is, the amount of water in the mix with the cement. The more water used, the less strength and durability the concrete will have; the less water, the better the concrete quality, as long as the mix is workable enough to permit a good solid job of molding it in place in the structure.

Several things affect the amount of water that will have to be used in the mix to make workable fresh concrete:

1. More sand in the mix than necessary increases the amount of mixing water. The correct amount of sand is best found by trial. If a mix appears to have an abundant portion of sand, each succeeding batch should be proportioned with less and less sand by some fixed amount, until a proportion is arrived at which clearly cannot be reduced without endangering sufficient workability. With each reduction in sand in this procedure, gravel should be increased by an equal amount to keep the batch the same size and cement content the same.

2. The colder concrete materials are mixed, the less water will be required. However, when average day and night temperatures are less than 40 degrees F. the temperature of freshly mixed concrete should not be less than 50 degrees F.

3. More water is required to mix concrete to a fluid, sloppy consistency than to a soft, mushy consistency that is plenty workable for placing even without vibration. Projects doing any amount of concrete work should have and use a concrete vibrator to consolidate newly placed concrete. Then still less water can be used in a mix of stiffer plastic consistency, which is amply workable and responsive to good placement with vibration.

About 3,000 pounds of dry sand and gravel are required with 6 sacks of cement to make 1 cubic yard of air-entrained concrete of medium consistency--not too wet, not too dry.

If sand and gravel are well graded, as described earlier, 1,100 pounds of sand should be a sufficient portion of the 3,000 pounds to make a workable concrete. At least it is about average for a starting mix. More or less can be used as seems necessary after the mix is tried out on the job.

Subtracting 1,100 from 3,000 leaves 1,900 pounds of gravel, 950 pounds of small gravel 3/16 to 3/4 inch in size and 950 pounds of medium gravel 3/4 to 1-1/2 inch in size, required for each cubic yard of concrete.

Since mixing is often done in mixers smaller than 1 cubic yard, these batch quantities can be reduced to weights of dry sand and gravel for 1, 2, 3, or any other number of sacks of cement, according to the size of the mixer.

| Sacks Cement per batch | Sand lbs. | 3/16"-3/4" gravel-lbs. | 3/4"-1-1/2" gravel-lbs. |
|---|---|---|---|
| 1 | 183 | 158 | 158 |
| 2 | 367 | 317 | 317 |
| 3 | 550 | 475 | 475 |
| 6* | 1100 | 950 | 950 |

*Amount for 1 cubic yard of concrete, approximately.

Batches should be based on a certain number of whole sacks of cement. Fractional-sack batches are rarely uniform unless the cement for the fractional sack is weighed for each batch. Cement in a full sack weighs 94 pounds.

If, with a little experience with project materials, it is found that these quantities of sand and gravel make appreciably more or less than a yard of concrete in place with 6 sacks of cement, proportionate decreases or increases in them can be made. Mainly, larger yield batches should be avoided because the concrete from such a batch contains less than the desired 6 sacks of cement per cubic yard. Smaller yield batches, although more expensive in cement, will be amply strong and durable.

If materials are wet, particularly the sand, and no correction is made for the weight of water in a batch weight of sand or gravel, the batch yield will be small. Also, a mix may appear to be undersanded if no correction is made for considerable moisture in sand used. For instance, if the sand contains 5 percent moisture, the 1100 pounds weighed out for a yard of concrete would actually be only 1047 pounds of sand and 53 pounds of water. That lack of 53 pounds of sand might make a noticeable reduction in workability. Actually, to get 1100 pounds of sand in the batch, 1155 pounds of this wet sand should be used. So, when sand is wet, even though a test of the exact amount is not made, a few more pounds of it must be used as may be necessary to keep the concrete at the same workability and volume yield per batch.

