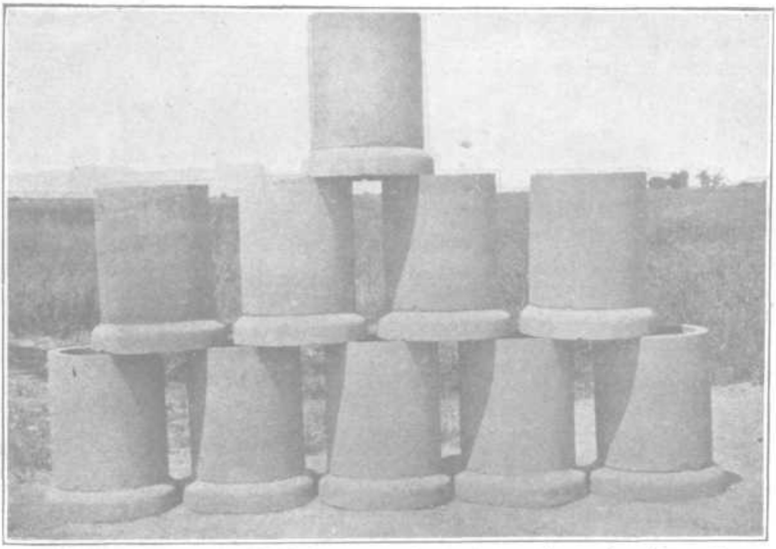
University of Arizona

Agricultural Experiment Station.

Bulletin No. 55.



Ten two-foot lengths of 15-inch cement pipe made from five sacks of cement.

Cement Pipe for Small Irrigating Systems and Other Purposes.

By G. E. P. Smith.

Tucson, Arizona, July 1, 1907.

UNIVERSITY OF ARIZONA
AGRICULTURAL EXPERIMENT STATION

The Experiment Station office and the botanical and chemical laboratories are located in the University main building at Tucson. The range reserves (cooperative, U. S. D. A.) are suitably situated adjacent to and southeast of Tucson. The departments of agriculture and horticulture and of animal husbandry conduct operations on the Experiment Station Farm, 3 miles northwest of Phoenix, Arizona. The date-palm orchards (cooperative, U. S. D. A.) are 3 miles south of Tempe, and 1 mile southwest of Yuma, Arizona, respectively.

Visitors are cordially invited, and correspondence receives careful attention.

Samples of water, fertilizers, etc., which are of agricultural interest, and which are received with full information, are analyzed free of charge as time permits.

The Bulletins, Timely Hints, and Reports of this Station will be sent free to all who apply. Kindly notify us of errors or changes in address, and send in the names of your neighbors, especially recent arrivals, who may find our publications useful.

Address,

THE EXPERIMENT STATION,

Tucson, Arizona.

CONTENTS.

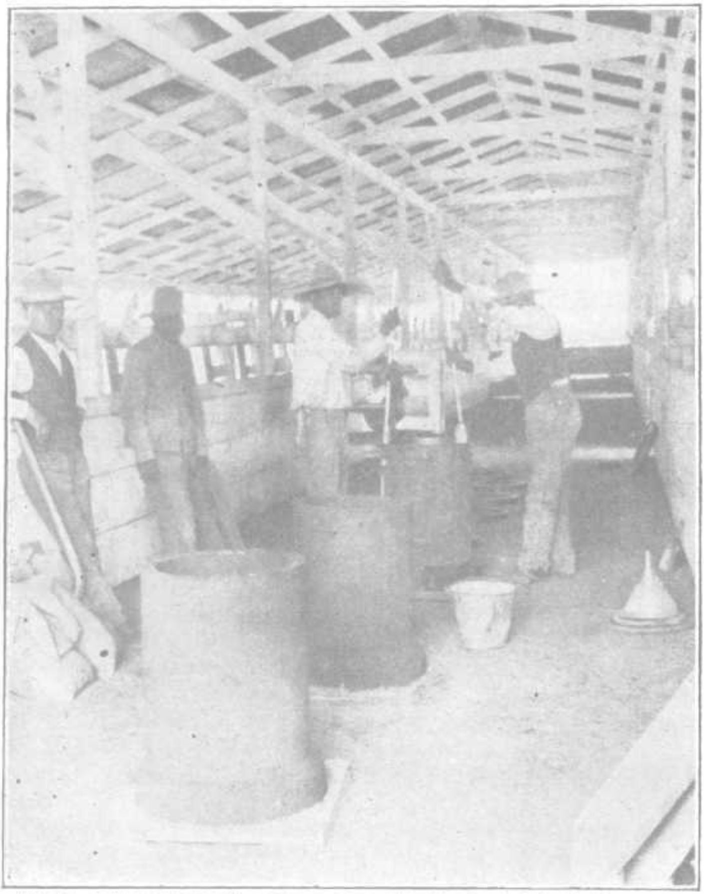


Fig. 1. View showing the manner of tamping the concrete in the forms.