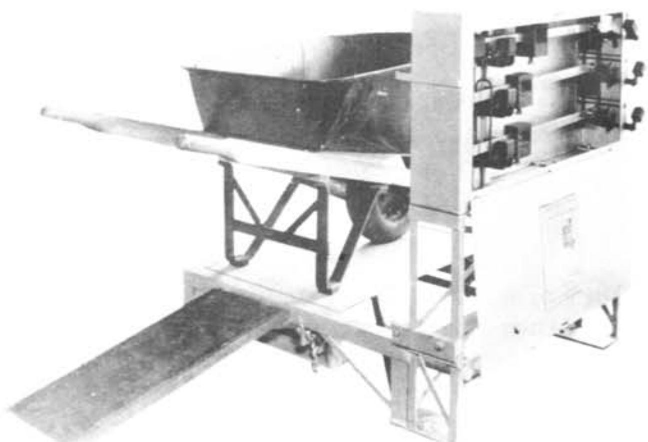
Summarizing proportioning, to start with at least, materials for a 1 sack mixture of good concrete should contain:-

1 sack of cement
183 pounds of fairly dry, well-graded sand
158 pounds of 3/16" to 3/4", well-graded small gravel
158 pounds of 3/4" to 1-1/2", well-graded medium gravel
Recommended dosage of an air-entraining agent
Only enough mixing water to produce a medium plastic consistency.
If in winter--add 1 pound of calcium chloride previously dissolved to make 1 quart of solution.

For a 2 sack batch use twice the amounts given for the 1-sack mix above, for a 3-sack batch, 3 times the amounts, etc.

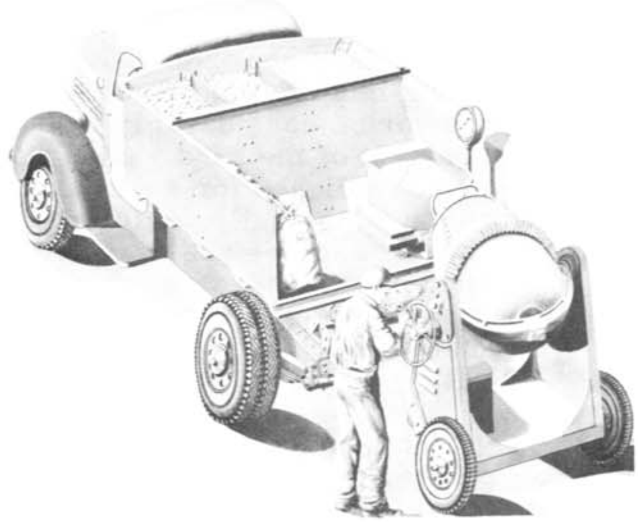
Batching

Uniformity of concrete mentioned earlier depends primarily on getting the same amount of the same materials in each mixer batch. The same amount is best assured when weighting is used. Batching based on weight is best because weight of sand varies considerably less than does volume of sand when the moisture content of the sand varies. This does not mean that all the material has to be weighed for each batch, although specially designed platform scales are available for doing so. Such a scale is the so-called wheelbarrow scale in the photograph at left.



The scale is easily transported, is light enough for convenient handling, and can be adjusted and leveled quickly. The scale shown has only two weighing beams, one for sand and one for gravel. The top beam shown is a tare weight beam for compensating for the weight of an empty wheelbarrow. In our work, where three sizes of aggregates are used, it is better to obtain a scale with three weighing beams in addition to the tare beam, one weighing beam for each size of aggregate; that is, sand, small gravel, and medium gravel. The tell-tale device or balance indicator on top of the beam box is a convenient means for indicating when the correct amount of material has been added. In operation, the weigh-beam poises are set to correspond with the desired gross weights (including moisture of the aggregates), and when any size of aggregate is to be weighed, the proper beam is brought into engagement by releasing the trigger on the outside of the box. It is not essential that the scale be at the stockpiles, for by keeping a small supply of each aggregate at the scale, the wheelbarrow or cart can be trimmed or added to as required. With a little experience, workmen become proficient in approximating the correct load.

For considerably smaller volumes of concrete, a standard platform scale can be arranged to weigh a wheelbarrow of sand or gravel. It need be used only at the start to determine the level to which each wheelbarrow must be filled, and to verify or correct these levels if the moisture content of the sand or either size of gravel appears to have changed. Wooden pieces can be made to strike off each wheelbarrow at the same level each time it is filled. The weight then will be the same as long as moisture content remains the same.



The arrangement of equipment on a job where small amounts of concrete were being placed in scattered areas, is shown in the sketch at the left. A supply of cement, sand and gravel was always available and made for ease in weighing these materials. By towing the mixer behind the truck, rapid movement from place to place was possible. For most O&M work, a 1-sack mixer is preferable.

On another project the mixer and a water tank also were placed on a "low-boy" trailer and moved from place to place.

In shoveling gravel from stockpiles it will be noticed that in some parts the gravel is small and in others it is large. In some parts there is considerable undersize material. Best uniformity and best workability is obtained in the concrete if workmen loading the wheelbarrows see that some of each of these different sized materials are included in each wheelbarrow load.

Once the amount of water required for the correct consistency of the mix is determined at the start, this same amount should be measured by volume, in so many buckets or gallons for each batch thereafter. It should not be done by counting while a hose is running into the mixer. If measured by hand, water should be available in an open barrel or tank from which it can be dipped using the measuring container. However, the consistency of the concrete should be watched and if it changes, the water volume should be adjusted accordingly. Drier sand or gravel inside the stockpile, finer sand or more fines in the gravel will make more added water necessary for the same consitency. If the change in consistency is due to extra fines, that will for a time have to be used, perhaps a reduction in the proportion of sand is in order rather than more water. Maybe the sand pile has been drying. As the wet interior is reached, a reduction in the mixing water volume will be necessary.

Liquid air-entraining agent is best batched by volume, dipping from an open container with a can cut down, or with holes punched in the sides, so that it holds only the correct amount for the batch. The same is true if calcium chloride is to be used. First it should be dissolved so that each quart of the solution holds 1 pound of flake calcium chloride. Then from an open drum, 1 quart of the solution should be measured into the mixer for each sack of cement in the batch.

## Placing

On the job, one usually hears of this as "pouring concrete". There is no objection to this common expression except that it is strongly suggestive of a mix that is far wetter and more fluid than it should be to make good concrete. The fluid idea also suggests flow, or flowing concrete from one location to another, which is contrary to good practice. Flowing is objectionable because it destroys uniformity; the rocks stay behind; water and fines flow ahead filling the corner, ends of walls and other parts which would then be the first to fail in durability because they are composed of inferior concrete.

So, it is best to "place concrete", whether we call it that or not. Concrete for each part of a structure should be placed where it is to remain. It should be a non-fluid but workable consistency that will stay where it is placed, and should be placed directly in ends of walls and corners of forms. Any unavoidable flow should be from those parts rather than toward them.

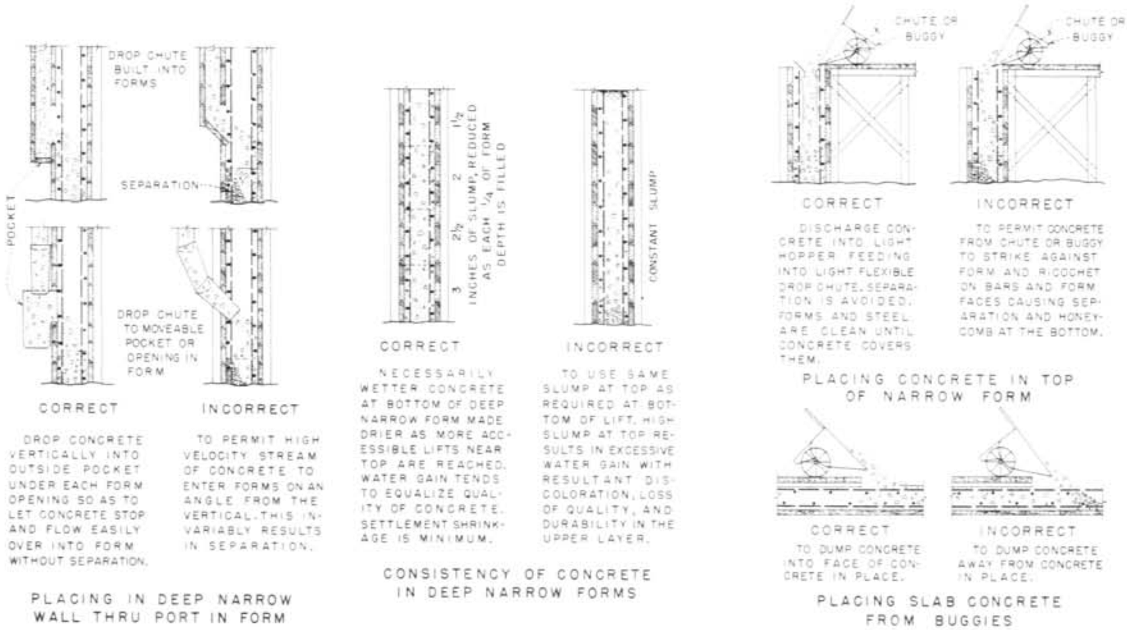



FIGURE 105 - CONCRETE WILL SEPARATE SERIOUSLY UNLESS INTRODUCED INTO THE FORMS CORRECTLY

A fluid mix that really would be "poured" is sure to be much weaker in strength, less durable, and certain to crack more when it dries out. Best concrete is a workable, mushy, plastic mixture that will not flow unless placed on a steep slope or in a chute on a 2 to 1 slope. Even stiffer consistencies will flow during vibration unless concrete is placed on a fairly level layer several feet ahead of where it is vibrated.