CEMENT PIPE FOR SMALL IRRIGATING SYSTEMS AND OTHER PURPOSES.

By G. E. P. Smith

INTRODUCTION.

Thruout Southern Arizona there are scattered many sparsely settled valleys, traversed by the characteristic rivers of the arid region. These rivers are normally dry beds of sand but at intervals they carry great floods of water. In most cases the soil both of the bottom lands and the adjoining mesas is fertile and easily cultivated, climatic and other conditions are good, and the markets are excellent. The water supply, however, is so slightly developed that agriculture is a very precarious business. Winter crops are sown with a large element of doubt as to whether harvests will be reaped and thru the summer much of the same land is not utilized at all, while adjacent areas of great productive capacity are still wastes of mesquite and catclaw. The water supply already developed in these valleys is largely derived from small ditches heading in the sandy river beds. A few pumping plants have been installed in favored localities.

While the area of irrigated land is being rapidly extended thruout the West and many monumental enterprises are being developed, yet the smaller valleys above referred to seem to have been neglected and very little change has been wrought since their occupation began.

Without asserting that there are unlimited, or even abundant, water supplies for these valleys, yet it is demonstrably true that their cultivation can be very greatly extended, not only by largely increasing the water supply, but also by the adoption of modern methods in the development, distribution and use of irrigating streams. At present the settlers are confronted with the many problems relating to such improved methods. The mountains must be surveyed for reservoir sites, the valley gravels must be explored and studied to locate and secure the water which they can yield, pumping plants must be more intelligently designed, for great economies are possible in their design and operation, the water must be saved from loss by seepage and evaporation in ditches, and the ground must be so mulched and cultivated as to conserve the water after it has been applied to the fields. It is no extravagance to say that by careful methods the present very low duty of water in these valleys can be more than doubled.

One of the most experienced irrigation engineers * in the West has recently stated that, of the millions of dollars spent annually by our irrigated districts for water and for applying it to cultivated crops, fully seventy percent of the money is wasted. What an opportunity is thus offered for investigation! What an argument for the introduction of methods that may result in utilizing a part of that seventy percent which at present is not put to any beneficial use. It seems imperative that agricultural interests should join in a campaign for a higher duty of water. The main purpose of this bulletin is to discuss one phase of this campaign, namely, greater efficiency in transmission and distributing systems.

The same authority quoted above states that as a rule cultivated fields do not receive more than 66 gallons out of every 100 gallons of water which pass thru the upper headgates, the rest being lost by seepage and evaporation. In Arizona the river beds and banks are usually of very porous sand and the ditches leading thru these deposits suffer great loss of water. Occasionally the extreme case occurs in which the entire flow is thus lost. One such case is shown in Fig. 2. The ditch represented has a valuable water supply at its head, and the vain effort is made to hurry the water over the sand on a steep grade. When the photograph was taken, the last drop of water was sinking away near the willow tree shown by the arrow, while three miles away alfalfa and other crops dependent on this stream were drying up and dying.

The following excerpts are taken from the records of the manager of the Cienega ranch near Vail, Arizona. They are measurements of the water in the Cienega ditch during the dryest month of the year and show a remarkable daily fluctuation

* Samuel Fortier in the Irrigation Age, Vol. XXI, No. 12.

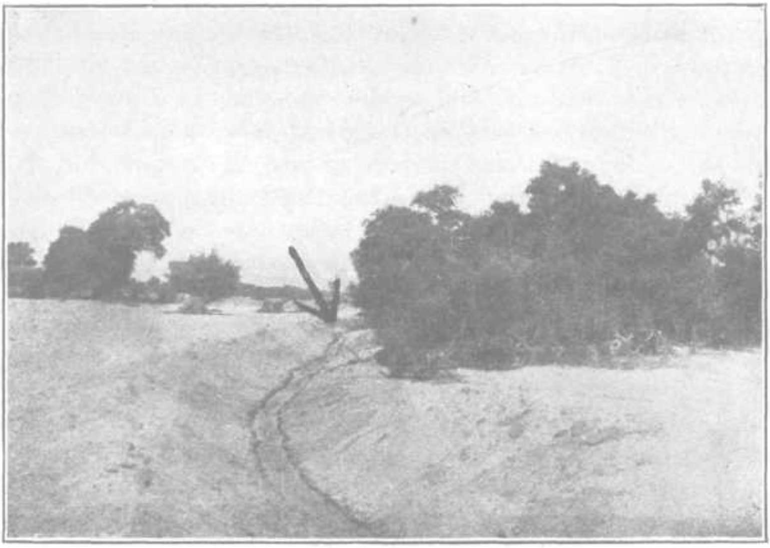


Fig . 2. Showing the wasteful method of carrying water in open cuts in sand. This stream diminishes from its head until near the foot of the large willow tree at the point indicated by the arrow the last drop disappears in the sand.