Several figures have been borrowed from the Bureau's Concrete Manual, including the one above, to illustrate how easily well

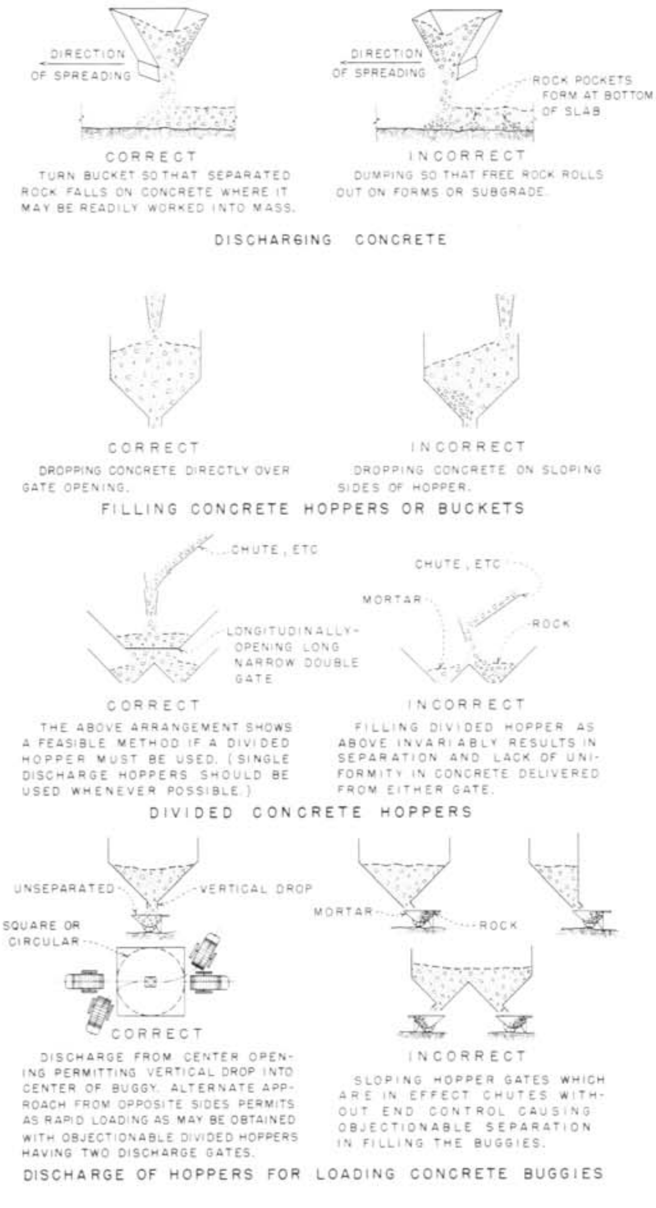



FIGURE 103- PROPER METHODS FOR LOADING CONCRETE BUCKETS, HOPPERS, AND BUGGIES AVOID SEPARATION OF THE COARSE AGGREGATE FROM THE MORTAR

mixed concrete can be UNMIXED by improper handling and placing. Beginning with the discharge of concrete from the mixer, as shown at left, each time the concrete falls freely into a buggy, wheelbarrow, crane bucket, hopper, or into the forms for a structure, it is likely to become unmixed. Unless care is taken to avoid this separation, rock tends to go to one side and mortar to the other. The wetter the mix the worse this will happen. The more it happens, particularly as concrete goes into the forms of a structure, the more chance there is that some of the separated gravel will not get worked back into mortar again, and rock pockets will show when the forms are stripped.