The shrinkage during the day is largely due to evaporation, but not wholly, for seepage from the ditch is very much greater during the day when the water is warm than during the night when the water is cool. The measurements were made on a Cippoletti weir.

Date 1907	Time	Flow Miner's Inches
June 19	5 a. m.	24.5
	9 "	26.0
	5:30 p. m.	7.5
" 21	7 a. m.	26.0
	5:30 p. m.	6.0
" 22.	8 a. m.	26.0
	3 p. m.	9.2
July 3	9 a. m.	13.0
	5 p. m.	0.0 ditch dry
" 4	9 a. m.	12.8
	5 p. m.	0.0 " "

There would be little satisfaction in commenting on such conditions if it were not possible to improve them. In seeking a remedy it is to be observed that seepage losses can be stopped by proper lining for ditches, while both seepage and evaporation are prevented by closed conduits. The materials available for these purposes are wood, cement and clay. All have been employed in various parts of the West. The only one tried so far in Southern Arizona has been wood; but its short life and the warping and leaking which it undergoes, together with high cost, unfit it for use in ditches. Cement pipe for small ditches and cement lining for large ones are from every point of view to be recommended. Clay tile lacks strength, and since at present it is subject to long freight hauls, its cost is very much greater than that of cement pipe. The latter is composed largely of sand and gravel found in the vicinity of the ditches and only the cement ingredient is subject to a freight charge.

There are other advantages in piping ditch waters besides the prevention of seepage and evaporation. The maintenance of open ditches is very difficult. Under the subtropical skies of Arizona weeds and algae grow rankly and unless removed at frequent intervals they soon obstruct and diminish the flow The Flowing Wells ditch near Tucson costs $80.00 per mile per year for cleaning alone. Furthermore, gophers perforate the ditch banks and cause the waste of rivulets for days or even weeks before the holes are discovered. Sometimes the holes enlarge and the ditch bank breaks with consequent loss of the entire stream. The maintenance of cement pipe lines should be very slight.

EXPERIMENTAL WORK WITH CEMENT PIPE.

With a view to determining the best mixtures and the exact cost of cement pipe in the Santa Cruz Valley and to demonstrate by an object lesson its many advantages, a moulding outfit was secured and some experimental pipes were made.

The size selected was of fifteen inches inside diameter, this size being of such capacity as to adapt it to many streams belonging to individuals or small companies of ranchers. Six lots of pipe were made, so as to give comparative results.

The first lot was a preliminary one intended to instruct the laborers in mixing and tamping the concrete.

In Fig. 3 is shown the pipe of Lot 2. It was made of a mixture of one part of cement to three and one-half parts unscreened arroyo sand. There were ten two-foot lengths, each hard and strong, of perfect shape and representing a cost of only 38½ cents per lineal foot. The amount of cement used was five sacks.

The third lot was made of a very lean mixture of cement, lime paste, and sand. The replacement of a portion of the cement by lime was made for the double purpose of reducing the cost and obtaining a denser and more impermeable pipe. Owing to the method of mixing, the lime paste became lumpy in the mixture. Moreover, on account of the slow hardening, the bell ends were considerably damaged by handling.

The fourth lot was made of a mixture similar to that of the third lot, but the paste was thinned to a consistency that permitted it to mix thoroughly with the sand, and the bell ends were made of a mixture of 1 part of cement to 3 parts of sand. The results were very satisfactory and the method for making such pipe will be described in more detail below.

The fifth and sixth lots were made in another locality and the sand and gravel were of a different character from those used previously so that screening was necessary. All above one-half inch in size was rejected. The remainder was separated by a screen having a quarter inch mesh into two heaps, sand and fine gravel, which could then be mixed into any desired proportions. In one case they were combined in equal proportions, and in the other case two parts of the fine gravel were used to one part of the sand. Theoretically the latter should make the stronger pipe, but the equal-parts mixture had the advantage of being somewhat easier to mold. Fig. 1 is from a photograph taken while making the sixth lot. It shows two tile completed and two Yaquis tamping the third tile. The location is in the feeding alley of a stable.

DETAILS OF THE MANUFACTURE OF CEMENT PIPE.

The pipe should, if possible, be made on or near the line of the ditch, where sand and water are at hand, and in the shade of

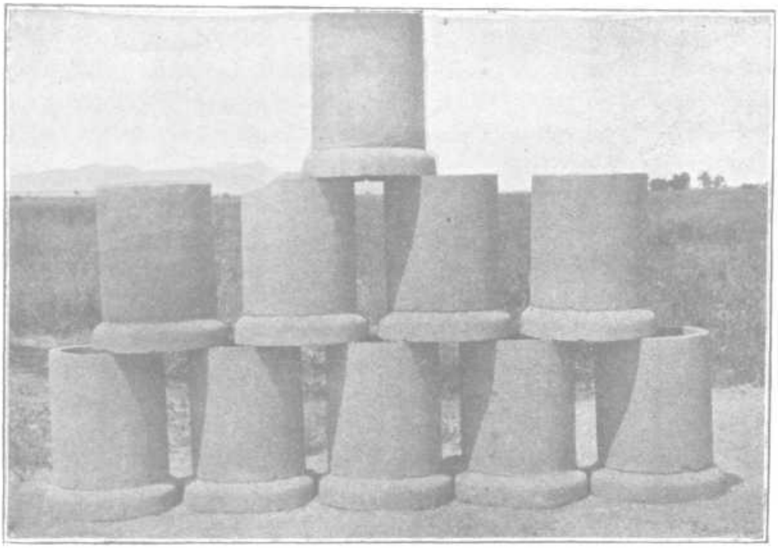


Fig. 3. Ten two-foot lengths of 15-inch cement pipe made from five sacks of cement. Cost, 38½ cents per lineal foot.

large trees or under a temporary canvas roof. The metal forms are set up on square wooden pallets of two inches thickness.

The sand should be selected with great care. It should be free from clay or dirt and preferably composed of grains of varying sizes. Roughly speaking, the strongest and densest sand for mortar contains two thirds coarse grains and one third much finer grains. Often a coarse gravelly sand can be passed thru a half-inch mesh screen and then mixed with one half its volume of fine sand.

A cement should be selected which is very finely ground, rather slow setting and of unquestioned soundness.

Assuming the diameter of the pipe to be fifteen inches and the proportions of the mortar to be one part of cement to three and one half parts of sand, a batch can be made up as follows:

1 bbl. (4 sacks)................cement
3-½ bbls. (7 wheelbarrows) ....sand

The sand and cement should be mixed dry and turned three times with shovels. Water is then added in amount sufficient to bring the mortar to a *dry* consistency, that is, in such condition as will require much tamping to cause water to stand on the surface. The batch should then be turned twice or three times and coned. Labor is cheaper than cement and it is profitable to work the mortar thoroly. The batch will be sufficient for eight two-foot lengths.

Three men are required, two to tamp and one to shovel the mortar. Two common laborers and a foreman are a satisfactory team and can mix, mold and sprinkle at the rate of forty pipes per day of nine hours. The tamping must be done in small layers, not over three inches at a time. When the mold is full and the top surface has been smoothed with a trowel, the mold can be immediately removed. Various simple forms of levers are used to separate the mold from the tile. Usually the inner form is first collapsed and lifted out, then the outer form, and last the castings around the bell.

An important feature in the manufacture of cement pipe is the curing. About twenty-four hours after the pipes are made they should be sprinkled with water so long as they seem to absorb it freely. For a week or ten days thereafter they should be wetted every day. They should cure in the air for an additional week or two weeks before being laid in the ground.

On the third or fourth day after molding cement pipe, a wash of pure cement should be applied on the inside of each length. A wide plasterer's brush should be used and the coat should be about one sixteenth inch in thickness. If the pipe is to be under a little water pressure such a wash will be very effective in preventing sweating. It also reduces the friction factor, thereby increasing the velocity of the flow.

The cement-lime pipe, though cheaper than the cement pipe, requires more attention in the mixing. The lime selected should be thoroly burned and should slake readily, forming a smooth unctuous paste. It is better to slake the lime at least a week before it is used and to reject all lumps which remain after that time.

Assuming the proportions, 1 of cement, ½ of lime and 6 of sand,by weight, as used in trial lots three and four noted on page 171, a batch can be made up as follows:

$\frac{3}{4}$ bbl.=282 lbs. (3 sacks) cement
141 lbs. lime paste=107 lbs. quick lime
$4\frac{1}{2}$ bbls.=1692 lbs. sand.

The lime should be diluted such an amount that no further addition of water is necessary to bring the mortar to the proper *dry* consistency. It should be added after the sand and cement have been dry-mixed. It can be poured from pails or drawn from a slaking tank elevated somewhat above the mixing platform.

It is to be observed that three-fourths of a barrel of cement is specified for the above batch. The remaining one-fourth barrel, in most cases one sack, should next be dry-mixed with three times its volume of sand and enough water added to bring it to the same *dry* consistency mentioned above. This provides the rich mortar for the ends of the pipe. From the two batches twelve lengths of fifteen-inch pipe can be made, all from one barrel of cement.

The cement-lime pipe should be air-cured for at least six weeks before being laid in the ground.

Some salient advice may be epitomized as follows:

1. Avoid very fine sand or sand containing dirt.

2. Buy the best cement. It usually costs but a few cents more than the poorer brands and is worth twice as much.

3. Do not make or cure the pipe in the direct sunlight.

4. Do not use a *quaking* or *mushy* mixture, because the molds cannot be removed from such pipe, without causing it to slump.