Separation is least with air-entrained concrete of medium consistency. When discharging and falling concrete is baffled and controlled in drop chutes so it falls straight down and not at an angle, there is little or no separation. A little experimenting will quickly demonstrate this fact. Fill buggies by vertical fall from a gate in the bottom of a hopper in comparison with separation in buggies filled from a sloping gate in the side of the hopper. Compare separation in concrete caught in a vertical piece of drop chute and made to fall vertically from the end of the chute, as in the figure on the facing next page. Clusters of separated gravel occurring as concrete is placed in the structure should be scattered before they are covered with the next batch. Even vibration does not always succeed in remixing unscattered, separated rock.

Concrete should be placed in forms in horizontal layers not over 1

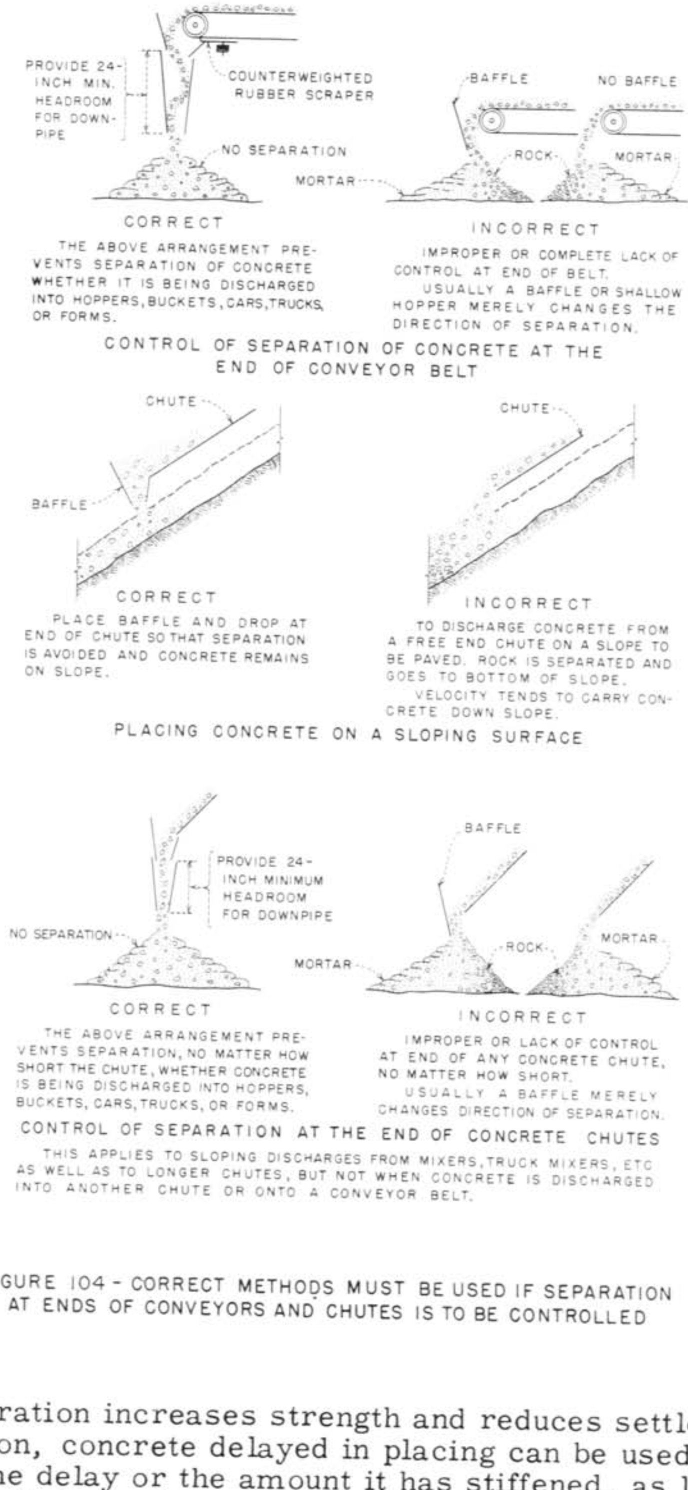



FIGURE 104 - CORRECT METHODS MUST BE USED IF SEPARATION AT ENDS OF CONVEYORS AND CHUTES IS TO BE CONTROLLED

foot deep if vibrators are not used, and not over 2 feet deep if they are used. Deeper layers increase chances that some concrete will not be properly consolidated. Rodding or vibration should follow just far enough behind to prevent the concrete from flowing out of place.