5. Mix thoroughly, tamp evenly, and keep the pipe wet while curing.

There is shoddy material in every line of business, and cement is no exception. Fig. 4 represents cement tile, made for irrigating purposes in California, which disintegrated while curing, and for which the cement manufacturers paid damages.

It is far from our purpose in publishing this picture to discourage the use of cement pipe. The intention is to prevent the construction of worthless pipe lines and the lesson is very plain. Such work is inexcusable. With the modern facilities for testing cement, the qualities of any brand or any carload may easily be ascertained in advance, and it is possible to design and construct pipe lines with every assurance that they will be permanent.

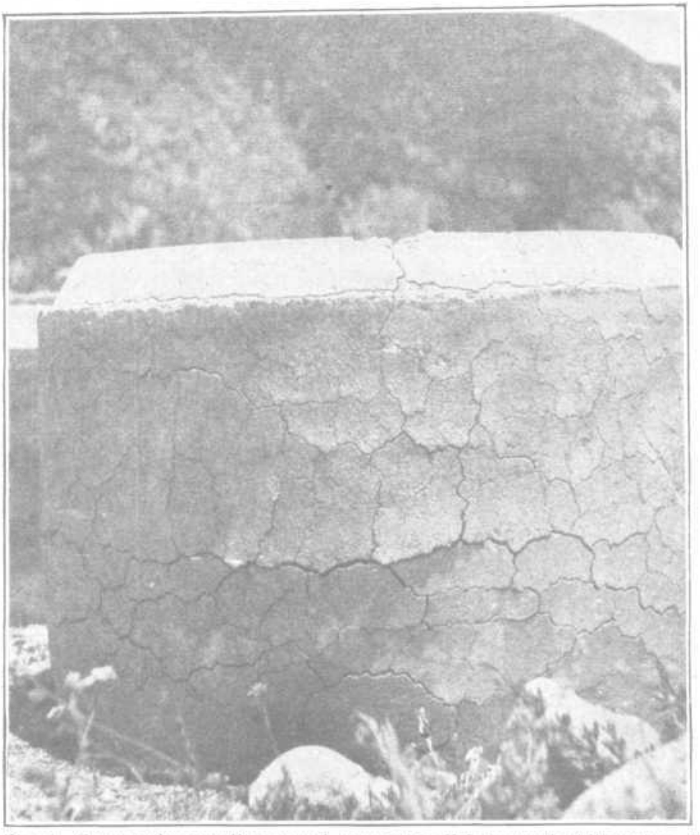


Fig. 4. Cement pipe standing on end, completely disintegrated while curing. Cause of failure was unsound cement. This is not an argument against the use of cement pipe but it demonstrates that good materials and skill must be utilized in its manufacture.

MOLDS.

Regarding the mold to be used and the shape of the tile there will always be differences of opinion. Several forms are on the market or can be rented by paying a small royalty. In California the bevel and tongue joint is used. It is more quickly molded, and is quickly laid. The bell and spigot joint, universally employed for vitrified clay tile, is liable to suffer injury to the bells, is somewhat more costly, but will probably be laid with tighter joints than the beveled end pipe, especially by an inexperienced person.

The molding outfit for the experimental work included both forms and cost $60.00. It could be made ample for continuous operation at forty tile per day for $75.00 more.

Considerable cement pipe has been built in California with continuous pipe machines which make the pipe in the ditch very ingeniously. The absence of joints may be an advantage, but it is believed to be outweighed by the greater ease of making the pipe on the bank, the greater opportunity of curing it well and for inspecting it and throwing out defective lengths before laying in the trench.

CAPACITY TABLES.

For convenience in determining the proper size required for any particular project, Tables I and II are given. They are computed from Kutter's formula, using friction factor of .013. This is a conservative basis, and well executed inside-washed cement pipe lines will have capacities ten percent greater.

TABLE I.

Capacity of 15-inch circular cement pipe running full.

Grade of Pipe Line		Discharge		Area Irrigated
Ft. per Mile	Ft. per 100 ft.	Sec. ft.	Miner's Inches	Acres
52.8	1.00	6.29	252	882
31.68	.6	4.88	195	682
21.12	.4	3.97	159	556
10.56	.2	2.79	112	392
5.28	.1	1.96	78	273
4.224	.08	1.73	69	242
2.64	.05	1.35	54	189

The last column is based on a duty of 3½ acres per Arizona miner's inch, which is equivalent to an average depth of 62 inches applied to the land in one year.

Cement pipe may be made in sizes from four inches up to ten feet in diameter, but the sizes feasible for irrigating ditches may have a somewhat smaller range. The capacities of several sizes from 8 to 36 inches are given herewith.

TABLE II.

Capacities of various sizes of circular cement pipe running full

Grade	Inside Diameter in Inches					
Feet per 100	8 in.	12 in.	18 in.	24 in.	30 in.	36 in.
	Sec. feet	Sec. feet	Sec. feet	Sec. feet	Sec. feet	Sec. feet
1.0	1.10	3.40	10.38	23.3	41.4	67.6
.6	0.84	2.64	8.04	17.6	31.8	52.2
.4	0.69	2.15	6.55	14.3	25.9	42.5
.2	0.48	1.51	4.60	10.83	18.2	29.9
.1	0.34	1.06	3.23	7.12	12.9	21.1
.08	0.30	0.94	2.88	6.33	11.5	18.8
.05	0.25	0.73	2.24	4.97	9.0	14.8

The capacities are stated in second-feet but the quantities can be readily reduced to Arizona miner's inches by multiplying by forty.

The heavy horizontal lines in Tables I and II indicate the minimum grades allowable for each size of pipe in cases where the water carries much sediment. For example, a 12-inch pipe line must have a fall of at least 0.4 foot per hundred feet in order to prevent the deposition of sand in the pipe. In case the water is clear or can be passed thru a settling basin before entering the pipe, the flatter grades can be used.

COST OF CEMENT PIPE.

The cost was quite accurately determined by observations on the first four lots. Being made in close proximity to the river sand and within twenty feet of an irrigating ditch, no allowance is made for sand or water.

TABLE III.

Cost per two-foot length of 15-inch pipe.

	Cement-Sand	Cement-Lime-Sand
Cement at $4.50 per bbl.	$0.563	$0.375
Cement, hauling 7 miles	.035	.023
Lime at $13.00 per ton delivered		.058
Sand, no charge		
Water, no charge		
Labor, Foreman $2.00 per day 2 laborers at $1.25 per day	.112	.112
Wash of neat cement	.06	
Cost per two-foot length	.77	.568
Cost per lineal foot	.385	.284
Cost per mile	$2032.80	$1499.52

These figures are based on Tucson prices during April, 1907. and must be modified to conform to the local prices at points where cement pipe-lines are contemplated. For example, the price of cement at Phoenix is ten percent lower than at Tucson and the price of lime is very variable. In some cases a considerable allowance should be made in the estimate for sand.

The cost of 500 feet of redwood flume built in the same vicinity as the cement pipe and at the same time was also observed. Its sides and top were of two-inch planks and its bottom of one-inch boards. The lumber was of inferior grade and full of knots. The inside dimensions were 12 inches by 20 inches. A flume of equal capacity to 15 inch pipe would be 12 by 16 inches, and the cost of such a flume per lineal foot based on the observed cost of the larger flume is as follows:

TABLE IV.

Cost per lineal foot of redwood flume 12 x 16 inches, inside dimensions.

9 ft. B. M. Redwood, merchantable, rough, at 4½c.. ...	$0.405
Hauling 7 miles....	.017
Carpenter work at $1.50 per day....	.052
Nails....	.011
Cost per lineal foot....	.485
Cost per mile....	$2560.80

The cost of the flume is therefore 25% greater than the cement-sand pipe, and 70% greater than the cement-lime pipe. The differences amount to $528.00 and $1061.00 per mile respectively. It must be borne in mind, too, that the chief advantages of the cement pipe are greater permanence and less loss of water by leakage.

Clay tile of 15 inches diameter cannot be sold in Tucson at less than 90 cents per foot and is therefore both high priced and lacking in strength. In Colorado where clay tile can be furnished at 50 cents or less per foot, laid, it is much used for carrying irrigating waters.

Lining of canals with concrete, crude oil, asphaltum, and puddled clay are all in varying degree efficient, but are not well adapted to small ditches and are therefore beyond the province of this paper. Much information concerning such linings has been published by the California Experiment Station.*

LAYING THE PIPE.

The pipe should be laid in the trench in the same manner as sewer pipe is laid, with straight alignment and uniform grade. The joints should be made with rich cement mortar and much depends upon the integrity of the man who places it. The entire circle must be gone around carefully. Each length must be brought to a firm bearing in the trench, and the sides filled in and lightly tamped. As the material is assumed to be sand, this will not be difficult, but it must not be neglected. Mr. Homer Hamlin, city engineer of Los Angeles, states that more pipe is cracked by not filling thoroly beneath the invert than from all other causes combined.

WATERTIGHTNESS.

Cement pipe, reasonably dense, and not under head or pressure will leak only at the poorly made joints, exactly the same as clay tile will do, and either kind of pipe will probably lose less water than escapes thru the joints and knot holes of a lumber flume. Under "reasonably dense" is included both mixtures described on pages 172 and 174.