Vibration should be used to consolidate concrete in place. In view of the great improvement it makes in the quality of concrete that can be placed, and in the kind of job it does in placing it, few O&M forces can afford to work without a concrete vibrator. Soft, near fluid concrete should not be vibrated as it will make the rock sink and the fines and water come to the top, thus further weakening the upper layer. Less water should be used in such a mix until a fairly stiff mushy consistency is obtained. This kind of concrete will not be damaged by the ample vibration necessary to consolidate it and get good formed surfaces.

Concrete can be vibrated to advantage any time until setting has progressed to the point that vibration will no longer again make the concrete plastic. Late vibration increases strength and reduces settlement cracking. For this reason, concrete delayed in placing can be used, regardless of the length of the delay or the amount it has stiffened, as long as it can be consolidated satisfactorily in the structure. Additional water should not be remixed with such concrete unless cement also is added at the rate of 17 pounds of cement per gallon of water, or a sack for each 5-1/2 gallons.

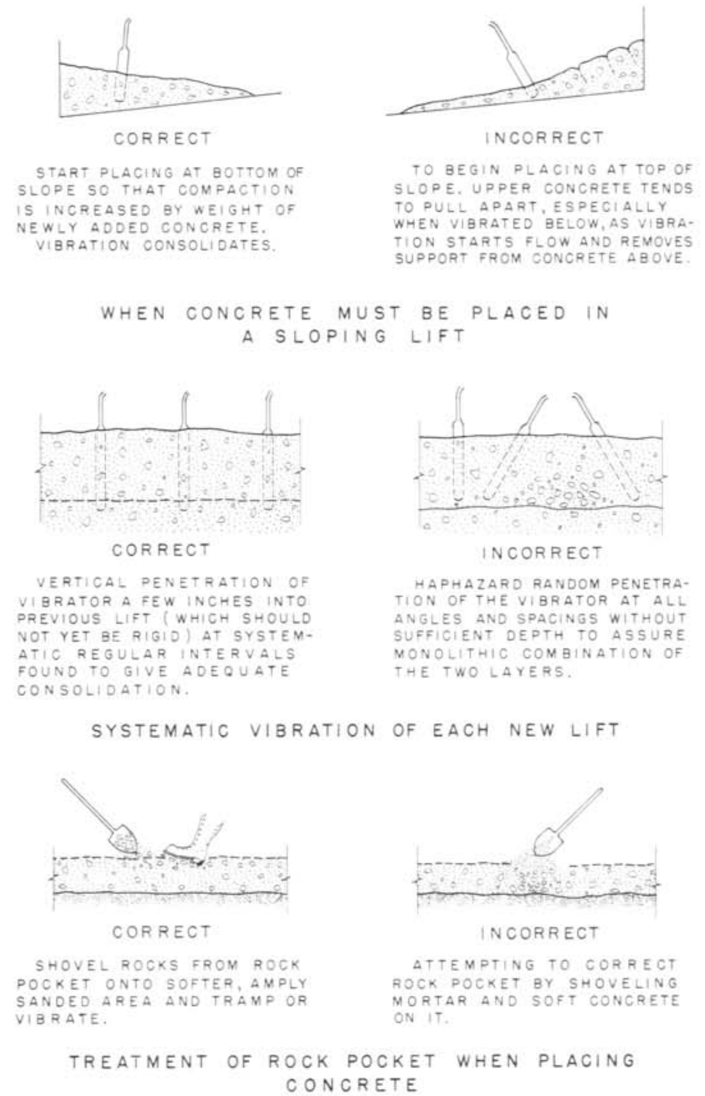
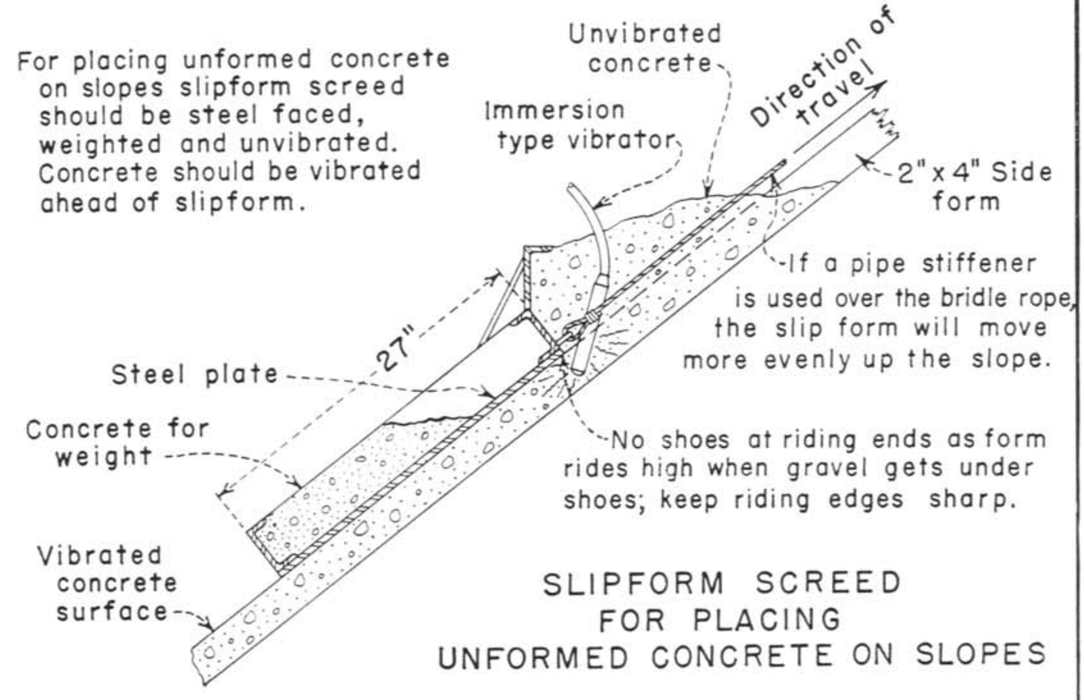