In order to exhibit in a convincing manner the watertightness of cement pipe, a length selected at random was stood on end, the bottom sealed with paraffine, and the pipe was filled with water. The depth of water was therefore two feet. Fifteen days later one half of the water had leached thru the pipe, mostly along the lines which showed poor tamping. The outside was covered with an efflorescence, and the concrete had apparently puddled itself completely as all leakage and sweating had ceased.

The pipe was again filled to the top with water, and the loss per 24 hours was found to be one fourth inch, which could be accounted for by the evaporation from the water surface. Other tests were made, using pipe made from different mixtures, some with inside wash and some without it. All tests led to the same conclusion, that while the pipe will sweat considerably at first, it will quickly become watertight.

* Bulletin No. 188, Agricultural Experiment Station, Berkeley, Calif.

The superiority of the cement lime mixture is very great when the pipe carries water under head. This is well shown in recent tests by the waterproofing committee of the American Society for Testing Materials.* A series of tests was made on mixtures of Portland cement and hydrated lime in 1 : 3 mixtures with the following results:

MIXTURE		Strength in 28 days lbs. per sq. in.	Permeability cu. cms. per minute
% Cement	% Lime		
100	0	357	794
90	10	305	715
80	20	315	430
67	33	250	220
50	50	206	10

The permeability was measured on discs one inch in thickness and three inches in diameter under a uniform pressure of ten pounds per square inch, equivalent to a head of 23 feet of water.

When cement pipe is to be subjected to heads exceeding ten feet, special water-proofing methods must be used. For high heads, also, reinforcement of strength is required, and the design should be entrusted to a competent engineer.

Tests by the U. S. Army Engineers and by the French Department of Bridges and Highways indicate that moderate additions of slaked lime in 1 : 4 mixtures have the effect of increasing the strength as well as the density. It has been the custom of some engineers to forbid the use of lime in cement mortars but such a position does not seem to be justifiable especially in Arizona where the economy in using lime is so marked.

As in the case of other forms of pipe lines, tree roots will seek leaky joints and may grow inside and enlarge, obstructing the flow. The preventatives are, first, to use great care in making the joints when laying the pipe, and second, to keep trees away from the pipe line. The notion that roots can penetrate sound pipe is without foundation.

* Reported in Cement Age, Vol. III, No. 3, August, 1906.

OTHER USES OF CEMENT PIPE.

SEWERS.

Several applications of cement pipe besides that to irrigating ditches should be mentioned.

For many years it has been an active competitor of clay tile in sewer construction despite the usually much lower cost of the latter. The city of Brooklyn, N. Y. has used cement sewer pipe almost exclusively for forty years, and now has over 400 miles of cement sewers in active use. No less an authority than Rudolph Hering advocates it in preference to clay tile. * Its advantages are many. It can be molded to any sectional form and will retain it, while vitrified pipe shrinks and warps while burning. It is tougher than vitrified pipe and withstands rough handling with less breakage. When washed inside with pure cement it is equally as smooth and frictionless as clean glazed tile, while both pipes soon become so coated with sewage that the character of the original surface is lost.

In Arizona, conditions are especially suited to the use of cement sewer-pipe. The long freight haul makes vitrified tile very costly. For the eight-inch size the cement pipe will cost 30% less than the tile, and in the larger sizes the economy will be still greater. Thruout Arizona these conditions are practically the same, and it is to be recommended that each city use the cement pipe. It can be made by the city or contracted to an experienced cement worker, in either case under the supervision of the city engineer. The mixtures employed for cement sewer pipe are 1 : 3 and 1 : 3½, usually the former.

BRIDGES AND CULVERTS.

Pipe culverts offer an ideal substitute for the wooden bridges over irrigating ditches both in the fields and in highways. It often happens that a single ditch owner has from six to twenty such bridges to build and maintain. The pipe culverts would cost less at the outset and nothing at all for maintenance.

The county roads could be economically improved by the use of pipe culverts in the frequent arroyos which are now a hardship and a menace to every passing team, more especially

* The Concrete Review, Vol. 1, No. 4, March, 1907.

to heavy freighting outfits. In many cases wooden culverts have been built by county commissioners but they are more expensive than cement pipe and it is well known that they quickly decay and have to be rebuilt.

GATES.

The cheapest material for directing water in and out of laterals and head ditches is the earth always close at hand, but the time consumed in building and removing the taps makes its use very arduous and costly. Lumber gates are therefore much employed, but the alternate wetting and drying soon destroys them. Cement pipe in two-foot lengths with sheet-iron curtains are to be recommended for this purpose.

DRAIN TILE.

Still another use for cement pipe in this vicinity is the draining of low lands. There are occasional sections of land close to the rivers which in the spring are too wet for cultivation. In several cases recently noted the water level was only six inches below the surface.

Such a condition usually results in the accumulation of alkali at the soil surface; but with a system of drain tile and the judicious use of flood waters from the river the alkali can be drained out, and the land brought under cultivation. This will be but one feature of the extension of agriculture in the valleys of the Southwest. When cement pipe is used for this purpose it is made straight without bell and is laid with open joints to admit the water. The cost is considerably less than for the tight pipe lines.

UNDERFLOW COLLECTING FLUMES.

Many of the dry water courses of the Southwest carry a strong underflow and after the flood seasons are past, much water is obtained by opening ditches or burying wooden flumes as deeply as possible in the river beds. But the recurrent floods fill the ditches and oftentimes float away the buried boxes so that the expense of maintenance and the loss of water at critical times is very discouraging.

It is evident that a flume for this purpose should have weight or be anchored down with piling, and it should have great bending strength, as portions of it may be undermined during floods One form of reinforced concrete pipe known as the Jackson pipe has had remarkable success wherever used and possesses merits whereby it surpasses every other type of construction for underflow flumes. It is shown in Fig. 5. The amount of steel reinforcement can be varied to suit the requirements and although

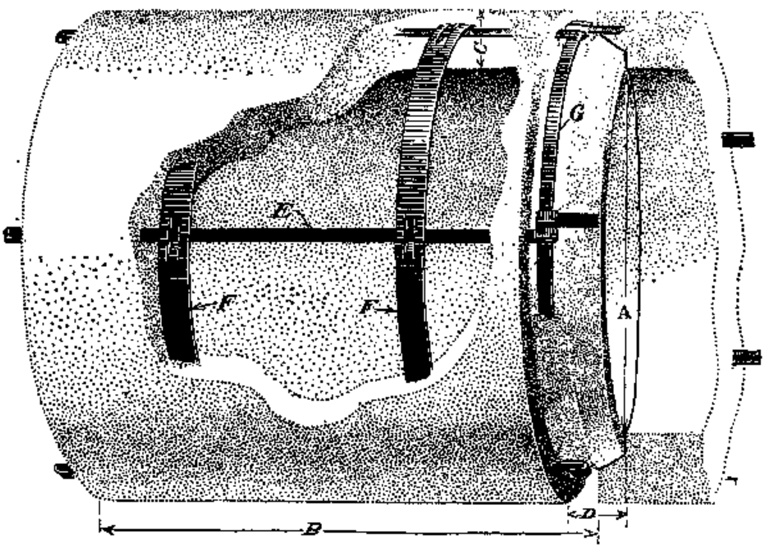


Fig. 5. Reinforced concrete pipe with interlocking joints.

A represents the inside diameter; B is the length of the joint; C is the thickness; D is the length of the tongue; E is the longitudinal reinforcement consisting of five bars; FF are the circular reinforcing bands.

the pipe should be buried beyond the probable reach of floods, yet if a portion is undermined by the scour or is subjected to lateral pressure, the steel would be very effective in maintaining the stability of the line.

VALUE OF PIPE LINES.

In conclusion, no stronger argument could be given for piping irrigating water than to mention the example of the Ontario, California, irrigating systems. * The entire colony is piped thruout so that the loss of water in distribution is practically nothing. As a result of this and other economies the duty

* See Transactions Am. Soc. Civil Engineers, Vol. LV, 1905.

of the water is nearly nine acres per Arizona miner's inch in the heat of midsummer. The average duty of water in the Santa Cruz Valley at the present time is not over two acres per miner's inch.

To illustrate the financial advantage of piping water in Arizona certain concrete cases will be cited.

In a certain ditch carrying about 100 miner's inches thru sandy deposits, the loss of water per mile exceeds ten percent, say ten miner's inches, capable of irrigating an additional 30 acres on the ranch, which would yield a *net* profit, estimated at $30.00 per acre in alfalfa, of $900.00 per year. This water could be carried in a 15-inch pipe line costing $2500.00 laid, the interest on which at 8% would be $200.00. The maintenance of the pipe should be very much less than that of the open ditch; the frequent cleaning of the weeds and algae would be entirely eliminated. The net profit resulting from the pipe line would therefore be $700.00 per annum.

Another example observed in the vicinity of Tucson is as follows:

Amount of flow	400 miner's inches
Loss per mile, 4%	16 miner's inches
Area that could be irrigated with this loss	48 acres
Estimated *net* profit from 48 acres	$1500.00 per year
Size of pipe line required	30 inches diameter
Cost per mile laid	$5500.00
Interest at 8%	$440.00
Net annual profit derived from pipe line	$1000.00 per mile
Net annual profit from 4 miles, the length of the ditch	$4000.00

The ditch flows thru adobe ground and the loss is extremely low, yet the profitableness of the pipe line is beyond question.

As to the permanence of well executed and protected cement pipe lines there can be no question. The cement mortars of ancient Rome are stronger now than the stones which were joined together. Concrete work in the sewers of Paris, several hundred years old, is in perfect condition. Much cement pipe in California that has been in the ground over twenty years is in excellent condition and there is every reason to believe it will continue so indefinitely.