FIGURE 106 - PROPER METHODS OF VIBRATING AND WORKING OF CONCRETE INSURE THOROUGH CONSOLIDATION

Several examples of the proper methods of vibrating and working concrete to insure thorough consolidation are shown in the figure at left. Placing unformed concrete on slopes in canal lining and elsewhere usually represents a large part of O&M concrete work. Too often this concrete is poorly consolidated because efforts to do so result in causing it to flow down the slope. Also too often, to hold it on the slope, concrete is mixed too stiff for effective consolidation in that position. Poorly consolidated concrete is either wasteful of material for results obtained or makes a weak slab which may fail its purpose. Such a failure is shown in the photograph on the opposite page, where it was necessary to remove the concrete lining. The lack of consolidation is apparent and the fines in the mix were not distributed throughout the mass. Neither was the reinforcement steel properly embedded within the concrete. Better vibration would have resulted in better distribution of the mortar throughout the mass.

Usually the mushiest concrete that will stay on a slope is not too wet for such work. It soon stiffens and in the meantime, screeding and shaping the concrete will do much to consolidate it. Best results are obtained if a slip-form strike-off screed is used. This saves a lot of hard work and holds the concrete in place while it is being spaded or vibrated along the headboard as the slip-form slowly moves up the slope. Such a device is shown in the lower photograph on the facing page, and a sketch of a similar device is shown on page 18. Note the position of the vibrator consolidating and working the concrete just ahead of the strike-off screed.

Also note that the screed is not being vibrated. To vibrate the screed causes the concrete to flow under the screed and result in a wavy surface.




SLIPFORM SCREED
FOR PLACING
UNFORMED CONCRETE ON SLOPES

Finishing

With few exceptions outdoor concrete should not be steel troweled in finishing. Such surfaces are not only less safe but often less durable. An exception is in canal lining where once or twice over with a long-handled steel fresno trowel often provides all the finish worth doing after good work with a steel-faced slip-form. A neat, even job of floating with a wood float is all that is necessary for unformed surfaces around structures.

The important thing in finishing is not to overwork the surface or to work the surface when it is wet. Overworking removes entrained air, brings excess water and fines to the surface, and results in poor durability and scaling. Finishers should wait until the wet shine is gone from the surface before performing floating or troweling operations. Even though concrete is not placed too wet, water may cover the surface of flat work after strike-off and floating operations. This water should be removed by draining, blotting with burlap, or dragging off in a loop of hose. Dusting of the surface with dry cement to soak up the water often results in a weak surface; a surface that is less resistant to weather, erosion, etc.

## CURING AND PROTECTION OF O&M CONCRETE

### Curing

Quite a little has been said about the damage of excess water to concrete in mixing, placing, and finishing. As soon as concrete hardens, the reverse is true. The more water in the concrete after hardening, the better. This a another way of saying that it should not be permitted to dry, internally or externally. In fact, it is better for it to have a little extra water on the inside.

This strange reversal is because cement must have water to become a hard substance capable of binding sand and gravel together. But the more water cement has before it sets, the weaker the binding of sand and gravel will be; and when cement has less water after it sets, the binding will be still poorer. Whatever the water-cement mix is to begin with, if it dries out soon after the concrete sets, and before the possible strength of that mix develops, its strength and serviceability will be less than they would have been had it been kept wet.

So, it is important to see that new concrete does not dry out. Drying is prevented when concrete surfaces are kept continually wet for several days, preferably at least a week. In warm or moderate weather, forms should be removed as soon as possible without damaging the concrete. Forms do not provide as good curing as water or damp backfill. In cold weather, when drying is slow, the protection wood forms give from freezing may more than offset their shortcomings as a method of curing.

A very practical and convenient means of curing is available in the white-pigmented sealing compounds. When applied correctly, these seal in enough of the original moisture to do a better-than-average job of curing. Unformed surfaces should be sprayed as soon as they have become dull in appearance after finishing. Formed surfaces should be kept damp, but not wet when sealed. The application is adequate when the surface is completely covered and evenly white.

Several manufacturers supply portable equipment for the application of curing compounds. For small work a "back-pack" type pressure tank similar to that used in weed spraying is adequate.

### Protection

In warm weather, probably the main precaution on O&M concrete work is to make sure that newly placed concrete is not allowed to become dry for at least several days. Any precautions that can be taken to keep concrete temperatures down are beneficial. At lower temperatures, less mixing water is required, strengths are better, and shrinkage is less when the concrete later cools in winter. It helps when possible, to keep materials in the shade; to cool them by sprinkling; to use cold water, maybe ice water in very hot locations; and to avoid working in the heat of the day.

In cold weather new concrete must not be allowed to freeze. In fall and spring, during weather that may freeze at night, but when day and night high and low temperatures average above 40 degrees F, no special precautions are needed except to make sure that the concrete does not freeze either of the first 2 nights after it is placed. Wood forms are protection during such weather and bare surfaces can be protected with light housing or canvas cover if it is not in contact with the concrete and forms a shallow air space over it.

In weather colder than an average of 40 degrees F. several precautions must be taken to be sure concrete will not be damaged by freezing at the start, or have poor durability later, because it was not protected long enough or well enough to begin with. In weather this cold, air-entrained concrete should be kept at a temperature not less than 50 degrees F. for 3 days and protected from freezing for the next 3 days. Without entrained air, the same durability cannot be attained in any weather, but for proportionally as good durability without it in cold weather, all 6 days of protection should be at 50 degrees F.

Additional maturity and strength is attained by the end of the protection period when 1 percent of calcium chloride by weight of cement is used as mentioned earlier. This is advised during the colder weather work except when the concrete must resist alkali sulfate attack. As calcium chloride detracts from resistance of concrete to sulfate, extra cement should be used instead. It not only provides extra early strength but considerably increases resistance to sulfate.

The easiest way to hold the 50 degree F. temperature depends on the shape and size of the work. It should not be attempted by mixing the concrete at high temperature. This should be less than 70 degrees F. Extensive flat work is best protected by reusable insulating mats, thereby taking advantage of heat generated during setting and hardening to keep the concrete warm enough, as long as the heat is conserved. Formed concrete can be enclosed with heaters inside. If forms are to be used repeatedly, they can be insulated with batts between the studs so that no other protection is needed.

Occasional checking with a thermometer is advisable to be sure necessary temperatures are being maintained. It should be remembered that corners and edges are the most vulnerable to freezing. Covers should be held up off them. Extra insulation should be provided at these places.

Usually hot mixing water is sufficient for heating materials to secure concrete temperatures between 60 and 70 degrees F. However, ice and frozen lumps in sand or gravel should be reduced to the point where they do not exist in the concrete after mixing. Before concrete is placed, frost should be removed from subgrade, forms and reinforcing bars. If frost is not too deep, subgrade can be thawed by heat from the earth below, by covering it for a few days with insulating blankets or a 12-inch layer of straw. Forms and bars can be defrosted by covering and heating.

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